LEARN DIE MAKING

DIE CUTTING AND DIE MAKING GUIDE

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INTRODUCTION

DIECUTTING

This e-book has been prepared to give all of the necessary information on packaging paperboard die cutting. In current circumstances, functioning of almost all industries would be unimaginable without the process of die cutting, but a packaging paperboard die cutting is also inevitable to satisfy the needs of both these industries, including tertiary sector, and individuals as well. It is varying in needs of either transport or commercial packaging paperboard. It stands behind a successful business operating of the biggest companies.

The design of new packaging papers and paperboards requires new up-to-date die cutting tools to be made that can satisfy needs of high precision, high speed and low cost. The important elements of a die cutting tool are materials that they are made of, that also follow the die making and die cutting development techniques.

Die cutting is an invisible process infiltrated in many segments of diverse industries. Experts in one of the many segments of the die cutting process are often unfamiliar with other areas of die cutting process. A company die-cutting individual component part of clothing or footwear does not know much about paperboard die cutting and creasing on high volume automatic platen presses and dealing with steel rule die making and die cutting techniques in the folding carton industry.

Die cutting in its most basic form is sometimes compared to a woman making cookies. She could roll out cookie dough on a kitchen counter and cut out shapes of figures using a tin cookie cutter. She is in effect die cutting her cookie dough into cookie shapes. This very concept has been used for decades to cut duplicate items out of many soft to semi hard materials like, leather, paper, fabrics, plastics and other materials, only it is done by big manufacturers with big automated and semi-automated presses in hundreds of pieces at a moment.

Die Cutting and
Die Making Guide

Die cutting developed with the outset of Industrial Revolution in manufacturing process. Manufacturers started to standardize the component parts of their products. In the beginning, the best examples were manufacturing of shoes and clothing, as well as a paper processing.

Leather shoes are manufactured from a number of component parts, including vamps, quarters, outer soles, inner soles etc. It was done manually for each pair of shoes before the Industrial Revolution, when and hand craft a pair of shoes or boots feet was hand crafted to fit each customer’s feet. Fitting of their produces depended upon the skill of the craftsmen. Since the outset of use of the die cutting processes, standardized footwear was made available to customers. Shoe manufacturers developed patterns in size ranges and started to cut out the parts using a pattern with a hand held knife and eventually cutting dies. Mallet handle dies were the beginning of the die cutting process as hand held die usually in the shape of a sole of a shoe that was used to cut the sole design out of heavy leather. The leather would be placed on top of an end grained maple wood block and the die would cut throughout the leather slightly penetrating the surface of the wood block. The sharp edge of the die cut through the leather and produced a perfectly die cut part of the shoe. Later, die-cutting machines or basic belt driven die presses were used to cut out shoe parts and eventually, with the development of the swing-arm clicker press it was enabled for heat-treated 9/16" and 3/4" single and double edge clicker dies to cut out the various right and left component parts of shoes.

Paper production has undergone strong development in the course of last two centuries. The first great improvement in its beginning was the use of papyrus by the Egyptians in the third millennium B.C., when the sheets of beaten papyrus stems were stuck together into scrolls. Papyrus was followed by parchment paper, made in the city of Pergamum in Asia Minor, in the second century B.C. Greeks and Romans had used animal skins to write on them, but durable and smooth parchment, which could be used for writing on both sides, was an improvement. After that, for centuries, paper was produced by hand from rag pulp. It was long before wood fibers began to be used for paper production and subsequently fibrous pulp and those were papers of a low quality, because not only the fibers were used, but also all parts of the wood. The method of papermaking developed in China was based on producing paper pulp from husks of cotton fibers; it was brought over Asia first to Spain and after that, it spread throughout Europe. In the first paper mill in America, sheets of paper were produced one at a time until a continuous process was developed. This process was patented in England under the name Fourdrinier and was followed by the invention of the cylinder-type papermaking machine that can produce a better quality paper in a continuous process.

These two papermaking processes are still used, although technologically improved. In paper industry, the first to come to the idea of die cutting paper was a printer in New York City who was setting up his printing press to crease some paper stock and applied too much pressure to the creasing rule in the press, so that the creasing rule cut into the paper. The printer had an idea to take the crease blade and ground a sharp edge onto the crease rule. He then put the rule back into the press and the rule cut through the paper. The process of paper and paperboard die cutting of was started, whereas in England, the first die cutting tools, i.e. steel rule cutting blades were produced.

From the early developments in the shoe and printing industries, companies producing other goods discovered that they could die cut thousands of identical parts to be assembled into products. The die cutting operation was always an integral part of the total manufacturing operation, which enabled manufacturers to be more competitive with increased speed of work, effectiveness and efficiency of production, with die cutting many different types of materials.

Die cutting is present all around us, starting from clothing with sleeves, pockets, collars, underlining and other components, leather gloves and bags to components of footwear. Many plastic components in home ware and components of devices and machines are die cut. The component parts of vehicles are die cut, including the upholstery and floor coverings and component parts in personal computer as well. The parts are all visible, wherever we turn around us, with a die cutting process behind them, a part of manufacturing that we cannot see.

Spongy insert for headlight's bulb

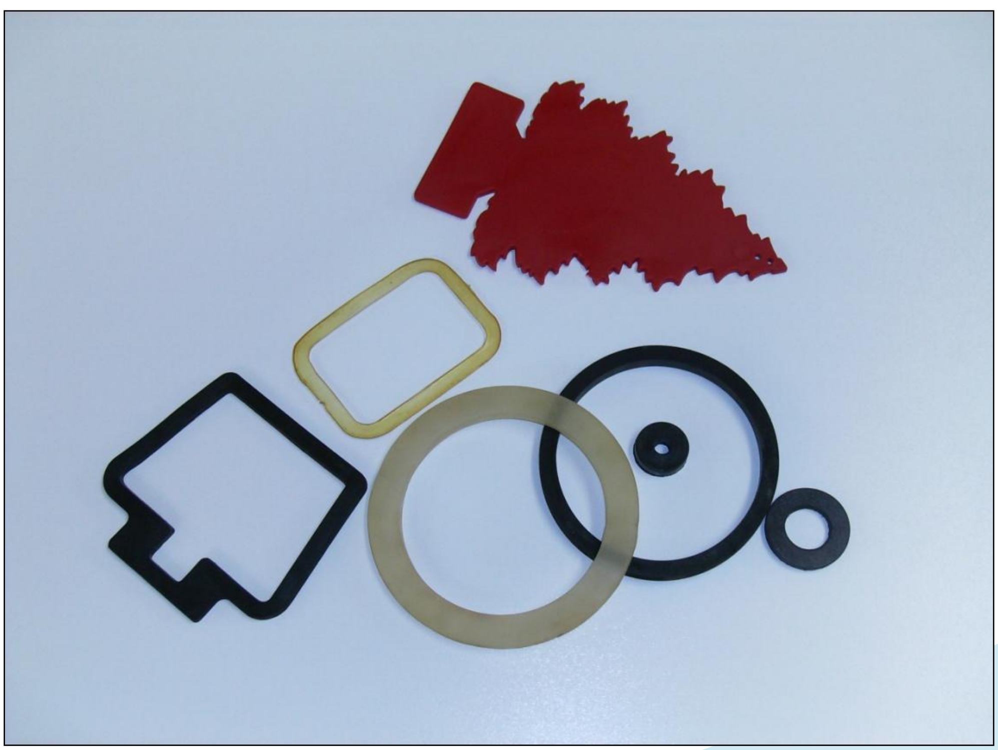
Engine Head Gasket

Foil with imprinted watch

A variety of stickers

Coasters

And a variety of rubber or plastic elements



We can see a great application for die cutting in the area of packaging of products. Every day some type of paperboard or corrugated packaging is used by everyone. Those packages are all die cut and many of them are thermoformed or blister packed. The parts of them are cut or trimmed by use of cutting dies.

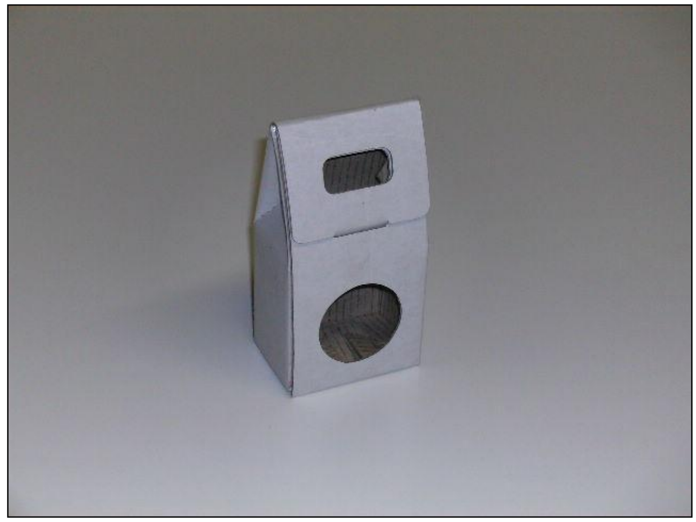
Tray with holder for windscreen ice removers with zipper opening

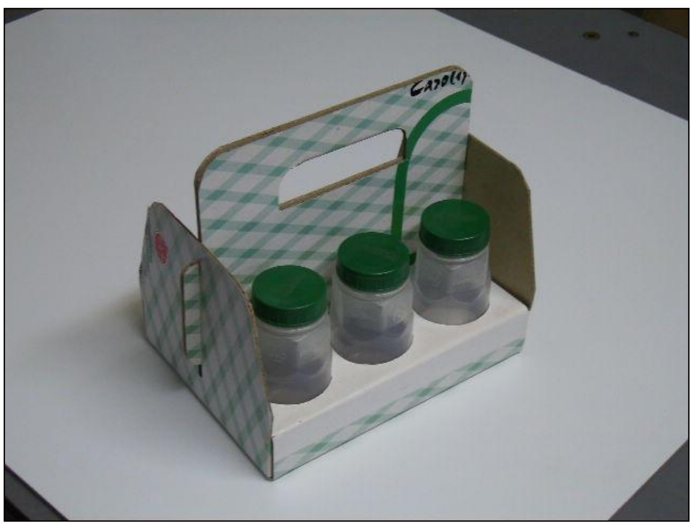
Tube style carton packages cutout with the same die but can be used for different products

One-piece display easel with holder for pharmaceutical product

Triangle package for wine bottles

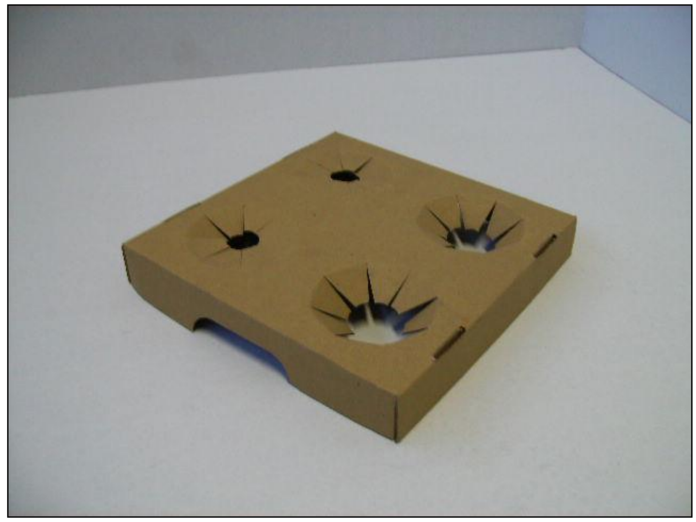
Small gable top package
with open window
and handle for packing a
small glass for brandy





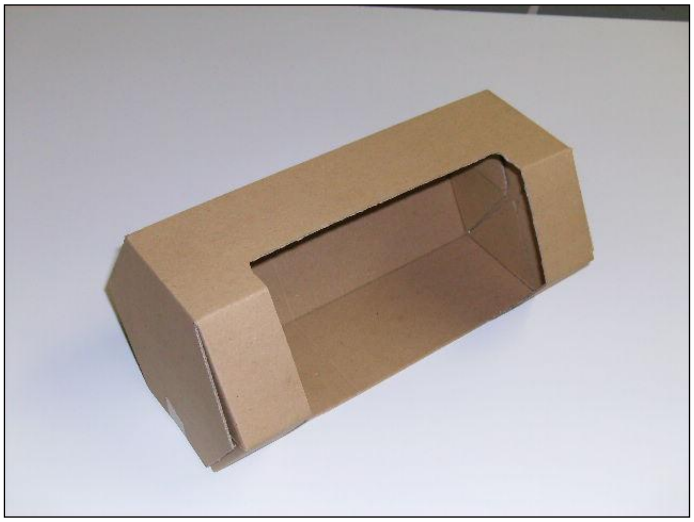
Six count spice carrier

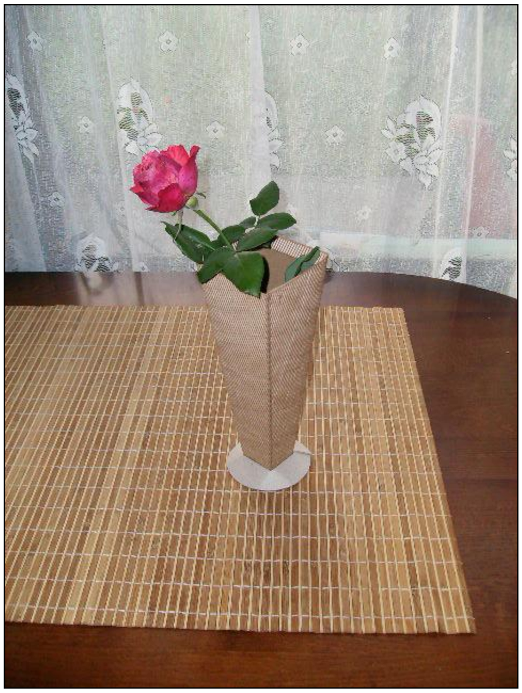
Four-count tray insert



Ten-count tray insert

Hexagon box with
open window





Flower vase

Corrugated two partition wine bottle carrier

Octagonal box with
lock and handles

Six count bottle carrier

A perfume bottle frame view tray

Gable top containers
With holders

Corrugated produce
shipper/display

Advertise pyramid

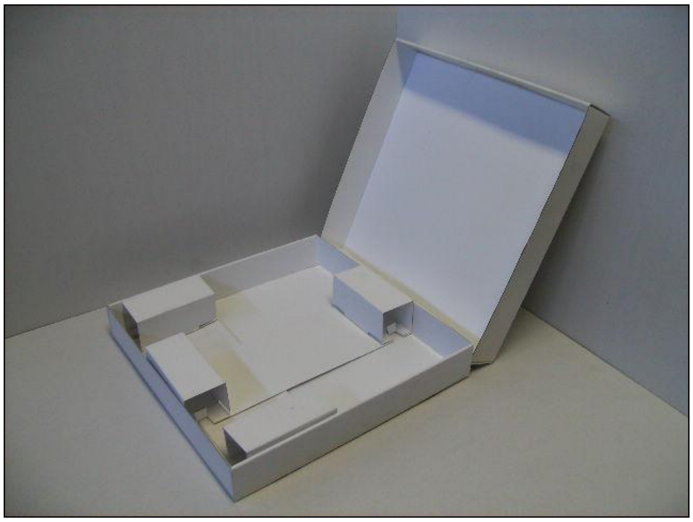
Gable top container
with handle for
Wine bottles

Corrugated promo-package
with closed window
for coffee bag and two cups

Triangle self-locking tray

Small corrugated box made of two glued two-layer corrugated papers giving the surface of the box a wavy texture

Corrugated cardboard doughnut shipper/display

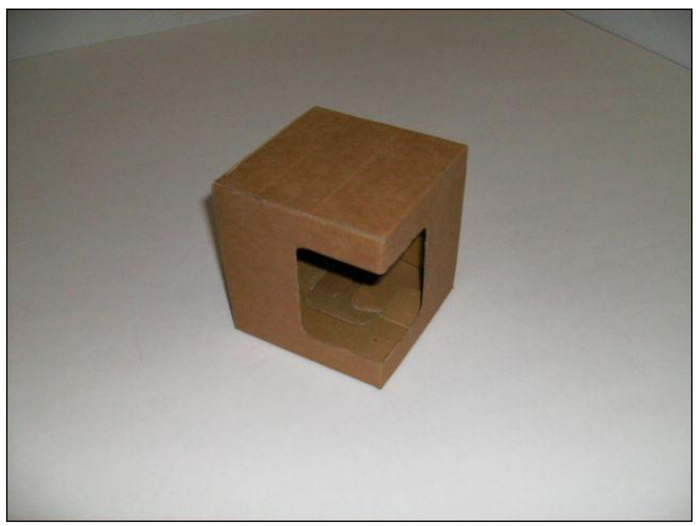


Two piece tray with scored sheets for product holding and protection

Tapered top with center handle tray package for pastry shops

Container with
separate tray lid

Box with corner
open window



Bag with glued sides and carrying handle

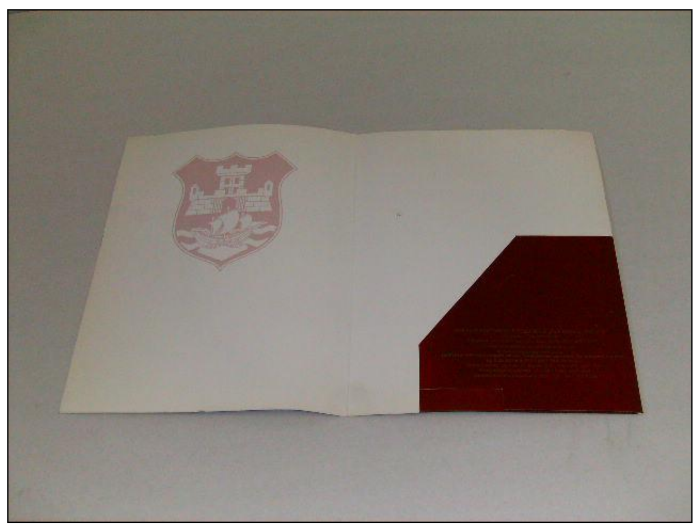
Folder for shallow products

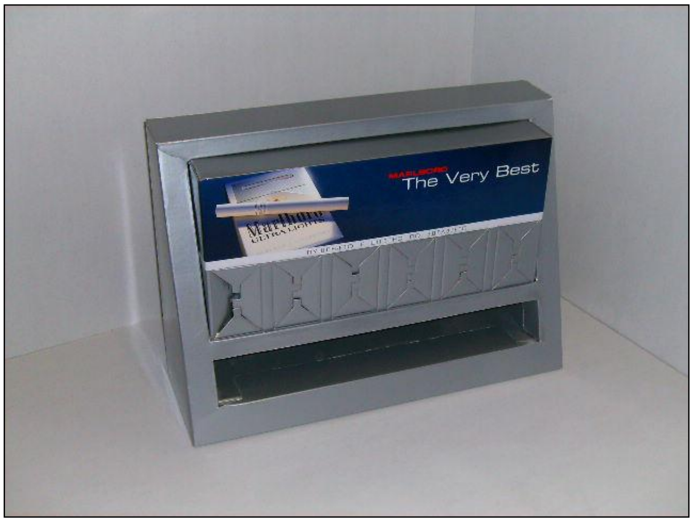
One-piece display stand

Gravity-fed dispenser for cigar packs

Two piece display easel with sample holder

Folder





Display with cigar pack holders

Container display with product dividers

Triangle display stand with
product holders

Plastic see-thru package
for another coffee package

There is a wide range of the applications of die cutting techniques. All kinds of plastic elements for installation in diverse devices in machines, including cars and vehicles, printed circuit boards in electronic devices, formatted products of paper industry are die cut. Food products, medical products, sanitary items and many other products are die cut, as well.

In last decade, die cutting process was recognized as an incentive to the transforming and growing economies of the Far East countries, which resulted, combined with a cheap labor, in boosting of those economies. Die cutting process helped their production, together with a cheap labor, to be competitive in prices on the world market. It is also manifested lately in the boosting economies of emerging markets, such as China, with a high growth of the Gross National Product followed by high rate of export, in numerous fields as electronics, clothing industry and production of machines and devices.

There is a wide range of types of cutting dies and die cutting press systems to cut and trim different materials. Which type of cutting die or cutting press will be used, depends on several basic elements of the material to be die cut:

- ✓ Thickness of materials
- ✓ Firmness of material
- ✓ Compression of material
- ✓ Surface coatings of material
- ✓ Single-ply or multiple-ply die cutting
- ✓ Stretch or distortion of the material while die cutting
- ✓ Effects of temperature and humidity

The best solutions to cut different materials or products depend upon the understanding of the basic elements of having a sharp knife blade penetrate through a particular layer of material to produce a good clean cut, while maintaining the integrity of the material. To obtain good die cutting, following elements in the die cutting process must be considered:

- ✓ Material to be die cut
- ✓ Cutting die used to cut a material
- ✓ Shape of a die cut product
- ✓ Hardened cutting surface that is either cut against or cut into it
- ✓ Cutting press adequate for purpose

The correct type of cutting die is an essential element in the success of the die cutting process both for big manufactures and for small businesses. There are different types of cutting dies that are best suited to cut different types of materials. There are certain techniques that are more appropriate to use for cutting one type of material over another. Die making and die cutting techniques are still in process. Die making and die cutting still incorporate many craftsmen techniques and the expert understanding of how to cut or trim one material over another material.

That information on the best techniques or methods cannot be easily found. Experts are actively trying to improve the level of die making and die cutting excellence. It has been only 150 years since the steel has come into a mass production. There is a variety of types, many of which serve for cutting dies to be produced

Numerous types of cutting dies are designed for the production of sheet-metal work on power presses and experts are striving to make new designs. However, generally they are classified in two types. Dies that just cut or punch flat blanks belong to the first type and dies changing the form from the original flat condition by drawing, forming or bending it belong to the second type. Nevertheless, the second type often includes features common with the first one, as a combination of cutting and shaping dies, firstly cutting out the required outline and then shaping it to the desired form. Dies of blanking type are mainly used to cut blanks from flat sheets or strips of a material. It cannot be drawn, formed or bent, but if the drawing process were following the blanking, then it would be considered a drawing die. A great number of such dies in use vary widely and range from simple and inexpensive blanking dies to complex and costly ones. The difference between die and punch should be explained here. The term die is mainly applied to entire press tool with component parts, whereas the terms punch and die are applied to parts of a complete die, a punch being usually the upper part but not necessarily. The form is generally distinguishing feature between the punch and the die. As mentioned before, there is a variety of dies with diverse applications, to start with plain blanking dies to multi-purpose dies, blanking and piercing dies, follow or progressive dies, piercing and perforating dies, shaping dies, multi-purpose dies for laminations, sub-press or self-guiding dies, drawing dies with many sub-types such as dies for drawing shallow shells, dies for drawing deep shells, dies for drawing shells having wide flanges and drawing dies for conical and tapering forms, drawing dies for spherical and oval shapes; then bending and forming dies, notching dies, expanding dies of rubber and hydraulic types and dies for special operations.

The aim of this e-book is providing information on metals used to make die cutting tools, the packaging paper and paperboard die cutting process. Therefore, the first chapter of this course deals with metals used in die cutting process and their composition and characteristics, which are important for this process. It will include in the first place classification of cutting dies with their basic features and references regarding their relevant applications, then the most important facts concerning metals and alloys used to make cutting dies, including an action of metal shearing and wear of cutting edges, an effect of clearance between punch and die, condition of sheared edge, where to apply clearance, dullness of cutting edges and heat-treatment of die steels explaining elements, which increase harden ability of steel, how the heating changes the structure of tool steel, grain size and toughness and cooling tool and die steels, as well as tempering tool steels covering the effect of double tempering and effect of hardening temperature on hardness after tempering and size changes during heat treatment.

The second chapter deals with packaging paper and paperboard, starting from basic data on paper and paperboard composition; paper and paperboard production; paper and paperboard characteristics; paper formats since it is produced in standardized formats; types and application in packaging paper and paperboard depending on the type of the product to be packed and material to be die cut; construction and types of corrugated paper and paperboard with elements and characteristics; cross-corrugated paperboard used for special purposes in transport packaging, often combined with wood packaging; types of corrugated paper used for transport packaging and types of corrugated paper used for commercial packaging, as well as types of special packaging paperboards and inner protection of paperboard packaging, refined paper and paperboard and other special papers, mostly used for printing, labeling and decorative purposes in commercial packaging.

The third chapter deals with the principals of practical die making in the packaging die making area, starting with the process of making a prototype for a package which is later to become a die; meeting with the elements from which dies are made of; showing you the basic operations in processing the die elements and how they after: board cutting, rule processing (cutting, mitering, bending, broaching, placing nicks), rule placing, rule pulling, rubber placing, counter form making, become a complete die ready to be put in a press and start die cutting packages. In short, the first two chapters are about the theory that die makers need to know before making a die which the third chapter shows. After chapter three you should be acquainted with die making skills as an average die maker.

CHAPTER I - METAL PROCESSING

LESSON 1 - TYPES OF CUTTING DIES AND THEIR APPLICATION

Cutting dies are generally classified in two types, the first of which just cuts or punches flat blanks of a material and dies changing the form from the original flat condition of a material by drawing, forming or bending it belong to the second type.

The first type includes several kinds of dies, the simplest being a plain blanking die used to cut plain, flat pieces of a material. A plain blanking die consists of a die-block with an opening that is corresponding to the shape of a part to be blanked out or cut, a punch that accurately fits the opening in the die-block and which performs cutting, by descending into the die-block opening and a stripper plate with task to strip a material off the punch when it ascends.

Multiple dies are used when large number of blanks ate to be blanked out or cut. They have greater number of duplicate punches corresponding to openings in the die-block. They cut as many blanks as a number punches is, at each press stroke.

Blanking and piercing dies are used if it is required to make firstly small holes or openings, known as piercing punches, on the part of a material to be cut and then a blanking operation follows to remove the complete part from a material. Many types of dies have blanking and piercing combination.

Follow or progressive dies are designed for die cutting when required shapes of a material are to be provided with perforations or some other operations that are to be done successively. Although two different operations are done, the completed part is die cut at each press stroke.

Shaving dies are occasionally used to finish the edges of that have been cut out with blanking die. The type of blanking die to cut heavy materials must have a certain clearance between the punch and die opening, depending on the thickness and kind of a material. This clearance causes to be rough and tapering, therefore shaving dies are used to get smooth square edges.

There are many other types of dies, more or less complex, as well as dies for special purposes and new types are constantly being invented to satisfy the needs of manufacturers and purposes that arise. Their application is expanding; therefore, it is important to be acquainted with features of metals used to make die cutting tools.

LESSON 2 - METAL SHEARING PROCESSES AND WEAR OF CUTTING EDGES

The following analysis is applied in the first place to hot and cold-rolled steels of various composition and physical characteristics, because the process of metal in shearing, blanking, or punching is one of the basic problems in the press-working of metals. Their structure is crystalline with a thin amorphous intra-crystalline binding material, which is stronger than the very crystals, under the condition of quick process and normal temperatures.

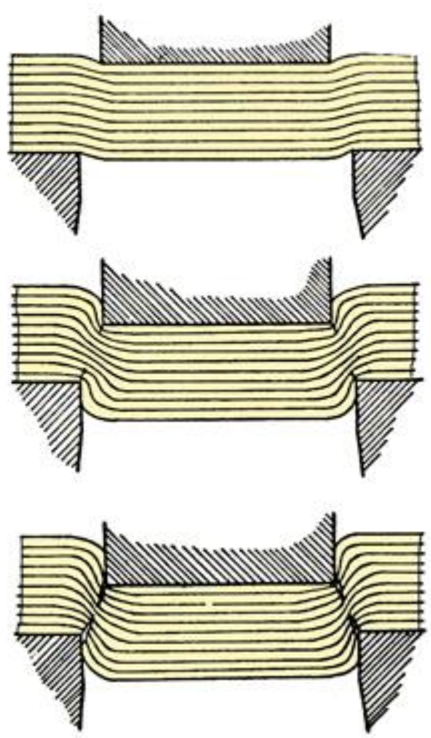
Permanent deformation occurs in the form of movement along the slip planes through the crystals when the elastic limit of the material is exceeded. Owing to the variation in size and structure of the crystals, slip occurs at different times and speeds, as well as in different directions in the different crystals. In case of occurring overstresses that exceed the cohesive strength of crystal fragments, fractures start spreading and following the path of least resistance and greatest strain. Therefore, the fractured portion of a sheared edge gets an irregular appearance and, in an instant, remaining crevices start further fracturing.

Thickness and physical properties, especially hardness of the metal, are the principal factors affecting shearing work; size, shape, subsequent operations, tolerances and finish of the job; then clearance, shear, relief and condition of the tools. The choice of a press plays an important role, too. Features and effects of variables mentioned are subject to this analysis.

LESSON 3 - SHEARING PROCESS IN BLANKING A DISK

The blanking of a disk from sheet metal has been taken to illustrate shearing. The material is soft ¼-inch hot-rolled steel. The process upon the metal in shearing is illustrated by the diagrams in Figure 1 to show the stages of the punch progressing through the sheet. The upper diagram represents the principal bending process, with a stage at which the elastic limit of a material is just beginning to be exceeded, the punch is penetrating just enough to start the fracture.

Figure 1



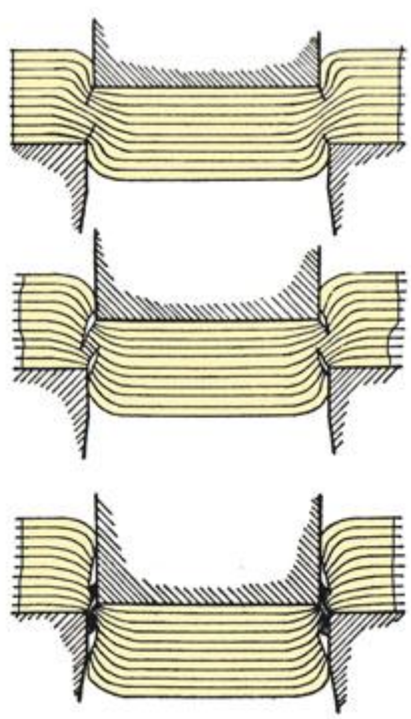
In the second diagram, there is a normal pinching or compressive stress between the edges of the punch and die and a tensile stress along the strata lines. The metal has been elongated locally along these lines and especially in the top and bottom strata. Here the ultimate strength is exceeded over the corners and fracture is started. As the punch advances, seen on lower diagram, the fractures spread quickly from each edge, the load dwindling eventually overcoming friction in pushing the blank through the die.

LESSON 4 - EFECT OF CLEARANCE BETWEEN PUNCH AND DIE

The first example represents practically an ideal condition for shearing, regarding clearance, i.e. distance between die and punch all around. The two fractures meet, giving a clean break and a minimum power requirement. An action of blanking a disk with insufficient clearance for its thickness and softness is illustrated in Figure 2. The fractures start from the corners, as in previous case, when the surface material has been elongated beyond its ultimate strength. However, they pass by instead of meeting, leaving a ring of metal that must again bee stressed to the point of fracture, with a further expenditure of energy; a ragged fringe left around the disk, which tends to wedge against the die as it is pushed through, is adding to the power required.

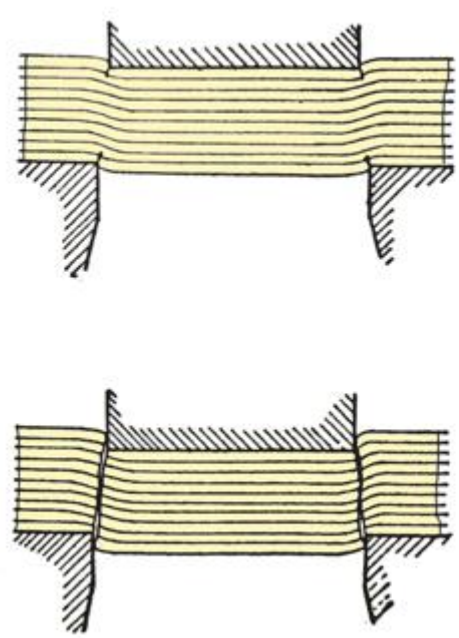
There is a "rule of thumb" that the clearance should be around one-eighth to one-tenth of the thickness of the material, depending upon its hardness. Hard material does not require nearly so much clearance for a clean fracture as a soft one.

Figure 2



As illustrated in Figure 3, the punch enters just a short distance, stretching the surface strata comparatively little before the fracture start. In addition, due to the hardness of the material, the break is completed almost instantly, so that the disk is completely severed before the punch has entered than a quarter of the thickness of a material. For softer metals, the punch must enter farther to cause fracture, even passing in some cases all the way through the sheet and actually pinching the blank out.

Figure 3



A little variation in clearance around a die makes the difference between a clean fracture and a poor one. A clean fracture results in less wear on the dies and insufficient clearance may become so small, as to permit of actual contact between the cutting edges. Therefore, cutting part blanks may cause breakage or at least excessive wear on punches. Off-center spring is equally capable of shifting the clearance with detrimental effect on the tool life.

LESSON 5 - CONDITION OF SHEARED EDGE

The condition of the edge of the sheet, blank or strip after the shearing process explains several points in press operations. The edge is shown in Figures 1, where the unsupported surface of the metal is drawn down in an easy curve to the edge. It is followed by a polished portion of the edge, which is indicating the depth of penetration before fracture occurs that is drawn smooth against the surface of the die or the punch. The remaining portion of the edge is the rough fractured surface, containing many fine crevices and breaks, which will serve as the starting point for further fractures. Where the fracture joins the other surface, the edge may be either a square break if the tools are sharp or a jagged burr if they are worn.

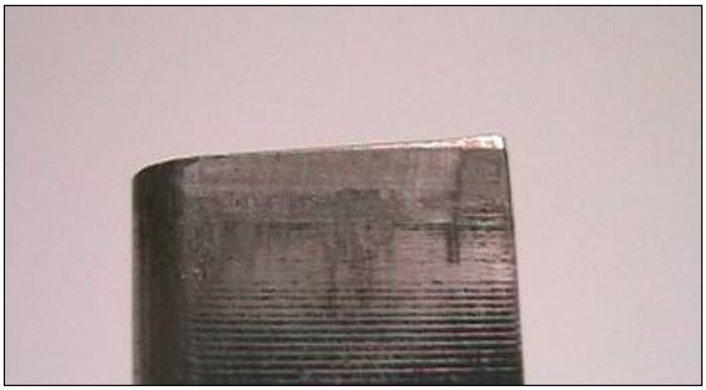
LESSON 6 - WHERE TO APPLY CLEARANCE

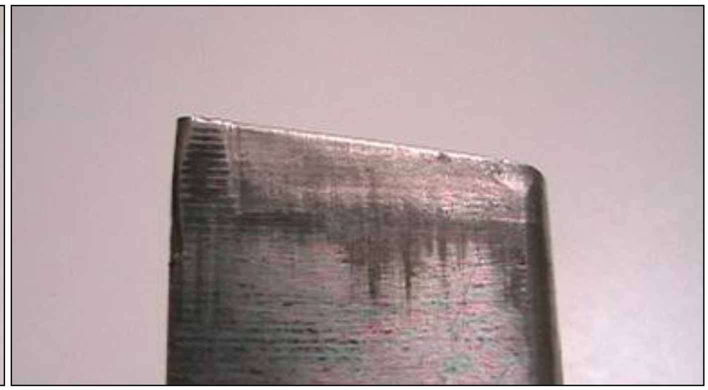
The clearance must obviously be taken into account in blanking or punching accurately to size. This point is shown in Figure 1. The die is larger than the punch by a sufficient amount to give a clean fracture. If the hole is to be held accurately to size, then the punch must be that size and the amount of the clearance added to it to determine the die size. On the contrary, if the disk or blank must be punched to an accurate size, that is the size of the die. The clearance allowance would then be deducted from this to determine the punch size.

LESSON 7 - DULLNESS OF CUTTING EDGES

Dullness is of interest as regards burrs and increased load and power requirement. It can be seen in Figure 1 that sharp cutting edges must localize and intensify the stresses that cause the fracture to start. Thus, the tensile stress in the surface strata will be much more severe over a sharp corner than over a rounded or dull corner, at any point of the progress of the punch. Compressive stress between the cutting edges of the punch and die is more highly localized, and hence more intense, between sharp edges than between rounded ones, at the same point of progress. Nevertheless, if the edges of the punch and die are dull or rounded over, the punch must penetrate further to cause fracture to start. The load duration is increased and hence the power required. In addition, the compressive stress is spread both ways over a larger area, increasing the crowding effect and the peak load.

Example of a dulled notching die





The burr left by a dull edge is merely due to the fact, that the metal follows the shape of the edge, as it is pulled down to the point of fracture. The fracture starts from the point where that radius joins the outside surface of the punch or the inside surface of the die. Thus if a punch face is flat, with a square edge, the edge of the punching is flat and fractures at that square edge. If the edge is rounded, i.e. dull, a burr remaining on the punching fits this radius very closely.

This can be used in some special cases when there is the need to dish or form the edges slightly while punching. If the punch face or the die is shaped as desired, the metal will follow that shape closely, as it is drawn during the portion of the stroke that the punch is penetrating to effect shearing. Applications of this principle are used in connection with hot work and in drawing and pinching-off paper shells.

LESSON 8 - HEAT-TREATMENT OF DIE STEELS

It is necessary to understand the changes that take place in the steel when it is heated, quenched and tempered to prevent the spoilage of dies during heat-treatment, as far as possible. This lesson deals with heating cycles for typical tool and die steels, the quenching or cooling procedure and the effects of single and double tempering operations on the structure and properties of the steel.

The life of tools and dies is mostly corresponding to their hardness or toughness. Therefore, the main objective of heat-treatment is to develop the maximum hardness in the material, consistent with degree of toughness required.

LESSON 9 - ELEMENTS THAT INCREASE HARDENABILITY OF STEEL

A high degree of hardness can be developed in plain carbon steel by heat-treatment if the steel contains over around 0.50 percent carbon, provided the section is not very large. Nevertheless, when tools are made in large sections and plane carbon steel is not hardened adequately, it necessary to add alloying elements in order to increase the harden ability. The elements usually used for this purpose are manganese, chromium and molybdenum.

Steel becomes hard during heat-treatment because of the formation of a microstructure called martensite. The wear resistance provided by the martensite structure is not sufficient for all applications and therefore, tungsten and vanadium, as well as chromium and molybdenum, are introduced into tool steel. These elements are combined with some of the carbon in steel to form very hard particles of carbides, thus giving the heat-treated steel of much better abrasion resistance, than it can be developed without the presence of alloy carbides.

When the tool operates at high speed or under high pressures, or is in contact with hot metal, as in forging, piercing, extruding and die-casting operations, special tool compositions resistant to the high temperatures, must be used. Vanadium, chromium and cobalt combined with tungsten or molybdenum give the steel the necessary resistance to softening at high temperatures.

The life of a tool or die is more dependent on toughness than on hardness in some applications. In such cases, by decreasing the carbon content of the steel or by heat-treating the steel to a lower hardness than the maximum attainable, a satisfactory compromise can be established between hardness and toughness. However, if a low percentage depends on providing the desired toughness, the alloying elements chromium and molybdenum must be added to get satisfactory harden ability.

LESSON 10 - TYPICAL TOOL AND DIE STEEL

The compositions of tool and die steels that correspond to the foregoing conditions are given in Table 1. Only five of the very large group of tool and die steels on the market are given, since they are representative of the essential types. One of these five types could be used satisfactorily for practically any application. Many varieties of steel available for tools and dies are justified because each one does some job more efficiently than any other does.

The first steel analyzed is usually referred to as plain carbon tool steel and is frequently termed a water-hardening or shallow-hardening tool steel. Many modifications of this type of steel are produced to provide small but controlled differences in harden ability. Several steels of this type contain small amounts of tungsten, giving the steel better wear resistance.

The feature of steel known as oil-hardening is also analyzed. It differs from the first type primarily in harden ability. Because of its greater harden ability, relatively large tools made of this steel can be hardened by an oil quench, unlike water quenching required for plain carbon steel; consequently, tools made from oil-hardening steels are not subject to big size changes and distortion during hardening, as those made from plain carbon tool steel.

Table 1 - Composition of five typical tool and die steels

Tool and die steels	Composition
Plain carbon tool steel	carbon, 1.14%; manganese, 0.22%; silicon, 0.16%
Oil-hardening tool steel	carbon, 0.85%; manganese, 1.18%; silicon, 0.26%; chromium, 0.50%%; tungsten, 0.44%
High-carbon high-chromium tool steel	carbon, 1.55%; manganese, 0.27%; silicon, 0.45%; chromium, 11.34%; vanadium, 0.24%; molybdenum, 0.53%
Molybdenum high-speed steel	carbon, 0.80%; manganese, 0.24%; silicon, 0.29%; chromium, 4.15%; vanadium, 1.89%; tungsten, 6.64%; molybdenum, 4.94%
Chromium-molybdenum hot-work steel	carbon, 0.38%; manganese, 0.50%; silicon, 1.08%; chromium, 5.00%; vanadium, 0.40%; molybdenum, 1.35%; nickel, 0.30%

Steel of the third analysis is referred to as a high-carbon, high-chromium steel or as air-hardening die steel. It possess a much higher degree of harden ability, but also contains

many hard chromium carbides that give it better wear resistance at a given hardness, than the first two steels. There are several carbon and chromium variations of this type.
The fourth steel is high-speed steel; i.e. it holds a sharp edge even when the tool is cutting fast enough to cause it to get red hot. The first three steels, would fail very rapidly under such high-speed cutting conditions because they would become soft when heated to a dull red color, though they could have been treated to the same hardness.

There are diverse of high-speed steels: some contain more tungsten and less molybdenum than given in the table 1; others contain more vanadium; and still others have up to 12 percent cobalt. Economical general-purpose steel is listed in the table.

The last steel is generally referred to as a hot-work steel or a chromium-molybdenum hot-work steel. It is used where the tool is in close contact with hot metal, such as in forging, extruding, or die casting operations. It has relatively low carbon content compared to the other alloy steels, but it has a higher hardness than the first two steels when heated to about 1100 °F and therefore will wear better on hot-work jobs. The high-carbon, high-chromium and the high-speed steel will also be wear resistant at 1100 °F, but not as tough as the hot-work steel, under the same conditions of high temperature.

LESSON 11 - EFFECT OF HEATING CHANGES ON STRUCTURE OF TOOL STEEL

The heating is the first step in the heat-treatment of steel. The purpose of heating is to form austenite, i.e. to dissolve carbon into austenite. The solution of carbon is necessary so that in the second step in heat-treatment, when it comes to transformation of austenite, the steel will develop the desired hardness. The hardness of steel cannot be effectively attained unless carbon, even a large amount of it in steel is first dissolved into austenite.

Figure 4

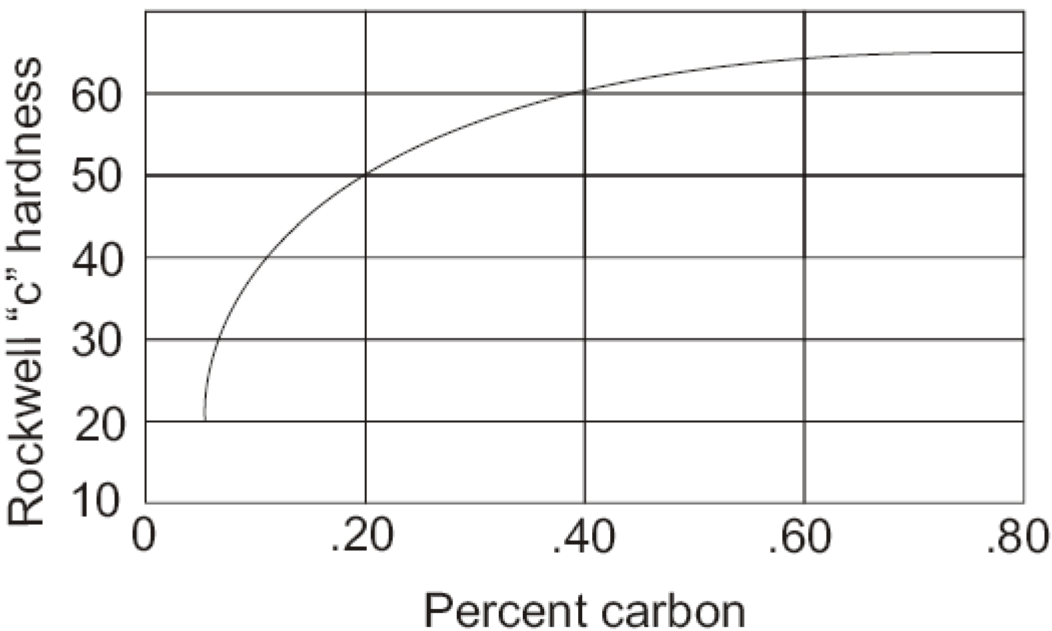


Figure 4 shows the relationship between the attainable hardness and the carbon content. The hardness increases rapidly up to 60 Rockwell C as the carbon increases to 0.40 percent, but from this point on, it increases gradually to 65 Rockwell C, as the carbon increases from 0.40 to 0.70 percent. The hardness remains practically constant above around 0.70 percent carbon. Therefore, to get maximum hardness in the steel, approximately 0.70 percent of carbon must be dissolved into austenite. All of the steels being analyzed, with the exception of the chromium-molybdenum hot-work steel, have sufficient carbon to attain a hardness of 65 Rockwell C.

In Table 2, the effect of the solution of carbides on the hardness of the high-speed steel, as quenched, is shown. This steel hardens does not reach maximum hardness until it is quenched at about 2100 °F. However, the recommended temperature, to which this steel should be heated before quenching is 2250 °F, due to effects of tempering. At least it is apparent that Minimum critical temperature to which this steel must be heated well above is 1530 ° F, before enough types of carbide are dissolved to obtain full hardening.

Table 2 - Effect of Heating Temperature on Hardness of Tool Steel

Austenitizing Temperature °F	Rockwell C Hardness	
	Molybdenum High-speed steel	High-carbon high-chromium steel
1600	53	50
1800	60	64
1950	64	59
2100	66	36
2250	65.5	..

It can be seen from Table 2 that when too much carbon is dissolved into austenite structure of some steels, the steel is softer rather than harder. The high-carbon high-chromium tool steel is capable of attaining its maximum hardness of 64 Rockwell C, when heated to 1800 °F. At higher temperatures, more carbides dissolve, and the resultant hardness of the steel when it cools is less, because of the fact that the high-carbon austenite is not transformed to martensite when the steel is cooled, but remains as austenite at room temperature. Since austenite is much softer than martensite, the steel is softer.

LESSON 12 - GRAIN SIZE AND TOUGHNESS

Grain coarsening and melting of the steel are important factors in the heating of tool steels besides the formation of austenite and the solution of carbides. The grain size in tool steels should be as small as possible, because fine-grained hardened steel is inherently tougher than course-grained steel. Coarsening of the grain does not occur until the temperature is well above the usual austenitizing temperatures.

The first two steels listed in Table 1 coarsen appreciably at temperatures as low as 1600 °F, but the high-speed steel still has a fine grain at 2250 °F. However, a startling grain coarsening occurs in high-speed steel when it is reheated to the high temperature for the second time. Coarse grains in the structure at the right produced by “double hardening” result with the fracture of steel, which gets a fish-scale appearance, those tools being generally very brittle, when treated in this manner. In case that a high-speed tool has to be hardened for the second time, it should be annealed fully before the second hardening. This annealing between hardenings prevents formation of large grains.

Melting of steel occurs during heat-treating in the case of high-speed steel. The molybdenum high-speed steel begins to melt at about 2275 °F and there is definite evidence of melting at 2300 °F, which results with the formation of a massive carbide network at grain boundaries, decreasing the toughness of high-speed steels.

Melting temperatures vary with the compositions of high-speed steel. For example, high-tungsten high-speed steels do not begin to melt until they are heated to about 2400 °F or higher. An increase of carbon at the surface of the steel brought about by contact of the steel with carbonaceous materials at the high austenitizing temperatures used for hardening lowers the melting temperature of the steel.

Apparently, changes occurring in heating control largely affect the ultimate hardness of a tool or die steel. During heating, austenite forms and carbides go into solution, the degree of solution being dependent on the steel composition and heating temperature. Heating should be at a high enough temperature so that a sufficient amount of carbon is dissolved to give the steel a high attainable hardness. However, there are many non-dissolved carbides in all tool steels, at the usual heating temperatures.

Overheating may cause tool failure. In the case of oil-hardening or plain carbon tool steel, overheating causes the grain to coarsen and the steel to become brittle. With a high-carbon, high-chromium type steel, too high heating temperature causes an excessive amount of austenite to be retained on cooling and in the case of high-speed steels, melting may occur.

The length of time that the steel is held at the required temperature determines the amount of carbon going into solution. The longer the heating time, the more complete the solution is. Consequently, the larger piece of steel, the longer is the time necessary to heat it. Usually, a quarter of an hour per inch of thickness is sufficient, although some recommend as much as an hour per inch of thickness. At very high temperatures used for high-speed steel, the time for heating is usually shorter, being about two to five minutes per inch of cross-section.

LESSON 13 - COOLING TOOL AND DIE STEELS

There are two temperature levels, which are important in the process of cooling tool and die steels from the austenitizing temperature. One of these is from about 1350°F to 900°F and the other is from approximately 700°F down to room temperature. The steel generally will be soft when it has been cooled to room temperature if the time taken in cooling from 1350°F to 900°F is long; if this period is short, the steel generally will be hardened. Some steels must be cooled through this temperature level in as short a time as possible in order to be hardened. Other steels will harden, even if the cooling time is not so short.

The cooling time can be regulated by the choice of quenching medium. If the tool is cooled in air, the rate of cooling is rather slow. For faster cooling, the part can be quenched in liquid at a temperature between 1100 and 400 °F and then cooled to room temperature in air. It can also be cooled in oil all the way down to room temperature. The fastest cooling is obtained by quenching circulating water or brine from 40 to 70 °F.

The time required for 1-, 2- and 3-inch rounds to cool from 1350 to 900 °F in air, in oil, and circulating water is given in the accompanying Table 3. It can be noticed that the time needed to cool the bar in air is much longer than to cool it in oil or water; that the oil quench takes a much longer time to cool than the water quench and that the center of the bar in the water quench takes a much longer time to cool than the outside.

Table 3 - Time Required to Cool Bars from 1350 °F to 900 °F

Bar size inches	Section of bar	Cooling medium		
		air	Oil	water
1	Surface Center	4 min	3 sec 10 sec	1 sec 4 sec
2	Surface Center	10 min	10 sec 30 sec	1 ½ sec 15 sec
3	Surface Center	17 min	20 sec 60 sec	3 sec 35 sec

When steel is cooled from 1350 to 900 °F, the austenite has a tendency to transform to soft mixtures of ferrite and carbide and it will be transformed if allowed enough time. The time necessary for transformation depends on the composition of the steel. The more complex the steel (containing more of the alloying elements as manganese, molybdenum, chromium and nickel), the longer the time required for transformation.

Carbon tool steel of the composition given in Table 1 and indicated in the upper right-hand corner, transforms very rapidly at this temperature level; the oil-hardening tool steel less rapidly; and the complex high-carbon high-chromium steel, the high-speed steel and the chromium hot-work steel require even more time. If transformation does not take place in this temperature range, the steel will harden while it cools to room temperature, whereas if transformation does take place, the steel will be either soft or only partially hardened, after it has become cooled.

LESSON 14 - TEMPERING TOOL STEELS

The final stage in the heat-treatment of tool steels is tempering, with primary purpose to toughen the steel. The tempering treatment consists of reheating the hardened steel to a temperature that is governed by the composition of the steel and its application and then cooling it to room temperature. Both air-hardening and oil-hardening steel are commonly used for precision die and other tool work. Non-deforming steels are made in both air- and oil-hardening types.

The hardness of the steel is decreased by tempering, but the improvement in toughness compensates for this. It is difficult to evaluate toughness in hardened tool steel. A number of testing procedures have been used, but none is universally accepted. It is difficult to create in the laboratory the conditions under which a tool may fail in service. The degree, to which steel is tempered, therefore, is still more or less according to rule-of-thumb and depends mainly on experience.

These relationships are correct for the steels as hardened conventionally. The change in hardness depends not only on the reheating temperature, but also on the time that the steel is reheated. It is possible to develop the same hardness with a wide range of temperature, if the reheating time is varied. The results obtained at a high temperature in a relatively short time can generally be reproduced at a lower temperature, if a long enough time is used.
The relationships would hold only for a uniform time, for example one hour, at each temperature. Usually, heating the steel at the required temperature for two to four hours is considered preferable to a shorter time, particularly for large sections, as the longer heating allows equalization of temperature throughout the section.

Apparently, the reheating at around 300 to 350°F has little effect on the harness of any of these steels. The carbon tool steel and the manganese oil-hardening steel are used with a temper as low as this, in order to retain as much wear resistance as possible. Since both of them have only a small amount of residual carbides, their wear resistance depends mainly on the hardness of the tempered martensite and they are used widely at a hardness of 62 to 64 Rockwell C.

In the shallow-hardening carbon tool steel, the residual internal stresses near the surface of hardened tool are in compression and therefore are effective in counteracting applied tensile stresses. For this reason, it is desirable in some applications not to relieve these internal stresses by tempering.

The high-carbon, high-chromium steel is generally tempered at between 450 and 550 °F to a hardness of about 58 to 60 Rockwell C, when used for cutting purposes; it can also be tempered at temperatures from 1100 to 1150 °F to a hardness of 58 to 60 Rockwell C, when engaged in other purposes, than high-speed ones.

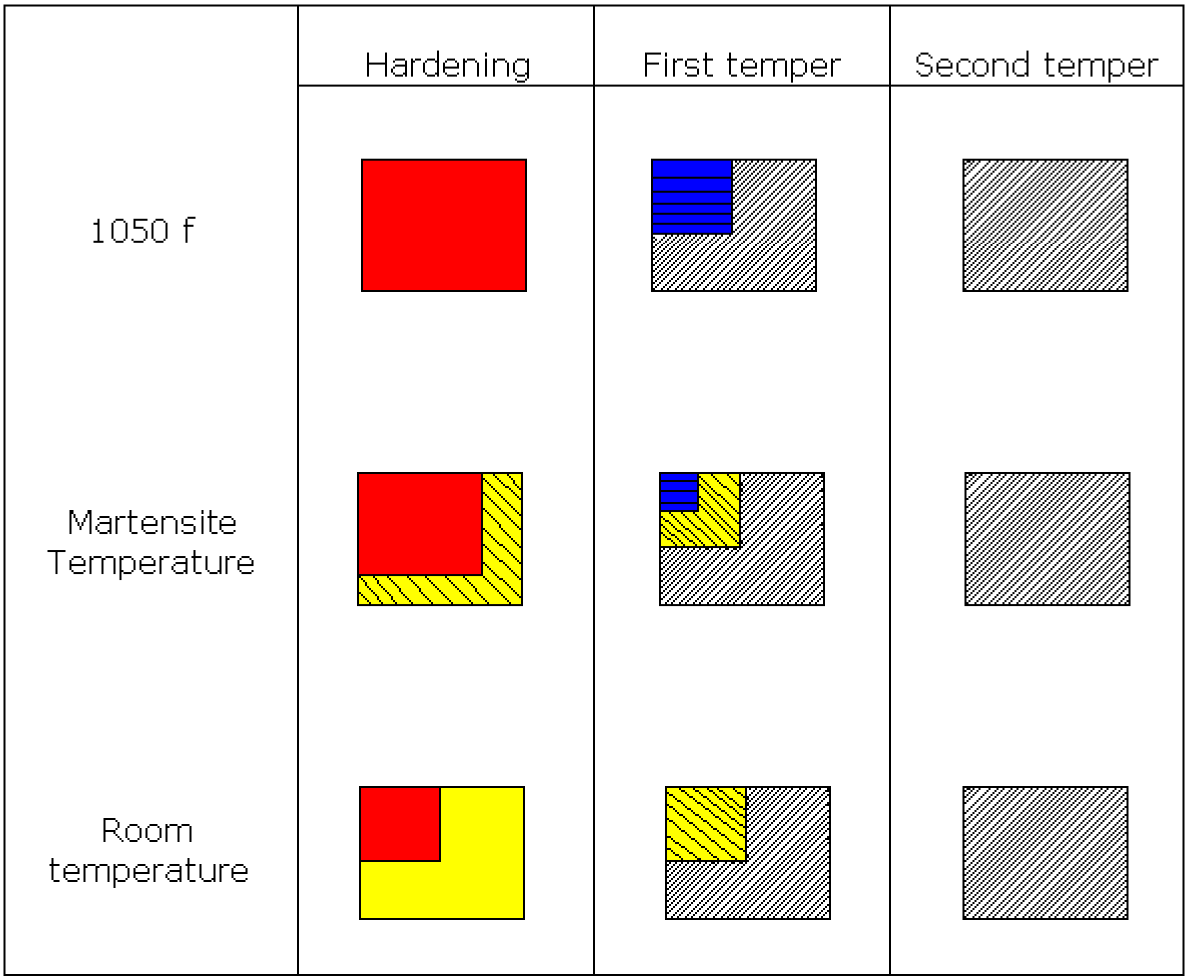
The hot-work steel is usually tempered at between 1100 and 1150°F to a hardness of about 42 to 48 Rockwell C. Although wear resistance is sacrificed at this relatively low hardness, it has been found that hot-work tools tend to split if they are used at a higher hardness. In many severe hot-work jobs, the surface of the tool attains a temperature of at least 1150 °F and it would automatically become tempered to the lower hardness, even though it was put into service at a higher hardness. On the other hand, the hardness of the hot-work steel as high as possible should be kept, in order to minimize heat checking, which is the ultimate cause of failure of practically all hot-work tools.

LESSON 15 - EFFECT OF DOUBLE TEMPERING

Double tempering is used in the treatment of high-speed steel tools to stress-relive the martensite. After hardening the steel by cooling it from the austenitizing temperature of 2250°F to room temperature, it is reheated to 1050°F and held at that temperature for two hours; cooled to room temperature; reheated to 1050°F and held at that temperature for an additional two hours; and then cooled to room temperature.

The sequence of changes that take place during this treatment of high-speed steel is illustrated schematically in Figure 5. In the hardening operation that is indicated in the column at the left, where the steel is all austenite, designated by the non-shaded areas, as it starts to cool from 2250 °F and it remains all austenite as it cools past 1050 °F down to the martensite temperature. As the steel cools below the martensite temperature, martensite that is designated by the sectioned area begins and continues to form until around 80 percent of the structure is transformed to martensite at room temperature. The non-shaded area represents the austenite retained at room temperature.

Figure 5



The middle column shows the changes that occur in the first tempering operation. When the hardened steel is reheated to 1050 °F, the martensite becomes tempered, as indicated by dark shaded area. At the same time, the retained austenite is not transformed to martensite, but it does undergo a change.
This change consists of a precipitation of alloy carbides from the austenite. The precipitation known as the “conditioning” of the austenite lowers the alloy content of the austenite, but does not change its structure. This is designated by the section with horizontal lines. When the steel is cooled below the martensite temperature, the conditioned austenite begins to transform to martensite.

The martensite that was tempered during heating remains tempered martensite, when the steel is at room temperature. Hence, a mixture of tempered and non-tempered martensite exists in steel at the end of the first temper. Non-tempered martensite is internally stressed and it is desirable to relive this stresses before the tool is put to work. Therefore, the steel is again reheated to 1050°F and the non-tempered martensite that was present after the first temper is finally tempered. No further changes take place during cooling, after which the tool is ready for service.

LESSON 16 - EFFECT OF HARDENING TEMPERATURE ON STEEL HARDNESS AFTER TEMPERING

The heating temperature for hardening the higher alloy steels may influence the hardness of the steel after its being tempered. This can be seen in Table 4, where the hardness is given for the molybdenum high-speed steel as quenched from 2100 to 2250 °F and for the same samples when single tempered at 1050 °F and when double tempered at the same temperature.

Table 4 - Effect of Hardening Temperature on Final Hardness of High-speed Steel

Austenitizing Temperature, °F	Rockwell C hardness		
	As Quenched	Single tempered at 1050 °F	Double tempered at 1050 °F
2100	66.0	61.5	61.0
2150	66.0	63.0	62.5
2200	66.0	64.0	63.5
2250	65.5	65.0	64.5

Although the hardness of the samples as quenched is practically the same for all, the hardness after tempering is lower. Hardness after tempering depends on precipitation of the alloy carbides from martensite and from retained austenite during the tempering operation and the amount of alloy that can be precipitated depends on the amount dissolved in the austenite during the heating for hardening.

The amount of alloy carbides, which dissolves into austenite increases with increasing heating temperature, particularly above 2100 °F and therefore, the higher the original heating temperature, the greater is the amount available for precipitation during tempering. Since the minimum hardness for good cutting efficiency in high-speed steel is about 63 Rockwell C, poor cutting efficiency may be expected from molybdenum high-speed steel tools, hardened at temperatures under around 2200 °F.

LESSON 17 - SIZE CHANGES DURING HEAT TREATMENT

The major factors of the changes in size, which occur in parts during the process of heat-treatment, are given in this lesson. Steel, like all metals, expand when it is heated and contracts when it cools. However, austenite is denser than its transformation products, all having different densities. The lower the temperature at which the transformation products form, the lower is their density, martensite having the lowest density of all. In other words, when austenite is cooled so that it eventually transforms into martensite, the steel first contracts because of the drop in temperature, but as soon as martensite begins to form, the steel expands because of the difference in density between the austenite and martensite. At last, when martensite is tempered, the density of the steel increases; that is, the tempering of martensite causes the steel to shrink in size.

Therefore, the successive changes during the heat-treatment of steel are firstly a contraction while the austenite cools, than an expansion when the martensite forms and finally a contraction when the martensite is tempered. This creates a problem if all of the austenite is not transformed during the hardening treatment, but is partially retained together with martensite, at room temperature. When this mixture of austenite and martensite is tempered, the steel shrinks at first and then expands if some of the retained austenite is transformed during the tempering.

Besides that, there are size changes brought about by the fact that in water quenching, as well as in oil quenching of some sections, there are sizeable temperature gradients from outside to center, which may set up sufficient stresses to introduce shrinkage in some directions and expansions in others. However, regardless all these sources of error, tools and dies are heat-treated satisfactorily in general, without cracking and within reasonable size tolerances. The quality of the tool steel and skill of the heat-operator play an important role in this process.

CHAPTER II – INTRODUCTION TO PAPER AND PAPERBOARD MAKING

LESSON 18 – PAPER AND PAPERBOARD COMPOSITION

Paper and paperboard are basic raw materials to make corrugated paperboard. Almost all paper is manufactured from wood. Cellulose fibers, accounting for around 50 percent of the content of wood, are the primary ingredient, followed by lignin acting as a fiber binder.

In modern papermaking, water plays an important role, but the papermaking process also uses sulfur, magnesium, hydroxide, lime, salt, alkali, starch, alum, clay. Plastics are used for paper coating.

Papers ready to use or make other products of them are delivered in flat sheets or rolls. The principle to cut them must take into account that the fibers in all papers and paperboards are aligned in one direction, which is known as grain.

Papers of several types are used to make corrugated paperboard. They are made of cellulose only, cellulose mixed with pulp and papers made of paper residues. Means of refining are different and their use depends on packaging type and application. Papers and paperboards can be refined to be waterproof or not to let vapor through, to be greaseproof or better to accept print.

LESSON 19 - PAPER AND PAPERBOARD PRODUCTION

The process of papermaking in a paper mill could be described as follows: the pulp is ejected in a thin layer onto the conveyer-sleeve. After that, the pulp is presses through a great number of cylinders and dried by a series of heated cylinders. Then, it is calendared and taken up by the web. Contrary to formerly used papermaking processes in which the paper produced was of low quality when everything from wood was used, the process of chemical pulping is frequently used nowadays. In this process, the wood is chipped into small pieces, the fibers are extracted through a chemical process and residue is eliminated. The pulp is then refined by washing and separating the fibers; the manufacturer can add various chemicals to increase bonding, texture and water resistance or can add pigments to color the paper, and coatings. Though more expensive, this process gives better-quality paper.

The cylinder machine is frequently used papermaking machine. It makes heavy grades of paperboard, generally recycled pulp. Since a paperboard is much thicker than paper, the drying operation lasts much longer. Large steam-heated cylinders drive the excess moisture out of the paper. After that, a coating is added in order to create a smooth surface.

LESSON 20 - PAPER AND PAPERBOARD CHARACTERISTICS

As it has been previously mentioned, basic raw materials to make corrugated paperboard are paper and paperboard. Packaging made of corrugated paperboard requires that these raw materials have certain characteristics, depending on the purpose, i.e. packaging type. The paper used for making waves has to have certain resistance to mashing and flat papers resistance to breaking and resistance to blows.

The paper for a wave has to be firm and at the same time, to impress creases on a roller to the very end, because that contributes to even firmness of waves. Besides that, the firmness of a wave depends on the paper structure and rigidness. Regular shape of waves cannot be obtained if the paper breaks.

The paper and paperboard are required to accept glues well and to glue together well. Glues used to glue corrugated layer to flat paper surfaces are of mineral or herbal origin.

The paper and paperboard should also be resistant to atmospheric impacts. Some kinds of transport require from corrugated paperboard packaging to be made of refined papers, which can resist impacts of humidity and water.

Considering different purposes of packaging made of corrugated paperboard, required characteristics are different. A paper and paperboard are required to have characteristics as constant as possible. A paper should not change while passing through heated rollers during the production of corrugated paper and it should not break on creases when it is folded; it has to be elastic and is firm at the same time.

LESSON 21 - PAPER AND PAPERBOARD WEIGHT AND FORMATS

According to weight (grams per square meter), there are several classifications. One of them is following:

- paper of weight 150 g/sq. m
- semi-paperboard of weight from 150 g/sq. m up to 250 g/sq. m
- paperboard of weight from 250 g/sq. m up to 400 g/sq. m

Another classification has these relations:

- paper of weight of 150 g/sq. m
- semi-paperboard and paperboard of weight from 150 g/sq. m up to 600 g/sq. m

- cardboard of weight from 600 g/sq. m up to 5,000 g/sq. m

Depending on the purpose, that is, whether transport packaging or commercial packaging paper is made, it is decided which paper will be used to make corrugated paperboard. Papers with higher weight are used to make the transport packaging from corrugated paperboard and vice versa, papers with lower weight to make commercial packaging.

The price of paper is usually given per weight, for most of papers and paperboards, except for wood-free copying paper that sometimes has a price per ream.

The paper is made in set-up formats. Most of commercial papers such as copy paper and writing paper are delivered in reams packed by 5 pieces in box and then put in standard pallets, adjusted for transport in big trucks or containers in overseas transport. There are kinds of paper delivered in reels like OCR (**O**ptical **C**haracter **R**eading) paper with special purposes, for example to make bank checks, or to be cut or already cut formatted endless forms such as NCR (**N**o **C**arbon **R**equired) paper, used for printing to produce several identical copies of documents in business companies, public enterprises, accounting departments, etc.

Table 5 - Standard paper formats

A		B		C	
Mark	Measures (mm)	Mark	Measures (mm)	Mark	Measures (mm)
4A0	1682 x 2378				
2A0	1189 x 1682				
A0	841 x 1189	B0	1000 x 1414	C0	917 x 1297
A1	594 x 841	B1	707 x 1000	C1	648 x 917
A2	420 x 594	B2	500 x 707	C2	458 x 648
A3	297 x 420	B3	353 x 500	C3	324 x 458
A4	219 x 297	B4	250 x 353	C4	229 x 324
A5	148 x 210	B5	176 x 250	C5	162 x 229
A6	105 x148	B6	125 x 176	C6	114 x 162
A7	74 x 105	B7	88 x 125	C7	81 x 114
A8	52 x 74	B8	62 x 88	C8	57 x 81
A9	37 x 52	B9	44 x 62	C9	40 x 57
A10	26 x 37	B10	31 x 44	C10	28 x 40

	inch		inch		inch
A0	33.11 x 46.81	B0	39.37 x 55.67	C0	36.50 x 51
A1	23.39 x 33.11	B1	27.83 x 39.37	C1	25.50 x 36.50
A2	16.54 x 23.39	B2	19.68 x 27.83	C2	18 x 25.50
A3	11.69 x 16.54	B3	13.90 x 19.68	C3	12.75 x 18
A4	8.27 x 11.69	B4	9.84 x 13.90	C4	9 x 12.75
A5	5.83 x 8.27	B5	6.93 x 9.84	C5	6.37 x 9
A6	4.13 x 5.83	B6	4.92 x 6.93	C6	4.50 x 6.37
A7	2.91 x 4.13	B7	3.46 x 4.92	C7	3.25 x 4.50
A8	2.05 x 2.91	B8	2.44 x 3.46	C8	2.25 x 3.25

Table 6 – Standard conversions

1 inch	25.4 mm
1 foot	30.48 cm
1 yard	0.9144 m
1 mile	1.609 km
1 cm	0.0328 foot
1 m	1.093 yard
1 km	0.62137 mile

There are standards for all types of paper that they have to fulfill in order to put in commercial use, which prove that they satisfy technical, technological and chemical requirements. Particular attention is lately put on the paper being environment friendly and marks confirming that are indicated on the packaging.

LESSON 22 - PAPER AND PAPERBOARD PACKAGING PRODUCTS

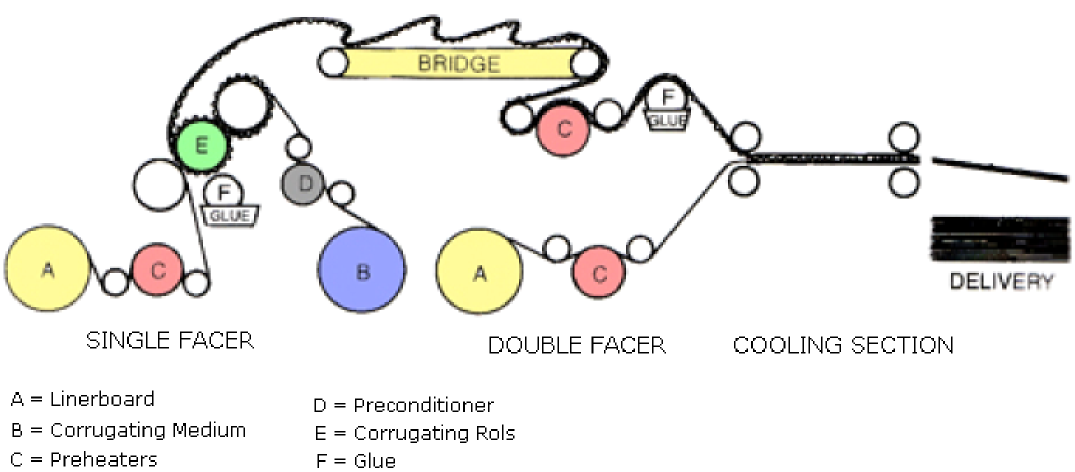
Contrary to the beginning of packing industry, when only several paper and paperboard packaging products existed, such as different types of boxes and packaging for bottled products, there is a variety of paper and paperboard packaging products today, followed by diverse materials that were designed with the development of technology and needs for packaging not only to have good physical, mechanical and chemical characteristic that are important for transport packaging, but also to be attractive to potential customer in the conditions of growing competition on the market, in a case of commercial packaging.

Besides boxes made of flat, corrugated or cross-corrugated paperboard that are basic packaging products, there is a variety of types of special packaging in all kinds of forms and new paper and paperboard products made depending on the purpose that they satisfy. They are much more visible in commercial packaging. Many types of folding paperboards or cartons, set-up or rigid paper boxes are in everyday use. There are die-cut three-dimensional displays that can be used in stores for practically all consumer products. With the expansion of self-service stores, the need for displays both for merchandise and for promotional products appeared, since paperboard was lighter and less expensive than metal.

Developing of papers with new characteristic gives new ideas to designers. In assembling the paper and paperboard packaging, a variety of specially made adhesives is created for paperboard packaging made of coated and laminated papers, for papers that require special types due to freezing temperatures or high moisture, such as self-adhesive and pressure-sensitive labels or resin emulsion adhesives for coated paperboards.

It is to be expected that the packaging industry will have the trend of increase in future period considering quantities, but the quality of packaging products as well.

LESSON 23 - CONSTRUCTION OF CORRUGATED PAPERBOARD - TYPES OF CORRUGATED PAPER AND CORRUGATED PAPERBOARD



The corrugated paperboard is a paper product, which is got by gluing together a corrugated paper with flat paper into a whole. Besides the corrugated paperboard, there is also a corrugated paper, which differs from the corrugated paperboard because it has not those characteristics, which the corrugated paperboard has and is made in a different way.

Considering the number of corrugated and flat papers, the corrugated paper and corrugated paperboard are classified, as follows:

a) Corrugated paper
- Corrugated paper
- Two-layer corrugated paper

b) Corrugated paperboard
- Three-layer corrugated paperboard
- Five-layer corrugated paperboard
- Seven-layer corrugated paperboard

LESSON 24 - TYPES OF PAPER USED TO MAKE CORRUGATED PAPERBOARD FOR TRANSPORT PACKAGINGS

The sulfate cellulose paper is mostly used to make corrugated paperboard as the type of paper with the greatest quality for its production. It can be bleached or unbleached. The sulfate cellulose has long cellulose fibers, which is a characteristic of this type of packaging paper.

It is in light brown color made of unbleached sulfate cellulose with characteristic of firmness to breaking, tearing and stretching, with one side rough and the other smooth, enabling good graphic imaging and good gluing. Smooth side is always outer side on corrugated paperboard, and rough side is inside and is glued to the wave. It is produced in weights from 100 up to 450 g/sq. m. The very sulfate cellulose paper and its excellent characteristics have pushed out wood from packaging. Of all types of papers in the production of corrugated paperboard, the sulfate cellulose paper is most often refined, either in the production process or subsequently. It is usually refined to be waterproof by means of bitumen, melanin or other resins, waxes and aluminum foil.

The paper made of semi-cellulose is used to make waves in corrugated paperboard. Its base is the wood of lower quality. It gives a wave of high firmness, which is particularly important in the production of corrugated paper. Due to that, and a low price, it is produced more and more to make waves. It is produced in weights from 112 up to 180 g/sq. m. Besides making waves in corrugated paperboard, it can be used for flat inner layer of corrugated paperboard packaging, but then it differs by its mechanical characteristics from the semi-cellulose paper for wave.

Plain chipboard is made of unsorted paper residues, cheap filling materials and insignificant quality of cellulose, usually in light brown or grey color. In the production of corrugated paperboard, the plain chipboard is used to both make waves and flat inner layers, but is of lower quality for wave than of semi-cellulose paper. If it has greater percentage of cellulose and sorted residues of sulfate cellulose paper, then it can be better to make waves than the paper of straw.

The straw paper is made by alkaline dissolving one-year old stems of grains. It is in yellow color. Although its quality is among the worst, due to the firmness of its wave and easy shaping, it is used a lot in the industry of corrugated paperboard. It is made in weights from 120 up to 180 g/sq. m.

Multi-layer papers, which can be as duplex or triplex, differ from other packaging papers only by the production process, where few layers of cellulose mass are mashed and stuck together making only one layer. Middle and inner layer are usually of lower quality cellulose mass, whereas the outer layer is of the first class. These papers are paperboards and can be differently colored. Multi-layer paper and paperboards are made in weights from 127 up to 450 g/sq. and are mostly used to make corrugated paper of better quality.

White or colored wrapping papers are sometimes used for transport packaging. White paper made of cellulose is used for inner layer of corrugated paperboard, especially for packaging of food products looking different and more hygienic than chipboard. If they are used for outer side of corrugated paper, their purpose is graphic solutions and advertising. However, it is used more in commercial paperboard packaging.

LESSON 25 - TYPES OF PAPER USED TO MAKE CORRUGATED PAPERBOARD FOR COMMERCIAL PACKAGINGS

The basic difference between papers for corrugated paperboard to make transport and commercial packaging is in their weight, because papers for commercial packaging are made in weight maximum up to 200 g/sq. m. for commercial packaging.

Woodless paper is made exclusively of sulfite cellulose without ingredients. It is always machine-made, smooth, satin-coated, and white or can be colored. It is mostly used for printing and writing, with the exception as an outer layer on corrugated paperboard for the packaging that needs excellent graphic imaging.

Wrapping superior-papers are made of cellulose with other ingredients and paper residues, in weights of 60-125 g/sq. m. They can be white, but also light brown. They are used only as an outer layer on corrugated paperboard for the packaging that needs good graphic imaging. Graphic imaging in commercial packaging plays an important role.

Sulfite paper is made of sulfite cellulose or cellulose of residue paper. It is usually made with 30% of residue paper at the most; it can be white or colored depending on the purpose and its weight is from 60 up to 150 g/sq. m. Like a superior-paper, it is used lately more as an outer layer on corrugated paperboard for the packaging that needs good graphic imaging.

Havana paper is a cellulose paper. It has glassy transparency, which is reached by heavy moistening and very sharp satin coating. It is hardly porous for grease and water. Therefore, it is used for the production of corrugated paperboard packaging of some food products, as well as more expensive cosmetics products that require elegant inner packaging. It is made in weights from 40 up to 70 g/sq. m and can be white or dark colored.

Parchment paper is a cellulose paper made by processing with sulfuric acid. It is greaseproof and waterproof and serves to pack fats. It is used for the production of corrugated paperboard packaging of some food products that are break-sensitive and can be white or dark colored.

Other papers can also be used in the production of corrugated paperboard packaging, with weights from 50 up to 200 g/sq. m, depending on the products packed in it. The purpose is to use them for graphic imaging with the aim of advertising.

LESSON 26 - CORRUGATED PAPER

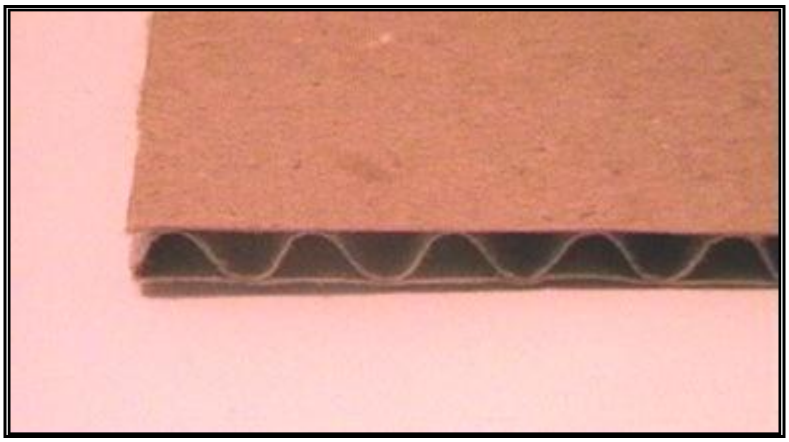
The corrugated paper is made from the paper in rolls on gutter rollers. The size of paper waves depends on height and depth of gutters on rollers. It is produced from different types of paper, qualities and weights, which depends on the purpose. A width and length of corrugated paper can be got at wish. Maximal width depends on working width of a machine, whereas the length is limited by the length of paper roll.

The two-layer corrugated paper is made in the same way as the corrugated paper. The difference between them is in fact that the two-layer paper is made of a layer of corrugated paper and a layer of flat paper glued together. It is produced from different types, qualities and weights of paper. The width of two-layer corrugated paper depends on working width of a machine, and the length on the length of paper from which it is produced, i.e. the length of a roll.

Two-layer corrugated paper is used for inner packing of products or for making cushions for inner packing of products.

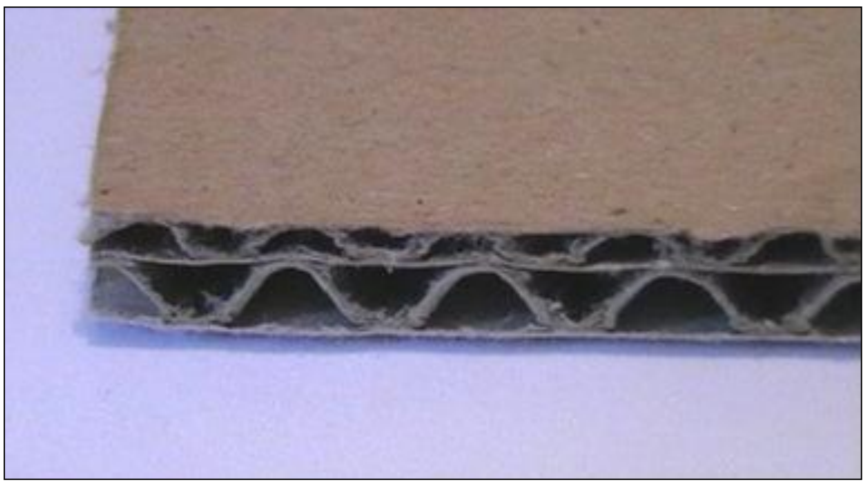
LESSON 27 - THREE-LAYER CORRUGATED PAPERBOARD

The three-layer corrugated paperboard is made so that on the two-layer corrugated paper another layer of flat paper is glued, of different qualities, types and weight. Since the three-layer corrugated paperboard is made of three paper layers, its mechanical characteristics differ from the two-layer corrugated paper. Whereas the two-layer corrugated paper is elastic, the three-layer corrugated paperboard is not. It has its firmness and rigidness. Due to that, it is its purpose in the first place to make boxes for packing of it. It can be also used for protection in inner packing, but not to wrap a product as with the two-layer corrugated paper, but to make small compartments and inserts for packing the products sensitive to outside blows or for their protection from mutual inner contacts. It can be also used as a means of isolation from heat and sound in the construction industry, if it is made of refined papers. The very quality of boxes made of three-layer corrugated paperboard depends on the product being packed, considering transport, handling and storage. It is used the most often to pack lighter products.



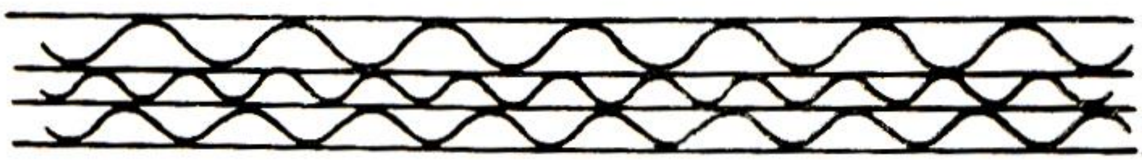
LESSON 28 - FIVE-LAYER CORRUGATED PAPERBOARD

As the three-layer corrugated paperboard consists of two flat and one corrugated paper, so the five-layer corrugated paperboard has five papers glued together in one whole: two corrugated and three flat. Two outer and an inner paper are flat, and corrugated paper is between them. A wave height of corrugated papers is different. The five-layer corrugated paperboard is made of papers of different types, qualities and weight. This type of corrugated paperboard is used as well as the three-layer one for making all kinds of boxes for packing and for inner protection of fragile products. It is used especially to pack different kinds of heavier products. It is more rigid than the three-layer corrugated paperboard and heavier by square meter as well.



LESSON 29- SEVEN-LAYER CORRUGATED PAPERBOARD

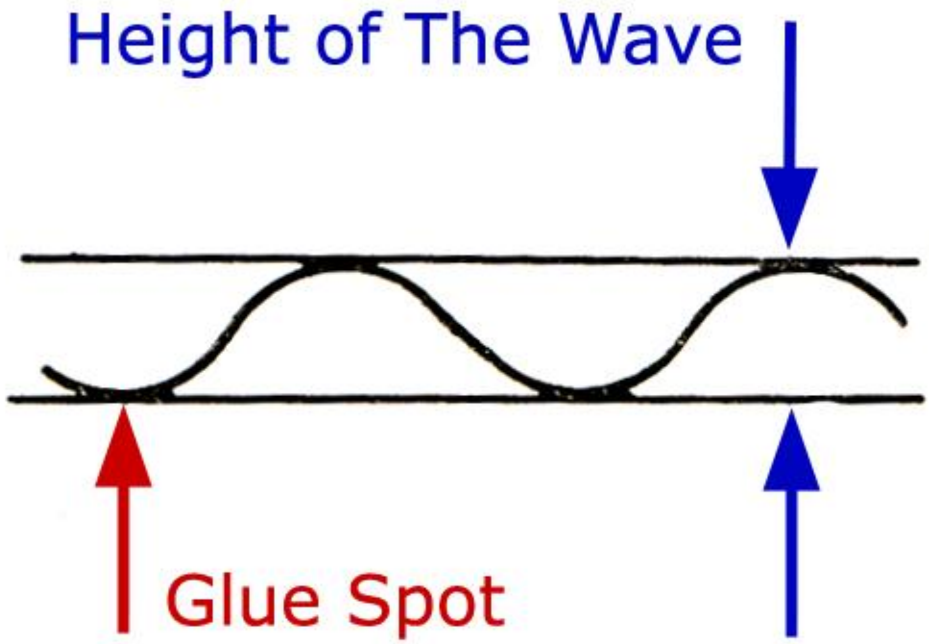
If two more papers are added to five-layer paperboard, one flat and another corrugated, the seven-layer corrugated paperboard will be made, which is more rigid than five-layer corrugated paperboard. It can be said for seven-layer corrugated paperboard that it is inelastic at all and hard to be penetrated. Firmly glued together seven layers of paper – four flat and three corrugated – give to the seven-layer corrugated paperboard some characteristics of wood, particularly in regard of rigidness. Because of that, from the seven-layer corrugated paperboard, especial boxes for packing are made, which differ from the boxes that are made of three-layer and five-layer paperboard. It has its especial purpose and it is used only for packing of heavy devices and machines. It is produced from different types, qualities and weights of paper. By square meter, it can weight even up to 2000 gr/m^2. The waves in the seven-layer corrugated paperboard can be of the same height, different height, or two waves the same and one lower or higher.



LESSON 30 – CONSTRUCTION OF WAVES ON CORRUGATED PAPER AND CORRUGATED PAPERBOARD

Corrugated paper and corrugated paperboard that have the same shape of wave and the same height of wave do not differ. However, the height of wave can be different. A wave is shaped so that that it can resist the best to pressures; therefore, the waves have the shape of powerful oval constructions whose tops are glued together with flat paper surfaces.

In the process construction of corrugated paper, gluing is an important factor, both from the aspect of gluing together papers and from technological, i.e. the production of corrugated paper. Papers must be glued together so that they cannot be separated by tearing out glued spots, but they will break on the spot where we wish to separate papers. They have to be of such quality that glued waves with flat papers make homogenous entirety. Glue must not break through the paper and it has to dry out fast. It has to have high viscosity to glue even to cover whole surface of papers, due to the speed of gluing.



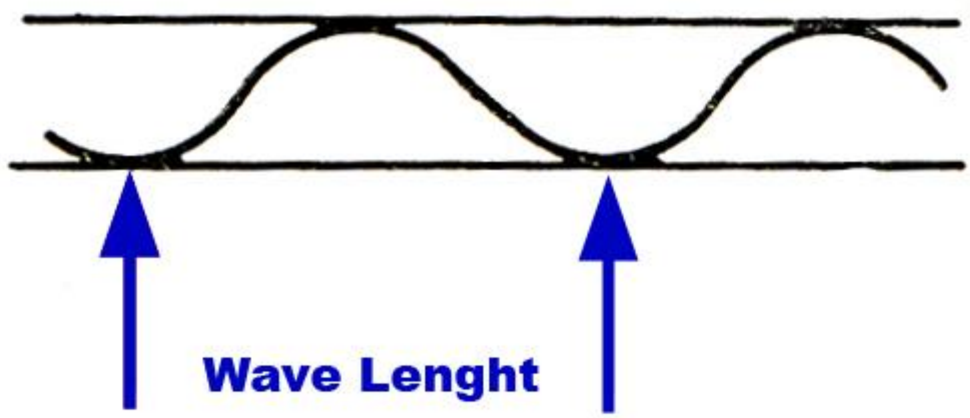
By their shape, the waves on corrugated paper and corrugated paperboard give elasticity, which is especially significant for the corrugated paperboard packaging. The value of waves is expressed only in case when they are well glued together with flat paper layers.

LESSON 31 - MARKS OF WAVES AND THEIR HEIGHTS

Based on heights of waves, the waves got their marks. Therefore, we have waves with marks A, B, C and E. Upon its height, its application in making a packaging and parts for inner protection of products in packaging depends.

Table 7 - Heights and lengths of waves

Wave mark	Length (mm)	Height (mm)
A	8.40	4.59
B	6.10	2.61
C	7.20	3.68
E	3.2	1.2



The waves A are the highest, so that they amortize blows the best. Therefore the two-layer corrugated paper or corrugated paperboard with wave A are used for packing of products which are very sensitive to blows during transport and storage. From corrugated paperboard with wave A, the packaging for transport of glass, earthen and ceramics products, as well as devices and apparatuses sensitive to blows, is made.

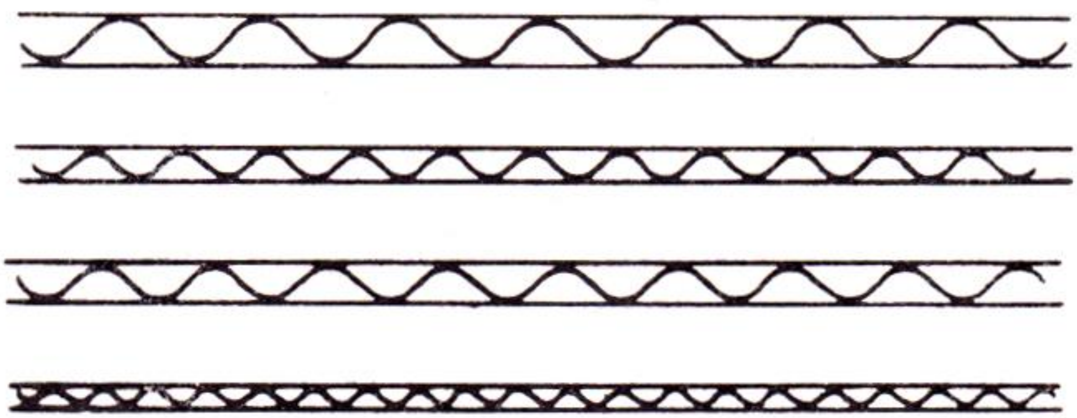
The waves B on corrugated paperboard for making the transport packaging are somewhat lower. They amortize blows with more difficulty, but therefore have greater resistance to oppressing, so that they can endure greater specific loading to the unit of loaded surface, than the packaging with waves A can do.

The corrugated paperboard with wave B is used for packing of products that are not so sensitive to blows, but can even out waves by their weight. The corrugated paperboard with wave B is used for packing the tin dishes with food products or products of industry, as well as heavier products.

The waves C are the attempt of combining characteristics of waves A and B and can replace them in some cases. Waves C mostly come in combination with wave A and B in making the five-layer corrugated paperboard. By their height, they are the middle between waves A and B.

The waves E are used for making the corrugated paperboard, which is used for commercial packing of products. Waves E are the lowest.

The three-layer corrugated paperboard can be made in all types of waves, whereas the five-layer or seven-layer are made with waves A, B, C and E, better to say by combination of these waves. The two-layer corrugated paper can also be made of waves A, B and C.



All kinds of papers are used to make waves, and the most often from paper made of semi-cellulose, straw, plain chipboard, etc.

LESSON 32 - NUMBER OF WAVES BY LINEAR METER

Upon the height of waves in the corrugated paperboard, the number of waves in linear meter depends. That number is different, i.e. the smaller the wale is, the number of waves by linear meter is greater and vice versa. An example is given in following table.

Table 7 - Number of waves by linear meter

Mark of wave	Number of waves by linear meter
A	120
B	167
C	140
E	295

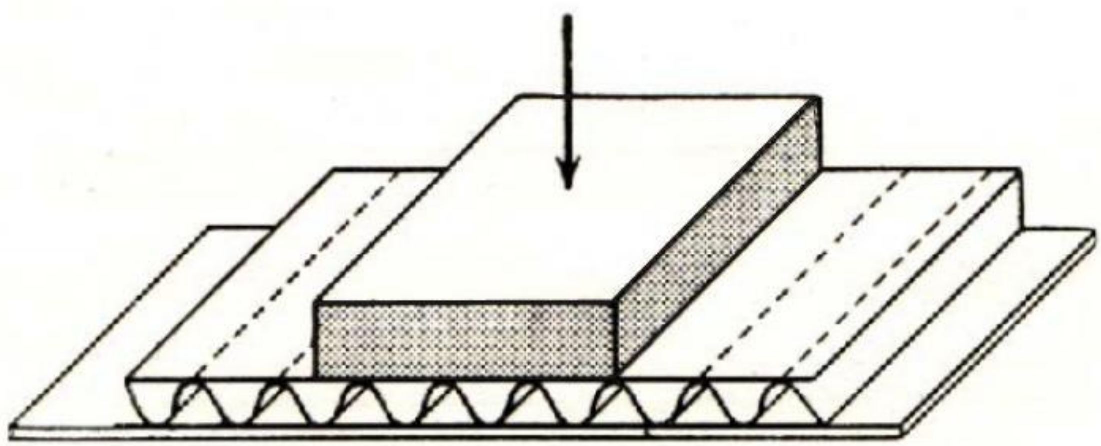
If the number of waves by linear meter is greater, then the consumption of paper for making the corrugated paperboard of certain type is greater as well. On average, around 35% more paper is used in making a corrugated paperboard according to types of waves. Of course, greater number of waves requires also greater consumption of glue.

LESSON 33 - RESISTANCE OF WAVES TO PRESSURE

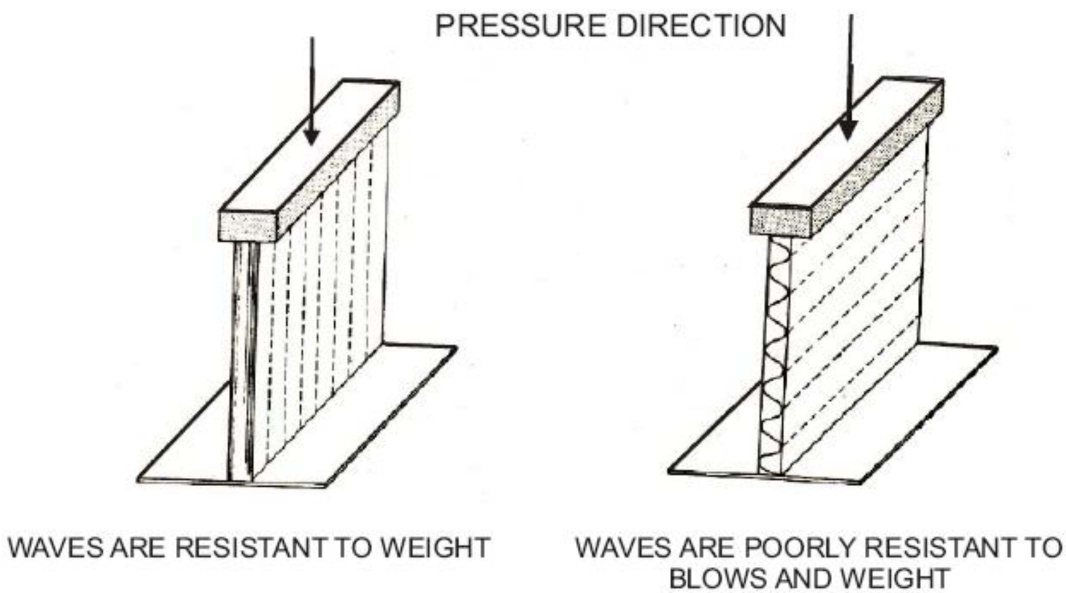
Four waves that we talked about up to now are diversely pressure-resistant. Although waves in the three-layer, five-layer and seven-layer corrugated paperboard may differ, the waves A or B are applied most often for the three-layer corrugated paperboard, for five-layer corrugated paperboard waves A with B, B with C and A with C, for seven-layer corrugated paperboard A and B, whereas the waves B or A are set between them. On all types of ordinary corrugated paperboard, waves are always set up in parallel with each other.

The firmness of wave arcs differs considerably, which depends upon the type of wave being used - the number of waves by length meter and shape of wale.

Therefore, e.g. the type B, which has more waves by linear meter than the types A and C, provides greater resistance to vertical pressure than types A and C.



WAVES ARE RESISTANT TO BLOWS



In case we load the corrugated paperboard parallel with the direction of waves, then the corrugated paperboard with wave A has the greatest “posts”, the wave is set vertically on the base and can bear greater loading than the paperboard with waves B and C.

If the corrugated paperboard should be set, so that loading falls vertically on linear meter but not on the tops of waves, then corrugated paperboard with the wave B bears greater loading than the corrugated paperboard with waves A and C.

Therefore, it can be said that the corrugated paperboard with the wave A serves as the best material for cushioning. Apart from that, the corrugated paperboard with the wave A has greater resistance to penetration than the paperboard with the wave B, whereas the paperboard with wave B is more resistant to tearing than the corrugated paperboard with the wave A.

Compared to mentioned characteristics, the corrugated paperboard with the wave C is somewhat between corrugated paperboards with waves A and B.

Just due to their characteristics, the corrugated paperboards with the waves A, B and C have especial purpose for making a packaging, particularly for making parts for inner protection of products in the corrugated paperboard packaging.

Therefore, the corrugated paperboard packaging is always made so that the waves regardless of their type are set vertically on the bottom of packaging, because only such packaging can be loaded under the greatest pressure.

During the calculation of loading moment on boxes, it was found out that they could be loaded the strongest on angles, and less in the middle, which depends upon the length of side.

To know how to load regularly a packaging is particularly important in practice, especially when the packaging is stored. Namely, then we should know that the packaging has to be piled so that angles are set on angles, that the boxes have to be always classified by size, and in no case to be piled in a storehouse so that the box angles should load the middle of sides.

LESSON 34 - SPECIAL TYPES OF CORRUGATED PAPERBOARD - CROSS-CORRUGATED PAPERBOARD AND ITS CHARACTERISTICS AND FOUR-LAYER CORRUGATED PAPERBOARD

Cross-corrugated paperboard differs from ordinary corrugated paperboard by waves set up cross-wards and to glue them together a flat paper layer is not necessary. The production of cross-corrugated paperboard and packaging was started in Lyon, France, of special machines, by the end of 1959.

As well as several kinds of ordinary corrugated paper exist, there are:

1. double cross-corrugated paper – corrugated paperboard with two inner cross-corrugated papers and two flat outer papers
2. double cross-corrugated paper – corrugated paperboard with two inner cross-corrugated papers, one middle flat paper and two outer flat papers
3. triple cross-corrugated paper – corrugated paperboard with three inner cross-corrugated papers and two flat outer papers
4. triple cross-corrugated paper – corrugated paperboard with three inner cross-corrugated papers, two flat between-layer papers and two flat outer papers

The cross-corrugated paperboard has not such a diverse application as corrugated paperboard since its production is difficult and it is not easy to make foldable boxes from it, but it can be successfully used for particular purposes like packaging for fruit and vegetables, heavy machines. In especial combination of packaging with wood, it replaces wooden boards.

Both cross-corrugated paperboard and corrugated paperboard are resistant to penetrating. Since the packaging made of cross-corrugated paperboard is more resistant than packaging of corrugated paperboard if loaded front to front, side to side, this characteristic enables its greater application, especially products packed in bulk or powder-like products, which cannot take over a share of loading to them. That characteristic opens the possibility of its great application in transport because it can be in any position without danger for goods to be damaged.

Four-layer paperboard is basically two two-layer corrugated papers gluer together. Doing this creates a three-layer corrugated paper board with a forth wavy layer which on the outside has a texture interesting for embossing and on the inside gives a better product protection. Characteristics of this paperboard are the same as the three-layer corrugated paperboard with the addition of the fourth corrugated paper layer. It is usually made with E type, for packages of smaller dimensions.

LESSON 35 - SPECIAL TYPES OF PAPERBOARD - FOLDING PAPER-BOARDS

The first machine-made folding paperboard, done with a die ruled for cutting and scoring a paperboard in a single impression, enabled a system in which small units are produced in manufacturing plants, which replaced sacks that were once the standard packages in food industry and grocery trade where the products are placed in paper containers made from diverse boards. An important function of such packages is dispensing of the contents over time. Therefore, a primary concern of packagers is to protect and preserve products for future use. Graphic and structural design has also given an opportunity to manufacturers and dealers to enhance their production, i.e. turnover.

The folding paperboard is economical in terms of both material and production costs. It takes up minimal space during shipment and storage due to being collapsible. In marketing aspect, the most advanced printing, embossing and decorating techniques can be utilized to enhance the paperboard's appearance and attractiveness of the package to customers.

There are many variations in the construction of folding paperboards and modifications of patterns are unlimited, depending only on designer's vision and imagination. They are precision-made nowadays. Low-cost packages and they become three-dimensional rigid packages when assembled. Some of them have a sealed inner bag to keep the product fresh. They can be filled in high-speed automatic, semi-automatic or manual process. Besides utilization of handling food, they are also used for pharmaceuticals, cosmetics, gifs, as well as for hardware and house wares.

In manufacturing of folding cartons, there are following main processes:

- Printing, done with several methods:
  - the letterpress method considered now as obsolete, transferring ink from a metal plate directly to a sheet of paperboard;
  - offset lithography, the most popular process for printing on folding cartons due to new high-speed presses and computer-aided systems giving high-quality color reproduction;
  - gravure printing, used for high-quality reproduction in large-quantity runs;
  - flexography printing, a low-cost, high quality method for medium production runs thanks to recent technological breakthroughs with fast-drying inks;
  - silk screening, a simple method of color printing in which a fabric mesh stretched over a frame is used instead of a printing plate.
- Die cutting - the process of creating shapes using cutting and stamping dies. There are three methods of die cutting:
  - hollow die-cutting, done with a hollow die and used for labels and envelopes;
  - steel rule die-cutting, used when a close register is required and several sheets can be cut at the same time;
  - die cutting using lasers - since a laser beam is extremely precise and sharp, accurate and clean cut is made as a result.
- Finishing operations, which include:
  - gluing; there are many types of glues and adhesives as a result of technological development, used depending on the purpose;
  - windowing (on-the-pattern cutting) - a window is often added on the folding cartons, by cutting straight and curved lines;
  - coating - a thin coat of rubber cement may be used, but since it is highly flammable and toxic, library paste is recommended;
  - laminating.

There are two basic types of folding paperboards. One type called the tray has a solid bottom hinged to wide side and end walls. The sides and ends are connected by a flap, hook or locking tab. These tray paperboards have a variety of covers and flaps extending from the walls and sides.

Another type of tray paperboard has two pieces, one of which being slightly smaller than the other, forming the base and cover of a box. Tray packages include cigarette cartons, bakery trays and pizza cartons.

The tube is one of the basic types of folding paperboards, whose body is a sheet of paperboard that is folded over and glued against its edges to form a rectangular sleeve. Its opening on the top and bottom are closed with flaps, tucks or locks. Sometimes, "undulated" packaging can be used instead, or together with a tube.

The tube-style paperboards are used for bottled products, cosmetics and pharmaceuticals. They give the product fully enclosed protection. There are many tube types available in diverse shapes, from triangular and quadrangular to octagonal and even rounded.

The cosmetics industry was the first to use packaging effectively, and its packages have the look of luxury and elegance. The cosmetics container is a folding or set-up paperboard embellished with refined colors, textures and graphics and plays a role of attracting potential customers.

Pharmaceuticals are also an important area for the packaging industry. Pharmaceuticals packaging uses all types of packaging, including paper and paperboard. Packaging plays an important role in providing sales appeal for over-the-counter drugs. The folding paperboard encloses a glass or plastic container for the medication and provides protection, as well as serves as a promotional tool.

Pharmaceuticals packaging has to preserve the potency of the medication, to protect the drug from harmful ultraviolet rays and from the heat, which can cause deterioration of the product. It also has to be childproof and tamperproof.

Pharmaceuticals industry used promotional packaging for the introduction and promotion of new products. In addition to product samples, these packages contained literature in time. Promotional packaging was followed by manufacturers of other products and services and is now used by all major industries

There are many other products, which could be included in special packaging, such as sleeves, wraps, folders, carrying cases and other that need no adhesives, all die cut and all applicable in several segments. Many of them are made according to patterns created by teams of designers whose task is to design new practical and attractive packaging for demanding market that would be corresponding to the product and have an appeal for the customer.

LESSON 36 - INNER PROTECTION IN PAPERBOARD PACKAGING

The undulated paper is made on special machines and is used as inner protection for packaging of bottles, jars and ceramics products. It is usually made of two pieces of paper, which stick to each other by their creases. These forms are made as tubes in different dimensions and have the ability of stretching.

This packaging material known as stiff comb is made of hexagonal paper forms glued together in the shape of bee honeycomb, whereas a flat paper is glued on its top and bottom. The needs of practice and possibilities of machines that make them determine their height. The material produced in this way is used to pack heavier products either alone or with corrugated paperboard and wood. It is more lately used for product cushioning in order to give them inner protection. The stiff comb packaging are more used in overseas transport, particularly if they are made of refined papers resistant to special conditions in regard of humidity, insects, temperature, etc.

Inside boxes, as additional protection, sawdust, foam paper, paper of lower quality and pieces of plastics materials can be put to prevent moving and damaging of products.

LESSON 37 - REFINED PAPERS AND PAPERBOARDS

Refined papers and paperboards are the products, which are refined in the production process by adding different chemical material that serve as fillings, brought or added to a mass in the production of paper or paperboard. Mechanical characteristic, as well as characteristics according to purposes for which they are intended, are given to papers and paperboards. Such papers or paperboards have especial purposes as for example the paper against insects and microbes, waterproof and greaseproof papers and paperboards.

Papers and paperboards can be refined in several ways:

- in the preparation of a cellulose mass to get paper with a product, which is added to a mass to achieve waterproof characteristic,
- bringing the material onto the paper - resin or synthetic material, bitumen, etc,

- by soaking a paper into solutions, which have refining materials in them,
- by plunging ready packaging into a solution of wax, paraffin, resin and other.

Mentioned refining procedures have their advantages and disadvantages. Refining procedures are applied, which correspond to required purpose the most and which are the most economical.

There are differences in opinions in regard of the production of corrugated paperboard packaging made of refined papers. Some experts have an opinion that corrugated paperboard packaging should be made with refined papers only on inner and outer side, whereas others think that all layers of such paperboard should be made of refined papers. That refers only to papers and paperboards to which materials for refinement, for achieving waterproof characteristic or humidity resistance are added in to process of a cellulose mass production. On papers refined by bringing a material onto them, protective layer is deposited on inner or outer side, depending on the conditions of transport and storage.

When impacts of water and humidity are considered, refined papers, taking into account their characteristics, are classified as follows:

- papers resistant to humidity and vapors, i.e., waterproof,
- paper non-porous for water and liquid, i.e. water-non-porous.

Characteristic of being non-porous is manifested in not letting a liquid through or "rejecting" it, whereas papers resistant to vapor and humidity, to prevent vapor and humidity to make impact on their characteristics.

To achieve above mentioned characteristics, corrugated paperboard packaging is refined with melanin resins, urethanes, waxes, paraffin, bitumen, silicates, polyamide resins, lacquers, polyethylene and other synthetic materials, metallic-finish and aluminum foil, all depending on possibilities and requirements of packaging and transport.

The corrugated paperboard packaging made of refined papers does not differ considering handling, transport and storage from other types of the corrugated paperboard packaging. All papers can be refined, but the types that are more qualitative for making transport corrugated paperboard packaging by their characteristics are refined the most, as for example a sulfate cellulose paper, duplex, and only at need for especial purposes plain chipboard, semi-cellulose paper and straw paper.

Refined papers and paperboards and packaging made of them have found greater application recently, particularly in the countries that send goods overseas and in internal transport of food and agricultural products, as well as other products that have to be protected from impacts of water and humidity during handling, transport and storage, or have to resist humidity during storage in refrigerator trucks or plants, or during storage in conditions of sudden changes in temperature and humidity.

LESSON 38 - PRINTING, DECORATIVE AND OTHER SPECIAL PAPERS FOR PACKAGING

Greater competition on the market with new products created and in competition for their place and trying to single out from other products on the market gave to the packaging an important role to attract customers. By the development of technologies, many special types of papers for printing and labeling were improved, and even new ones created. Decorative papers are also made in a variety of types and forms.

Papers used for box wraps and box coverings include papers with flat finish that can be coated or uncoated and with glossy finish serve as a good printing surface, flint paper with fine-quality surface and high gloss, metallic-finish paper with decorative effect, friction glaze with good appearance at low cost,

Foam paper is made by laminating foam polystyrene sheet to paper and mostly used as protective cushioning for wraps.

Glitter paper that has metal embedded in paper surface and aluminum laminated foil are used as a decorative paper. Cosmetics and luxury items are packed in packaging made of more expensive papers, such as half-fine embossed papers that are looking elegant, with continuous metallic surface, papers with iridescent or pearlescent coating and tissue, which is specially treated for texture water and printability and designed to attract appeal.

Vacuum metalized papers are used as wrappers for food and confectionary products, as well as labels for batteries canned products. Glassine being grease and oil resistant is used to make trays for food products. Parchment paper, as already mentioned, is water resistant and used as a wrapper for greasy and oily products; polyethylene and saran-coated paper are moisture resistant and widely used for food products, including cracker cartons and bread wrappers.

CHAPTER 3 – DIE-MAKING PROCES

LESSON 39 – PROTOTYPE MAKING

After decided to pack a product in to a paper package, the first thing that needs to be done is to build a prototype of the package. Successful prototype is being examined and after proven good and acceptable; making of the package is being ordered.
For developing a prototype, you need to know:

- The product and all of its characteristics: weight, dimensions and nature of the product,
- Transport conditions, handling and storage and atmosphere conditions,
- Capability of the producer of paperboard packaging to produce such packaging,
- Special demands of the users of the package, if there are any, and
- Insurance

But not even this is enough, for building a prototype from a corrugated paper which will be a "good enough package" you need to know:

- Closing type
- Method of marking about handling, and
- Special demands of transporters, insurance companies, etc.

When all of this taken in to consideration, then you first should determine:

- Type and shape of the package,
- Packaging material, i.e. what kind of a corrugated paper will be used, with how many layers and what duality,
- What would be the inside package, what paper quality of the inside package, how to place the inside package considering the shape of the product,
- Material for closing the package and the means of closing, and
- Man-handling considering the nature of the product.

When all of this is determined, then you can build a prototype of a package or a corrugated paper box for packing a certain product.

When the prototype is finished, then you start working on the graphics packaging processing, such as advertising, required data about the product, markings considering handling…

Even before measuring the product, meant for packing, it is strived to reduce the dimensions of product as much as possible to a minimum. That is why when measuring the product you measure its:

- Shape, dimensions, and
- Placing the parts of the inside package when it's about packing different products – electric motors, radio receivers, television sets, porcelain sets of dishes, or products that do not have a symmetrical geometric form, therefore the inner packaging is necessary.

When packing products in a commercial package you have to consider the number of the products to be packed, for example tin dishes, boxes, glass bottles, by weight, and than the shape of the package by length, width and height. While determining the package of the sort like this is simple, determining the package for a product that has a particular shape and that needs to be fastened in the package to give a homogenous package is somewhat harder.

When you determine the parts for inside protection, types and dimensions, then you determine the dimensions – space which the product with the protection parts takes. Then you drew a blueprint for a prototype, and you hand build the parts for inside protection. Place the parts on the product and determine the dimensions of the package.

After all this is done, the product with the protection parts according to the sequence of putting inside is placed in the package and tested how the protection parts and the product handle themselves in the package, and if needed the protection parts and the package are adjusted.

This still does not mean that our prototype was finished; it still needs proper markings of handling. Then again the inside protection parts and the package are tested and adjusted according to the results and perceiving during the first testing.

Prototype has to be done precisely at the end, because only then will later be possible to build a good package.

Operations from receiving the product, for which you have to make the package prototype to the last stage, before going in to serial production, could be sorted like this:

- Studying the product and packaging regulations (standards),
- Determining the quality of the prototype,
- Taking the fundamental measures for making,
- Making blueprints,
- Planning of the graphics processing,
- Prototype making,
- Prototype testing,
- Prototype improvements based on the results of testing, and
- Developing the final proposition with graphics solutions for a serial production.

You can see that developing a prototype is not such an easy work and because of this, it should be entrusted to experienced creators. When all operations with developing the prototype are successfully completed, the prototype is then given to the client, which gives his remarks and suggestions. The client can take part during the process of making the prototype if he wants to, or he could be called.

After making the prototype, the producer of packages then does a "zero" series, which is then sent to the client for testing purposes and based on this testing to give his suggestions. Only after the final corrections on the prototype, a package for a certain product is being produced.

LESSON 40 - PACKAGING EXAMPLES, PROTOTYPES TESTED BY CLIENT

When decided to pack a certain product, the producer sends to client several package samples so the client could then test them using monitoring methods, see what kind of quality is he getting, check the inside package, and check the quality of closing.

This is important and useful, because clients' suggestions can be very useful for the producer, so they should always be sent in writing or suggested in the contract, order and delivery of boxes (packages).

In this line of work, cooperation between the producer of the packages and the client who wants to pack a certain product is eminent. If the user knows any packaging regulations, he can critically consider and give suggestions if he finds out that certain corrections on the packaging contribute to improving the package. Suggestions of the client may have foundations in the suggestions of the final users, buyers of the product. This gives him certain advantage in redesigning of packaging considering the experience that he has in packing of products in some other packaging or by other packaging producers.

If it is found out that the customer had no damages in longer operating contact, that the packaging must be studied again to make the method of packing simpler, or vice versa if major losses are found out, to improve the method of packing and the quality of packaging.

There is no doubt that such a package can be made in which the product could with 100% certainly be transported, but such a package will certainly be costly. Such a package is by no chance economically justified, but instead you should go with a simpler package, with which sometimes even the loses could be justified because they would still be less than the difference in costs between the 100% certain package, where the package is expensive, and the package which is cheaper and the losses are small.

Therefore, the studying by monitoring method is always useful as well as studying the examples because based on that you could obtain important data for new orders of packages.

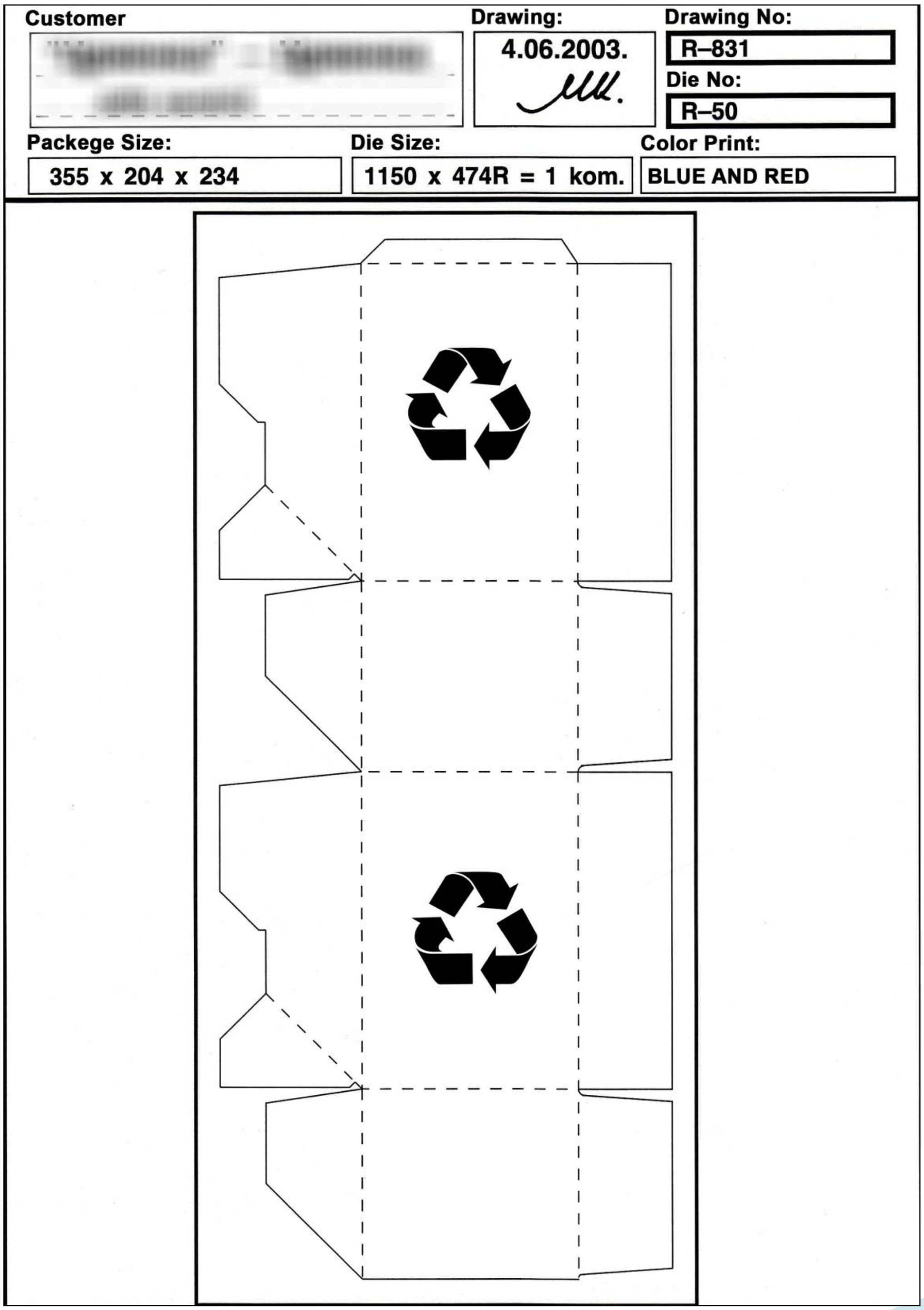
LESSON 41 - DIEMAKING IN THE PROCESS OF MAKING PROTOTYPES AND PACKAGES

During its development a prototype could be made by hand, or for every version of it a proper die could be made according to proper blueprints. Even though such a method is a lot more expensive, it gives the best possible image of the package to be because such a die could later, after all the testing, be used for serial production. So in order to cut down expenses it is preferable to keep the number of “testing dies” to a minimum. Which are why the first prototypes should be done by hand and the final tryout should have a proper die.

Example that will be shown is about making a die for packing a CD writer. But this writer was not bought by a client and no order has been made to make a package for it. It was bought in a computer shop as an already packed product. So we are skipping the entire process of making the prototype, but making the copy of a finished package.

This is one of the most important rules in die making, taking in to account the material thickness in determining dimensions of the package. Especially when it comes to making package from corrugated paper. If you take the measures of the product alone and take them as final, it could lead to problems in the later stages in prototype and package development. It’s like making a package for a different product, and it usually leads to making a smaller package than required.

So the first thing to do is to make the proper blueprints (die design). Blueprint represents a technical drawing of the package in a developed form that corresponds to the measured dimensions (length, width and height). In this case the measures could be taken from the CD writer or the package of the writer. The inside measures of the package are the same as the measures of the writer, but the outside are measures are larger for 2 material thicknesses for length and width, and 4 for height. So it is easier to take the inside measures or, as it should be done, the measures of the writer. When making the blueprint you have to consider the thickness of the material by adding 1 thickness to the measured dimensions (length, width and height).



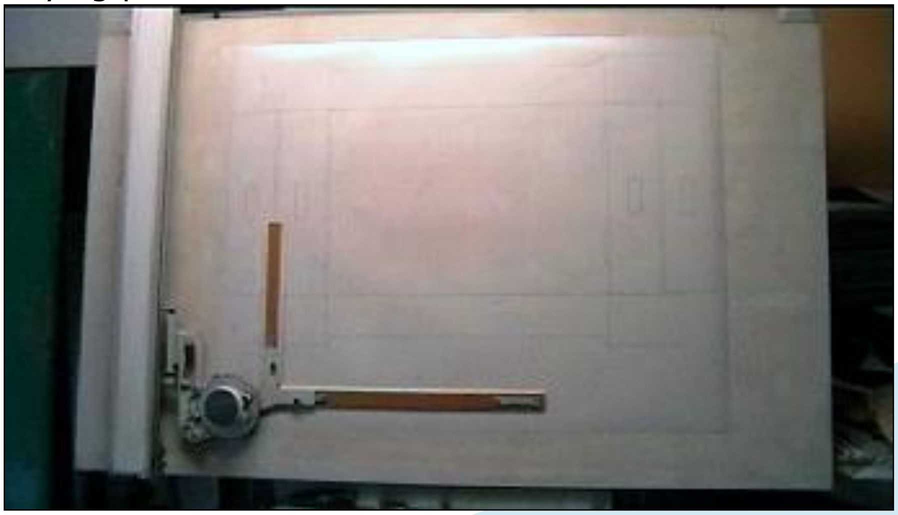
Blue Print Example

In now days the most widely used ways for making blueprints is using computers and programs such as CAD/CAM which in great deal makes working easier, gives many manipulation possibilities and high precision. They also provide control over the entire process of making the package from making the prototype to the making of the die for the package because they can be connected to other computer controlled machines (CNC lasers, rule processors, plotters, etc.). They can also calculate expenses, make printing preparations etc.

All of this represents the latest technique in die-making and using such methods costs great deal of money. But it hasn't been always like this. In the earlier days for making blueprints, and dies, a lot simpler and, compared to latest technique machines, cheaper methods. For this example we will use one of these methods to make our blueprint; the drawing board.

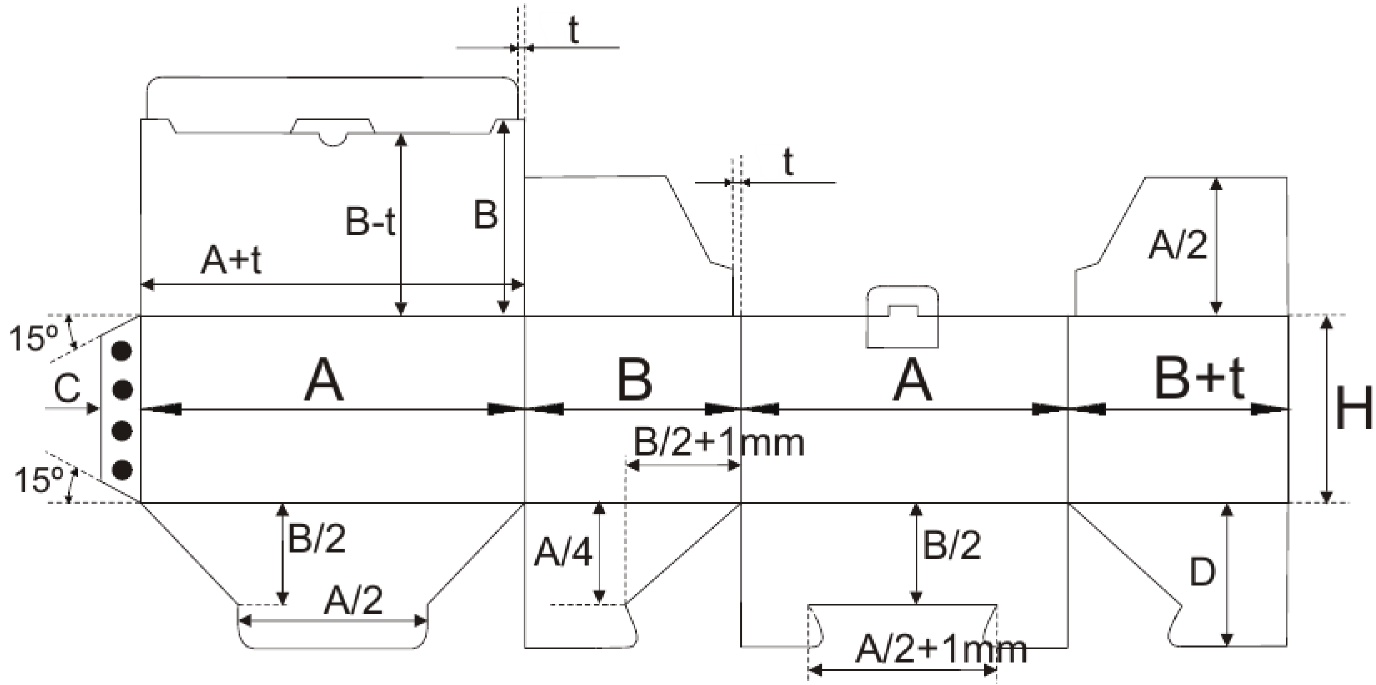
A drawing board is a kind of multipurpose desk which can be used for any kind of drawing, writing, sketching on a large sheet of paper, drafting precise technical illustrations. With the rapid use of computers drawing board is becoming less common. Work produced on a drawing board cannot easily be reproduced and manipulated in the way electronic documents can. Various types of drafting machine are often attached to the board surface to assist the drawing process. Parallel rules often span the entire width of the board and are so named because they remain parallel to the top edge of the board as they are moved up and down. Drafting machines use pre-calibrated scales and built in protractors to allow accurate drawing measurement.

Even though drawing boards are “out of date” they are not thrown out completely. While using computer programs requires higher knowledge and taking special courses, drawing board represents an improvement compared to common ruler and pencil. Drawing board can provide a satisfying precision in the tolerance level.



Die Cutting and Die Making Guide

When making blueprints for packages you have to follow certain rules concerning projecting dimensions of the package in a developed form. These rules refer to the elements that make a package complete (closing type, package bottom, with or without gluing). These elements are defined in the process of making the prototype for the package and for our example the form is defined like this:



A-length	H-height
B-width	t-material thickness
C-width of the glue lap	D=A/4+B/4

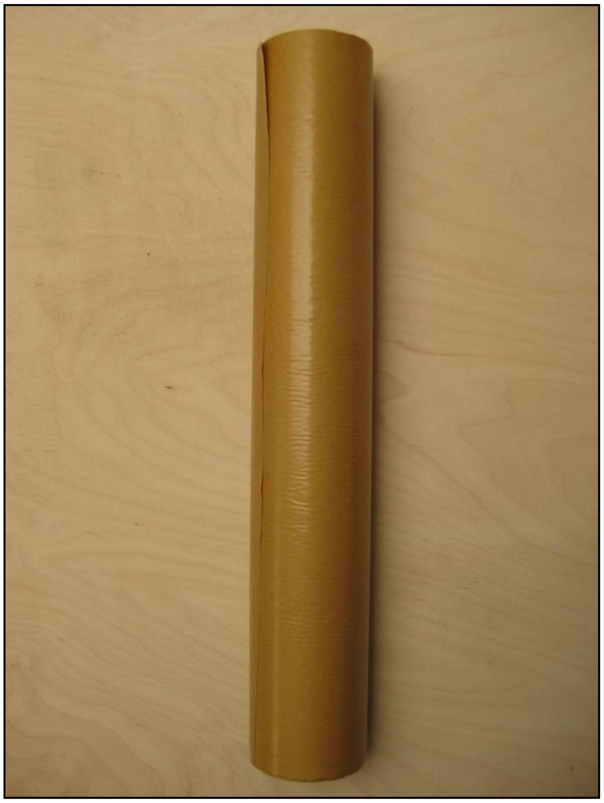
The closing type used here is an auto split lock top combined with a resealable top. The bottom is a snap lock bottom. The dimensions defined in the picture are obtained by adding 1 material thickness to the length, width and height of the material to be packed, in this case CD writer. The reason for this is that when bended material goes inside by ½ and outside by ½ of his thickness. Since the material is bended on both sides, left and right, two bandings make 1 material thickness that goes on the inside and needs to be added to that dimension in order to compensate for the bending. So dimensions A, B and H are (a+t), (b+t) and (h+t) where a, b and h are length, width and height of the object to be packed (CD writer).

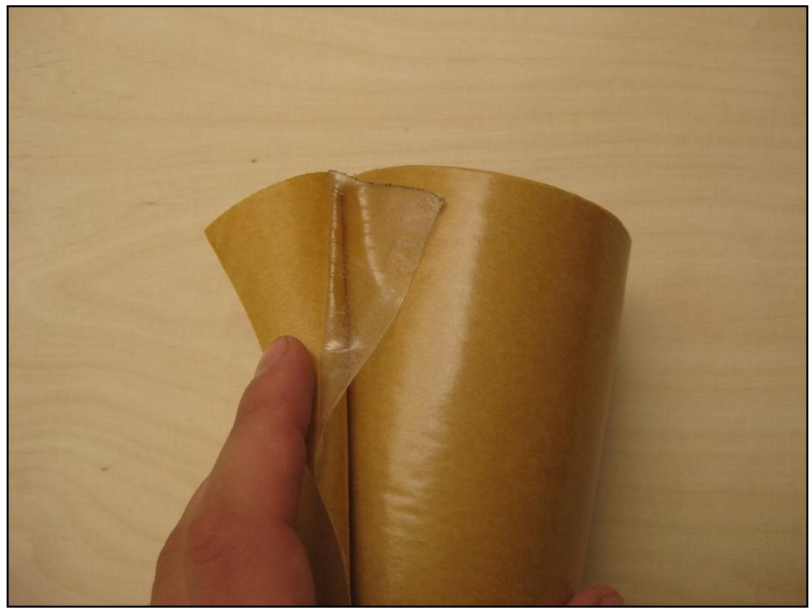
Die Cutting and Die Making Guide

The paper that was used to draw the blueprint is waterproof. Using ordinary paper is not recommended because of the reactions to temperature and humidity that would lead to image distortions.

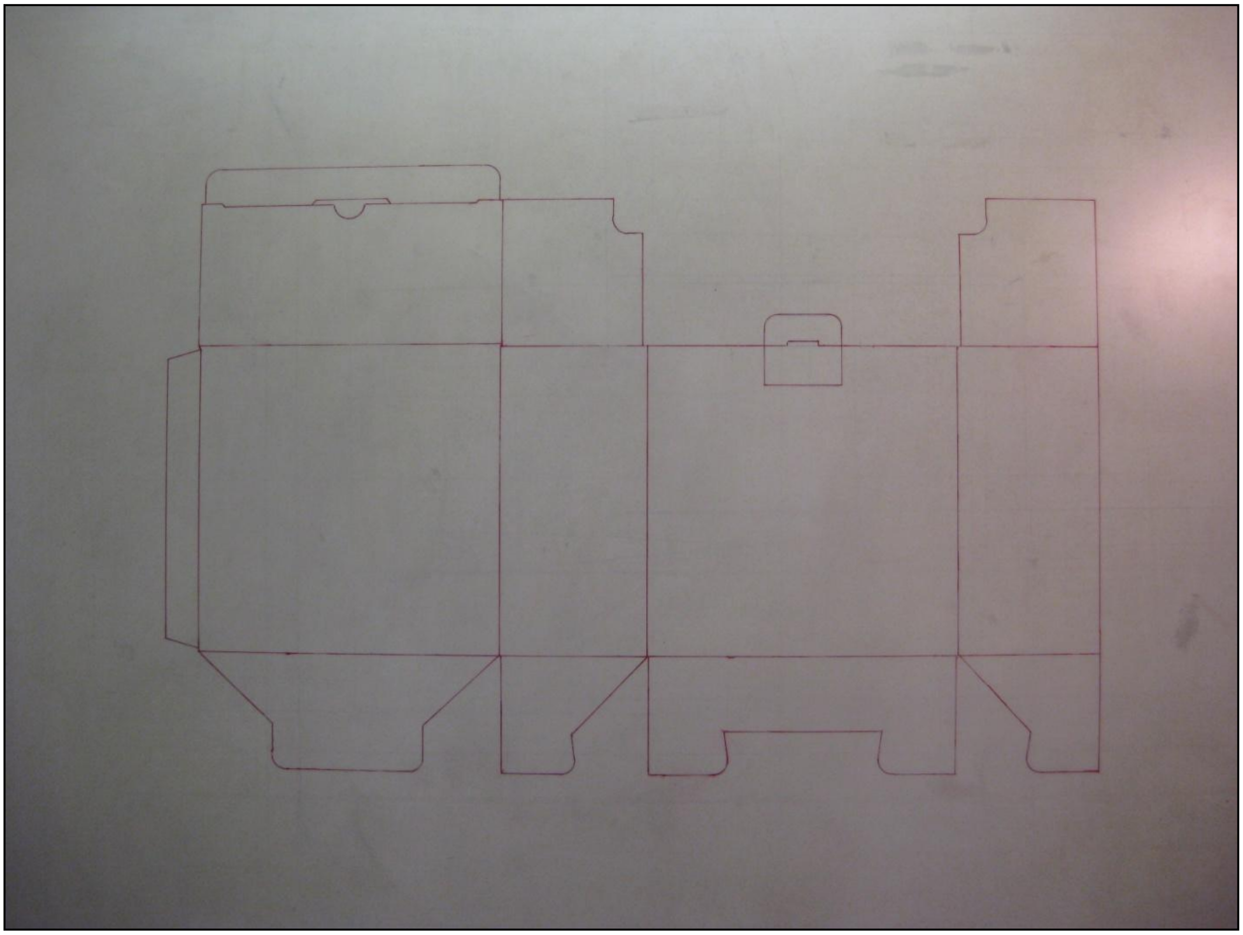
Another way of making blueprints is making it using computers and programs for technical drawings, CAD images, and printing the image on plastic see-thru foil (film). Printing is done on machines called plotters, who can print large scale images. This foil is then glued on die-board.

This type of blueprints is very precise, lines are a lot straighter and thinner, and generally better to work with. The foil is glued with either liquid glues or double side adhesive tape which comes in different sizes. Best for these purposes are the ones that are made like roles, wide around 50cm (~20 inch).





The drawing that we made in real size is:

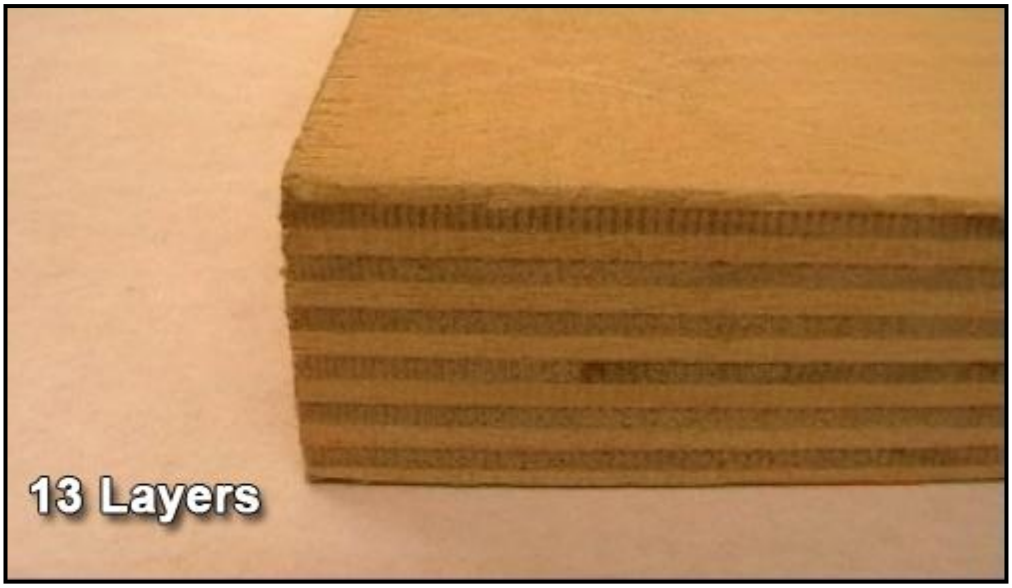


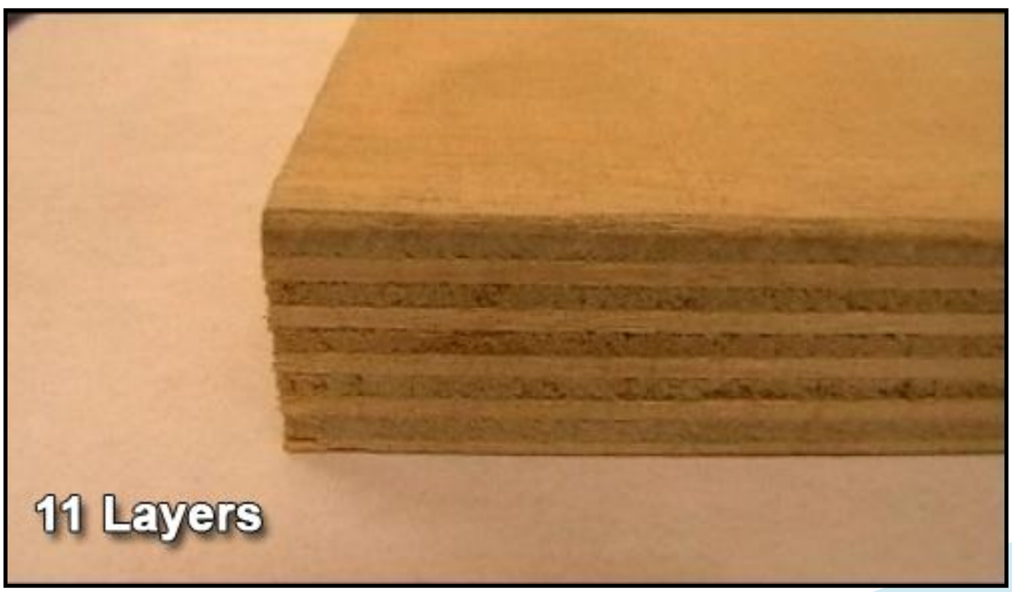
This one is done on a drawing board, and I both cases one very important rule is to make this blueprints mirror image of the package itself. The reason for this is because the die punches the sheet material that is processed facing up. So if there is an image printed on the material for dicutting it is most important to reverse the image while die designing.

After finishing the draw we move to making a die. Here will be explained how to make a die that consists of three basic elements: wooden board (plywood), knifes called “rules” and rubbers.

LESSON 42 - PLYWOOD

Plywood is a type of engineered wood which is made from thin sheets of wood veneer.





Wood veneers are thin slices of wood, usually thinner than 3 millimeters (1/8 inch) that are glued together with the direction of each ply's grain_differing from its neighbors' by 90° (cross-banding). Veneers for plywood are obtained by "peeling" the trunk of a tree (log) called a peeler. The wood is turned against a very sharp blade and peeled off in one continuous or semi-continuous roll. The veneers are then glued together and baked in a press at 140 °C (280 °F) and 19 MPa (2800 psi). Wood grain describes the alignment, texture and appearance of the wood fibers.

The plies are bonded under heat and pressure with strong adhesives making plywood a type of composite material. The reason for using plywood instead of plain wood is its resistance to cracking, shrinkage, twisting/warping, and its general high degree of strength. Since plywood is an engineered wood its characteristics can be controlled to meet specific performance requirements.

On plywood characteristics also affects the type of wood used. For example beech plywood has a high hardness; wood veneers are thicker than usual so the plywood has fewer layers. Because it has larger hardness it is harder to cut, and it is not most resistive to moisture. On the other hand, birch plywood is softer, liter and easier to cut. It has thinner and more layers, better moisture resistance, generally better looking texture. Probably worst quality plywood is poplar plywood. It is has small hardness, less layers, light weight and generally poor characteristics. But it also has the lowest price. This type of tree is commonly known as paper wood, because it is widely used for the manufacture of paper. Some plywood made for die making purposes only have coating, which gives better rubber adhesion.

For the die we are making we will use plywood of 15 mm (5/8”) thickness with 11 layers. You can also use 18 mm board for making cutting-dies. Using 15mm or 18 mm boards depends on market or costumer demands. Different board thickness also responds to the purpose of the die; striping board is made with a 12 mm (1/2”) board, striping tools on a 15 mm board, blanking tools on an 18 mm board.

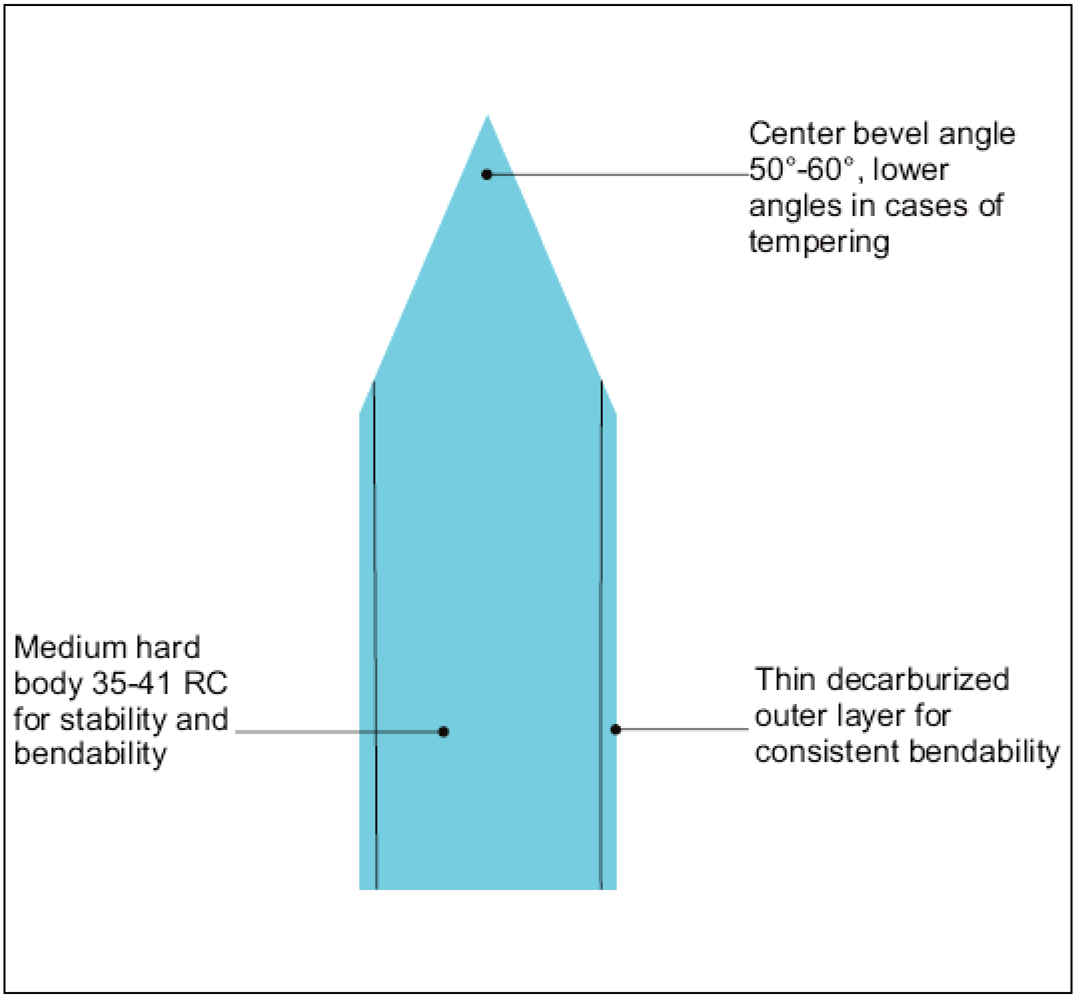
LESSON 43 - RULES

There are 2 main types of rules:

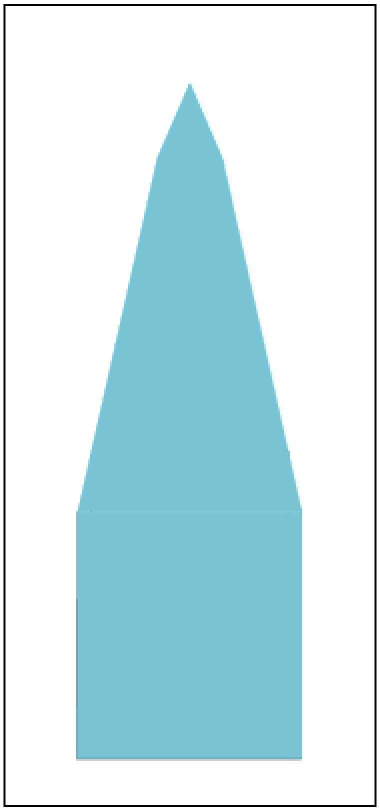
1. cutting rules
2. creasing rules

Cutting rules are steel knifes specially made for dies made on flat plywood board. These rules have a medium-hard body hardness from 35-41RC to provide stability and bendability without fissures at very small angles. Some producers, in order to get higher quality, have heat treated the bevel of the rule which increased the bevels hardness up to 56RC. This kind of treatment gives the rule prolonged working life. The angle of the bevel varies from 60˚-50˚ and in cases of hardened bevels with ultra-coatings 42˚. The rules have uniform straightness, height and width. Width of cutting rules can be 1 (0.35mm), 1.5, 2 (0.71mm), 3 (1.07mm), or 4 pt (1.42mm). Height is standard and for all cutting rules by all producers is 23.8 mm (0.937”); except the rules for stickers, their height is 23.6 mm because they are not supposed to cut all the way thru.

Width of the rule to be used depends on the thickness of the material to be cut. 2 pt rules are used in the largest number of cases and they are meant for thicknesses up to 0.6 mm.



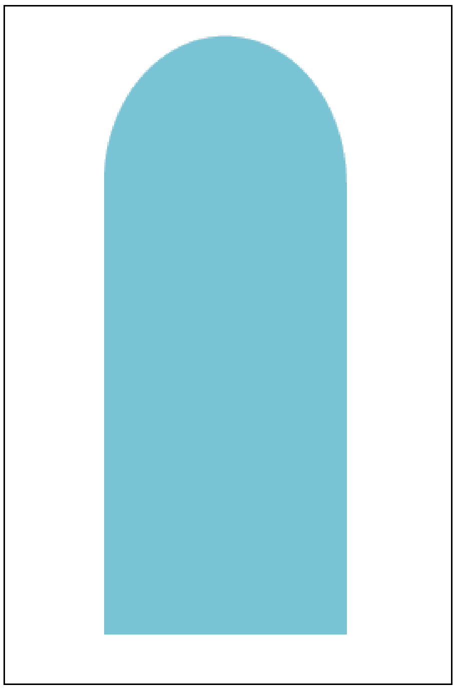
When, according to material thickness a, 3 pt cutting rules are required, instead of normal center bevel rules, it is better to use faceted cutting rules. Their narrower cutting angle will reduce the corner effect and penetrate the board a lot easier. These rules are used for material thicknesses from 0.6-1.5 mm.

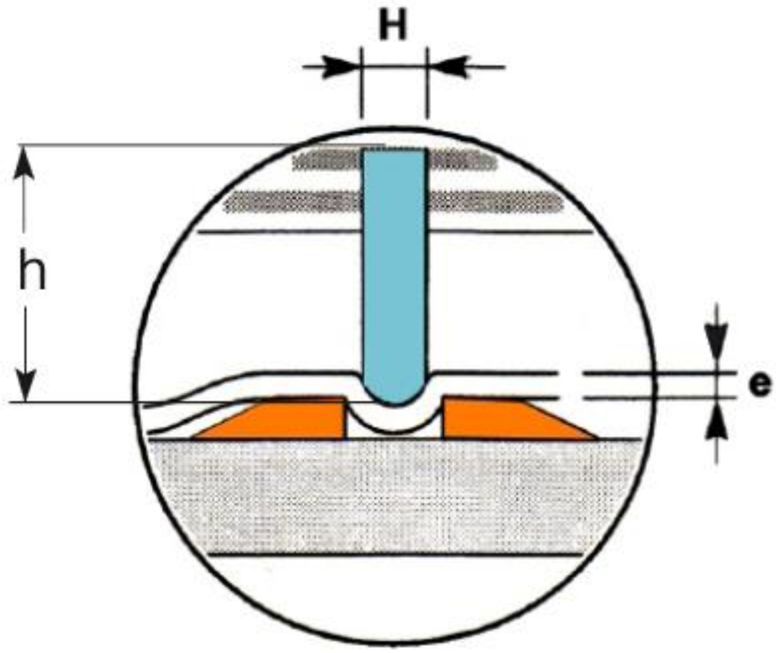


Creasing rules are made out of the same material like cutting rules. Their hardness is around 45 RC, thickness can be 1.5, 2, 3, 4, 6, 8 pt, height from 22.6-23.6mm. Height of the rule to be used depends on the thickness of the material to be cut. This height is calculated by using a simple formula:

$$\boxed{h=F-e}$$

F-height of the cutting rule (23.8mm)
e-thickness of the material





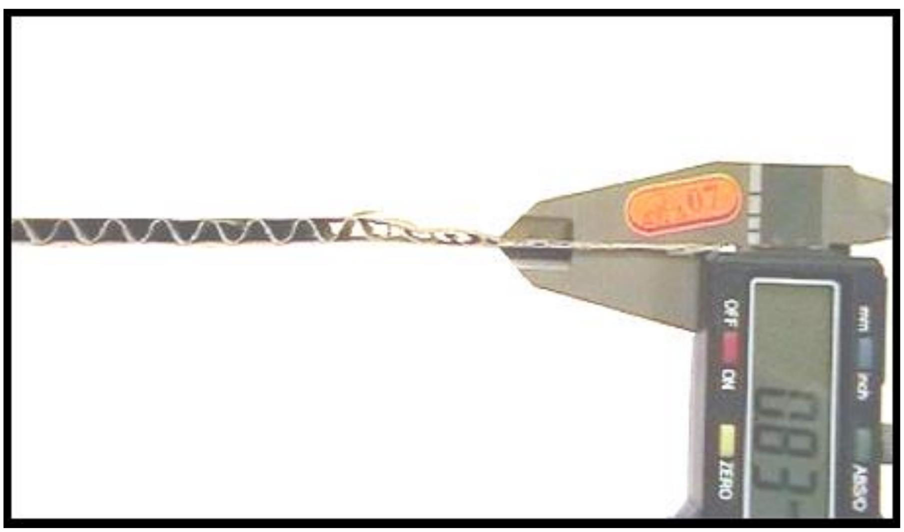
Thickness of the rule to be used is also dictated by the thickness of the material.

Thickness of the material (e)	Thickness of the creasing rule (H)	
0.1-0.6mm	2pt	0.70mm
0.6-0.8mm	3pt	1.07mm
0.8-1mm	4pt	1.42mm

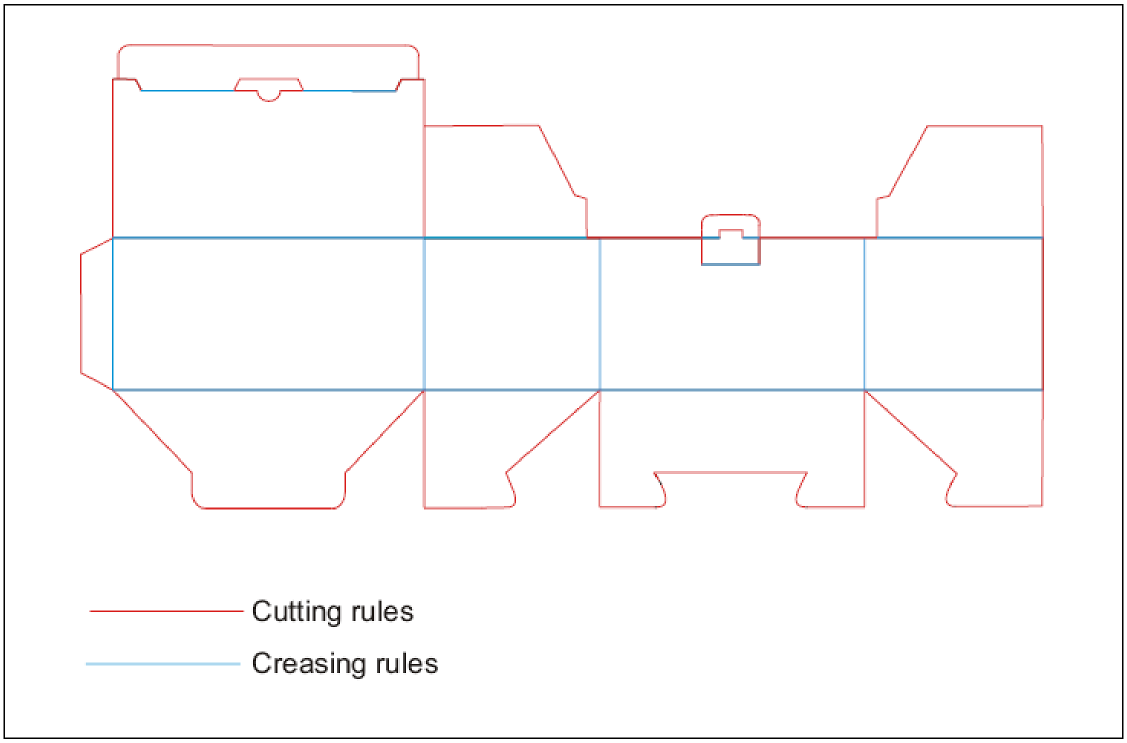
Rules usually have their height and width written on them, but if they don't they should be measured using a micrometer.

The thickness of the material should also be measured using a micrometer but when measuring corrugated paper or carton board, it should first be pressed in order to measure the minimum thickness. This is done if the data is unknown.

On this picture e=0.83 mm

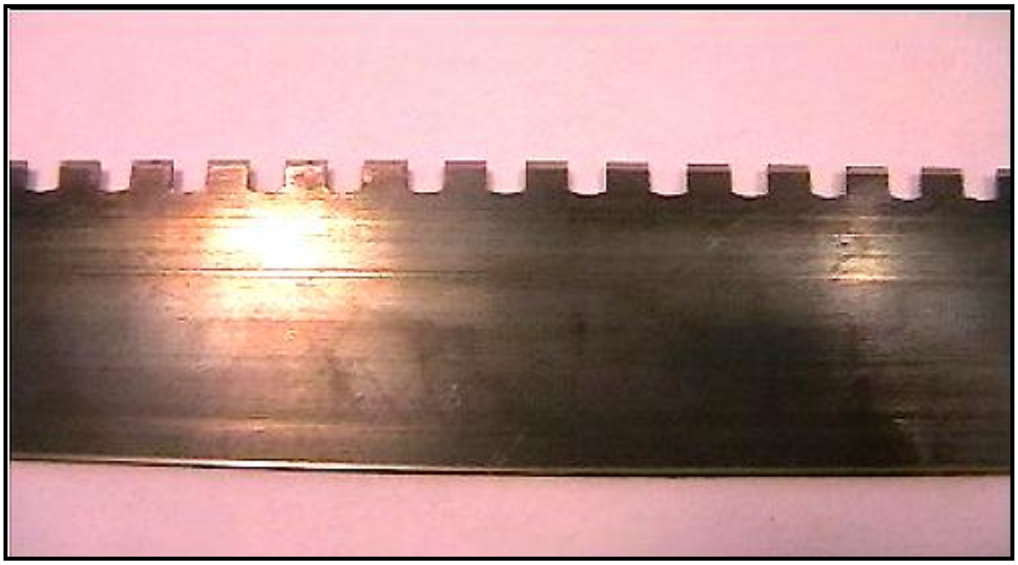


The package that we are making will have cutting and creasing rules placed like shown on the picture:

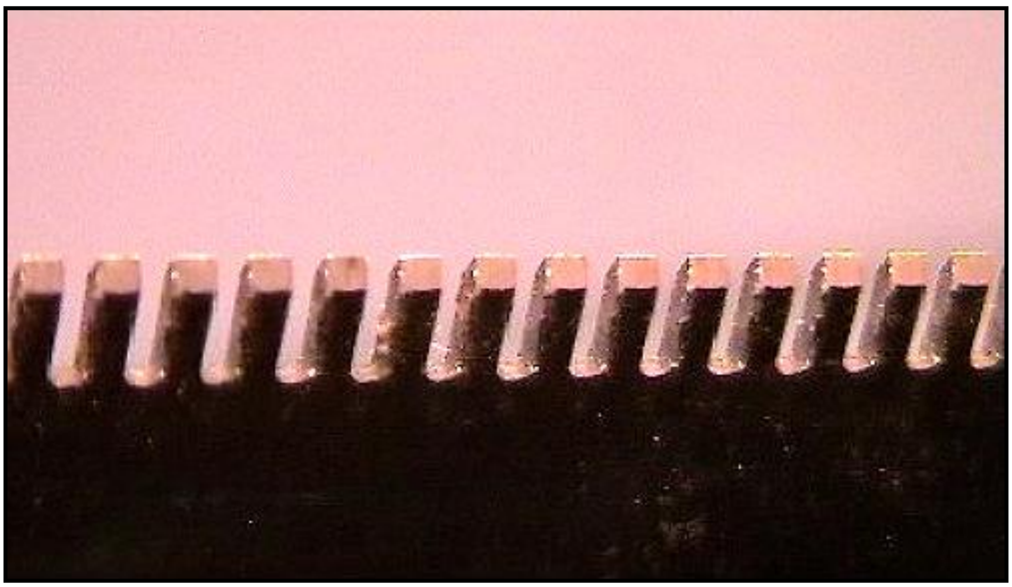


Another type of rules that has a growing use in die making area are perforating rules. These rules are a combination of cutting and creasing rules. Their shape and form is dictated by the on-going development of packaging designs. Designers are making more and more innovative packages, which are more commercial than the ones before, and rule producers are trying to meet with the markets demands. Their height is from 22.8-23.8 mm and their purpose depends.

This type can be used instead of creasing rules for corrugated card board boxes. The effect is easier creasing and without using creasing counterparts.

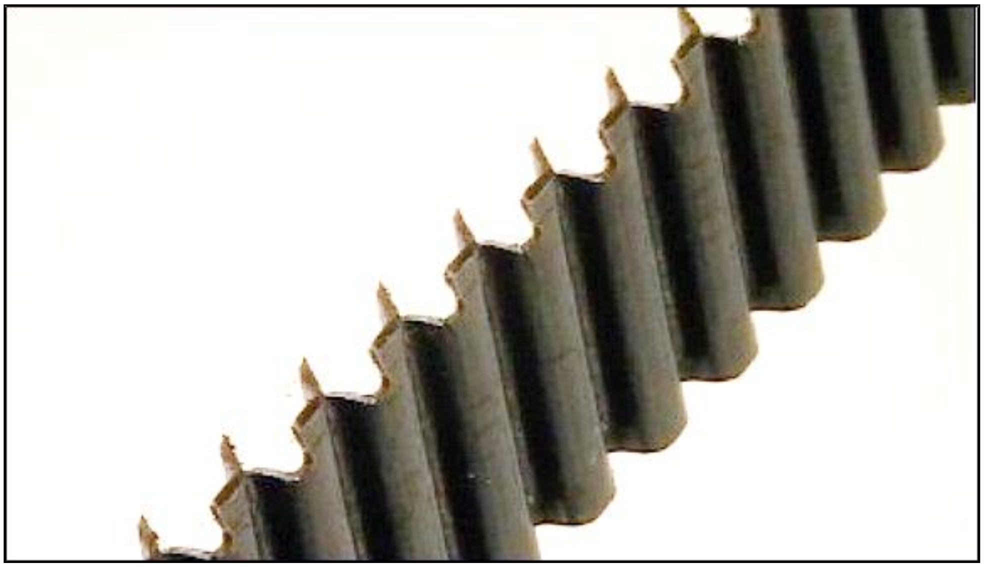


This one for easier tearing of package openings or striping parts of the package

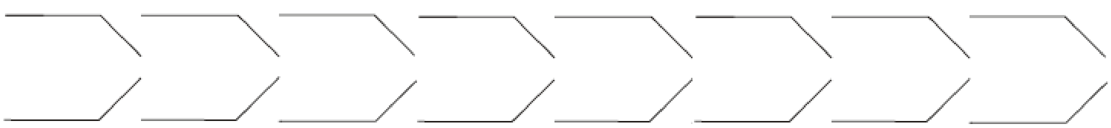


Glue flap perforating rules have a height smaller than a cutting rule and are used for roughing up the glue flaps to provide a good surface for the glue to bond to

Zipper rules are type of cutting rules with their top part punched and turned at a certain angle. There are left and right hand versions.



One side



Cut gained when both applied

It is already said that rules have their characteristics written on them, here is an example:

LESSON 44 – BOARD CUTTING

The size of plywood that would be used for the tool should be determined in the stage of prototype designing; it can be determined by a client, technical characteristics of the machine that will use the tool or as in this case after making netting of packaging (a box in spread shape drawn on paper). The plywood dimensions are obtained by adding 50 to 100 mm to the dimension of border edges of the surface taken by our netting. Generally you should respect a minimum of 15-20 mm between the line in which a rule is supposed to be placed and the edge of the board. After this, we move to cutting off the gutters in which rules will be inserted.

That can be done by two methods:

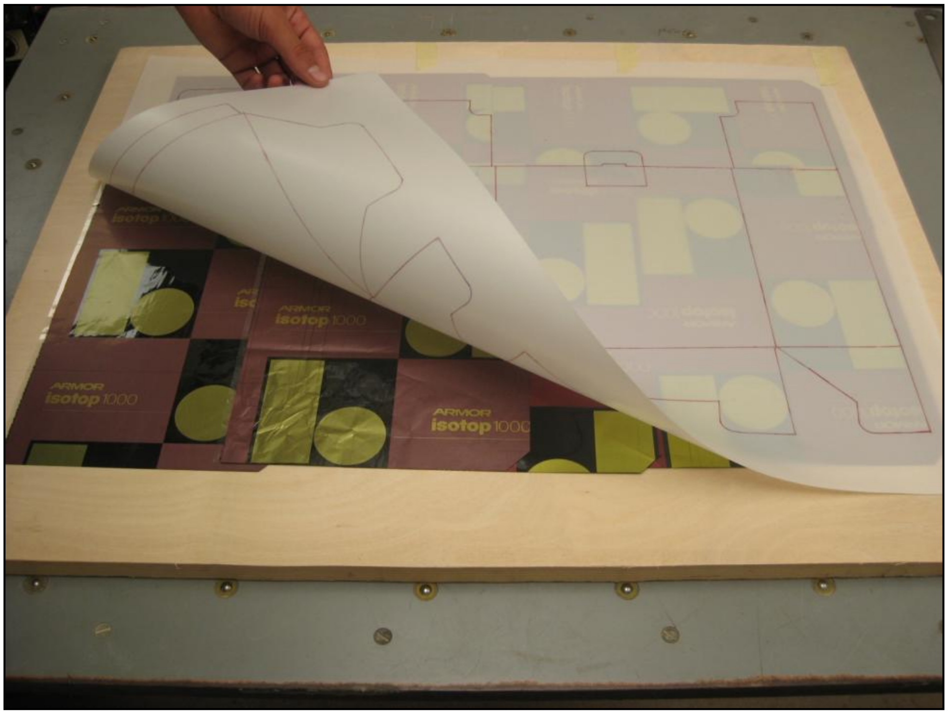
1. using laser or
2. classic method by using saws (circular saws, jigsaws).

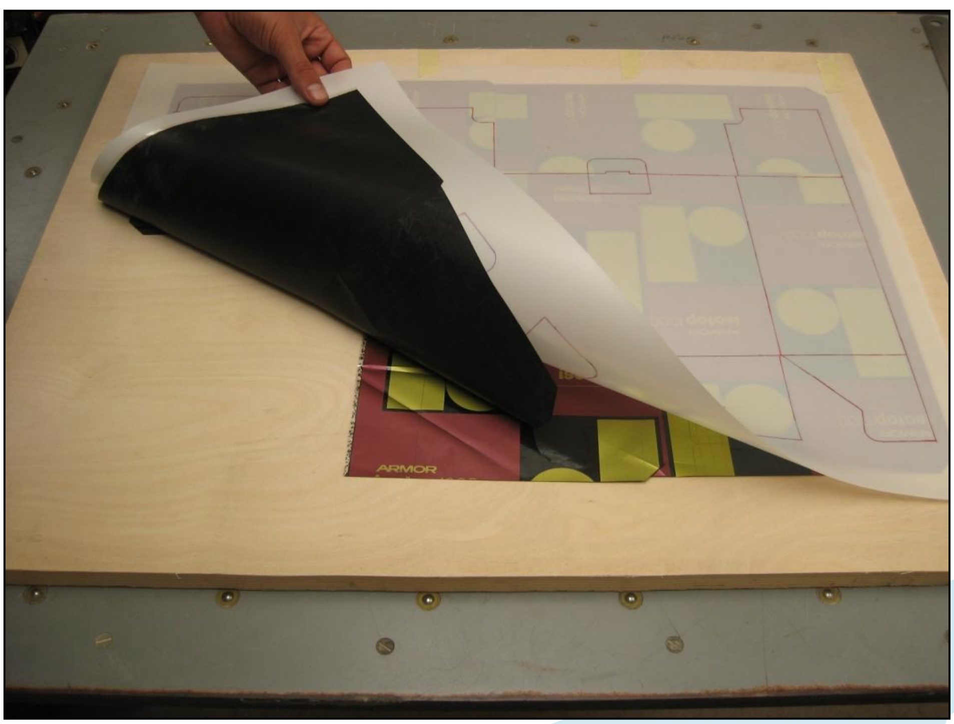
Use of laser represents newly developed method, while manual cutting by a saw has been already obsolete and that method is scarcely used. Nevertheless, apart from it, a great number of factories in the business of packaging production or production of tools only, while using the state-of-the-art methods of tool manufacturing, have not completely thrown out from their old machines. Although the methods are obsolete, they can still provide satisfying quality and can be useful in the case of troubles with newly developed machines.

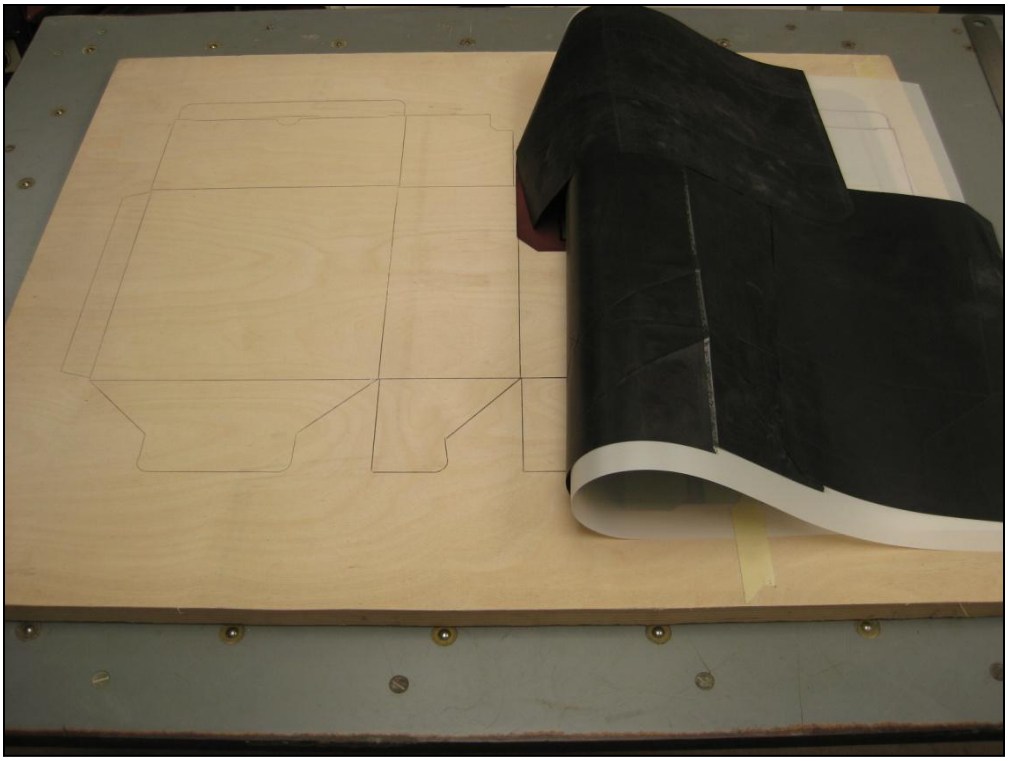
Smaller producers and producers in poorer countries still use actively this method because either new equipment costs too much for them, or they have no need for so big productions, considering that new CNC machines provide higher working speed. Only companies that have big clients, who need serial production of millions of units (packages), can prosper from using CNC machines.

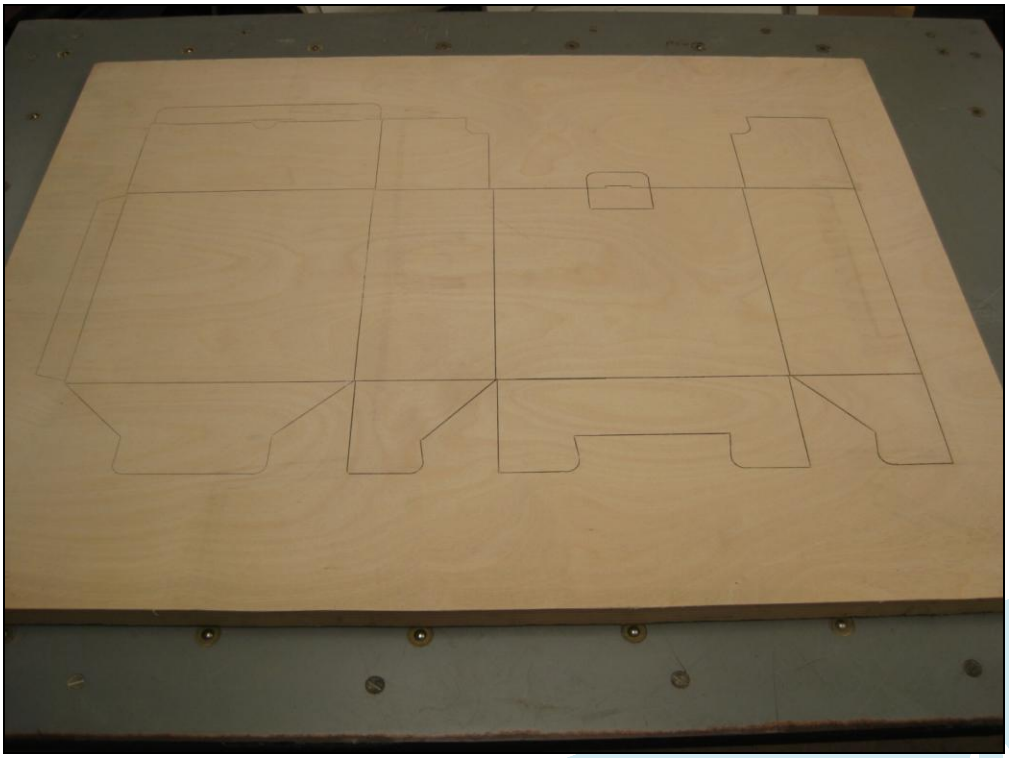
In order to start with plywood cutting, we firstly have to move netting over it. Methods for this are following: copying the netting directly on plywood, gluing the design on plywood or copying it by carbon paper.

Copying by carbon paper:

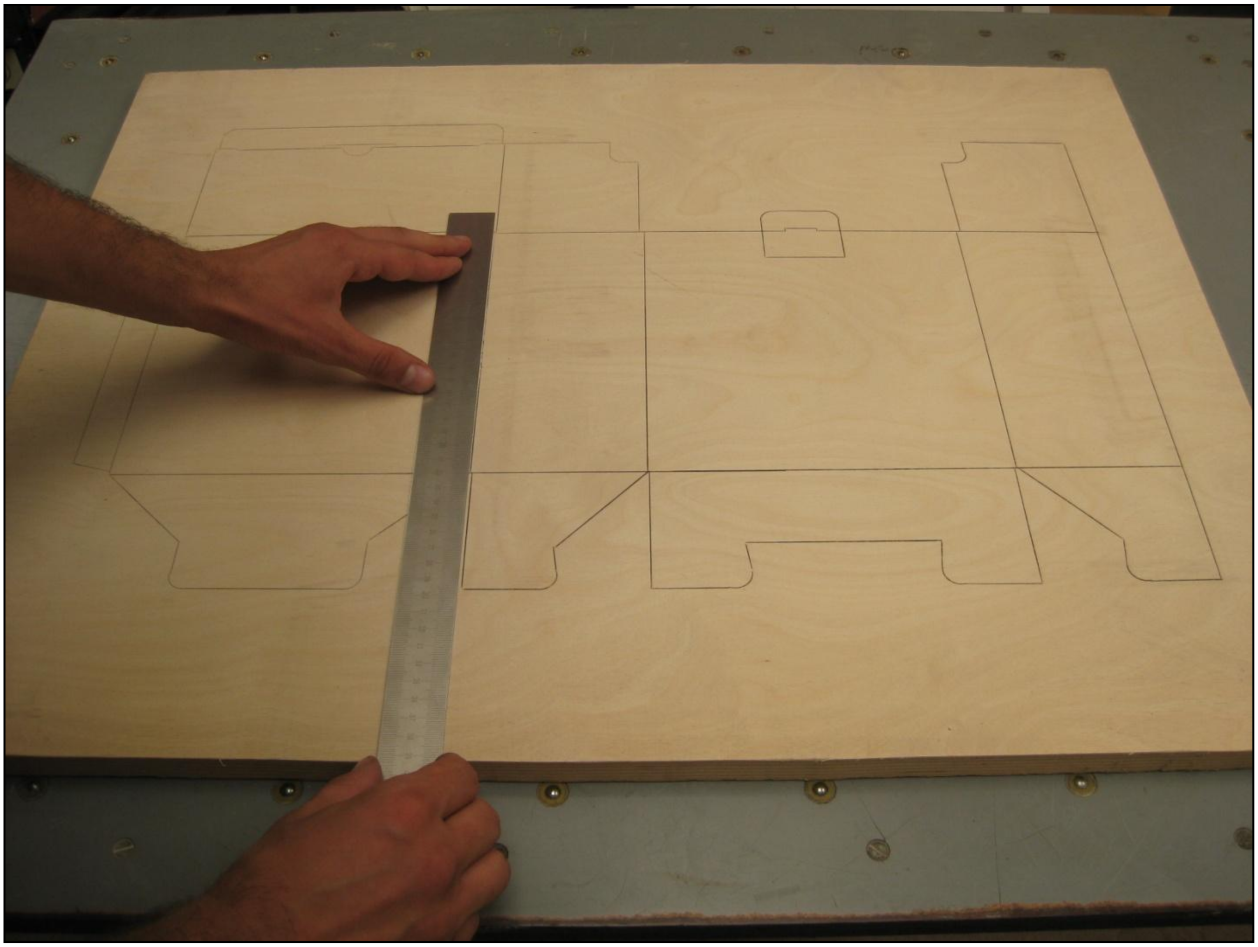




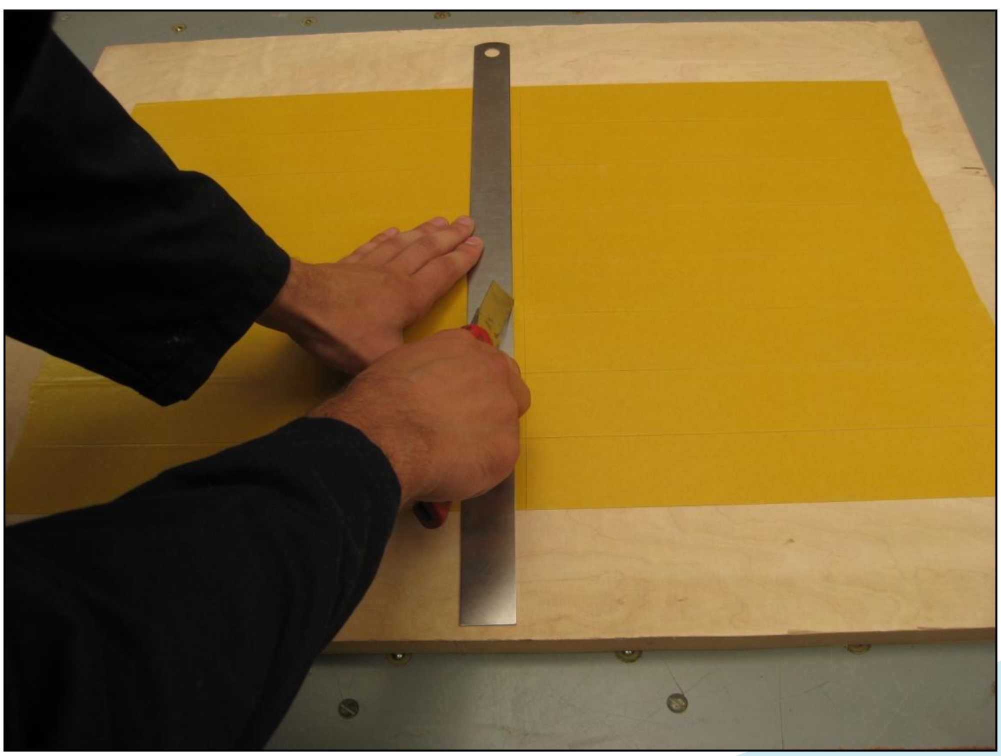


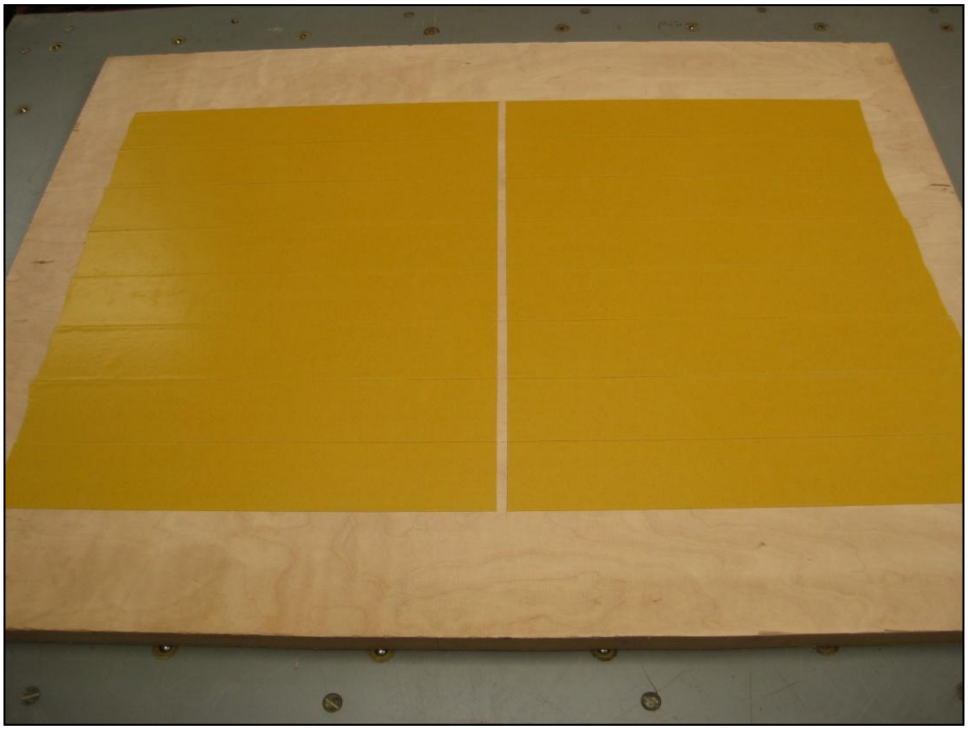


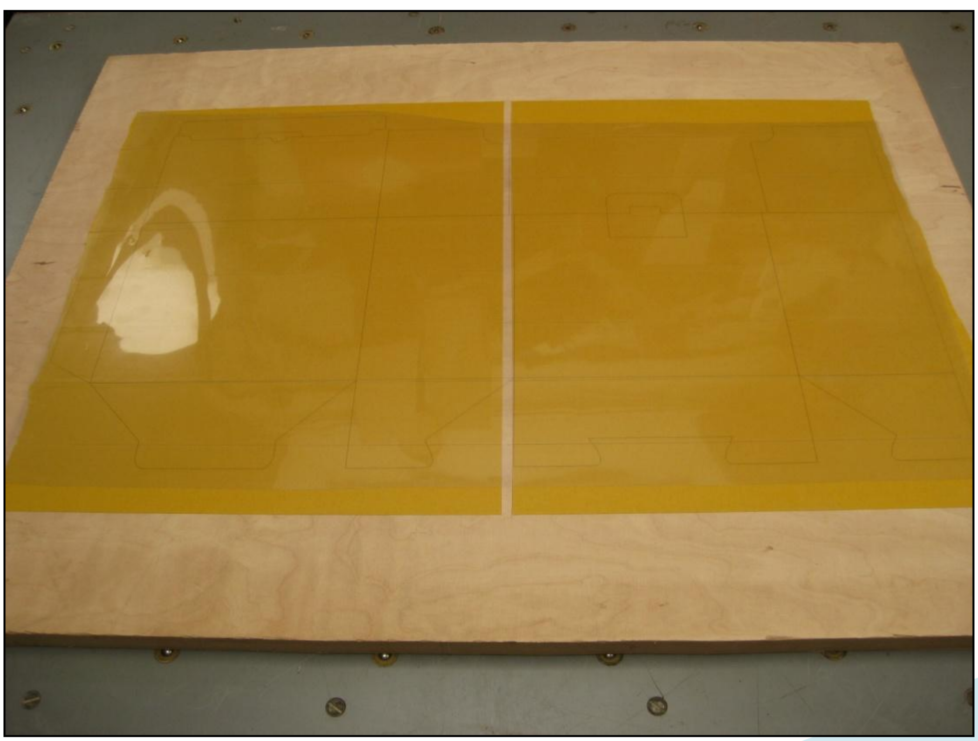
When that is done, before the start of cutting (sawing), the concordance of measures on plywood with those on the design must be determined.

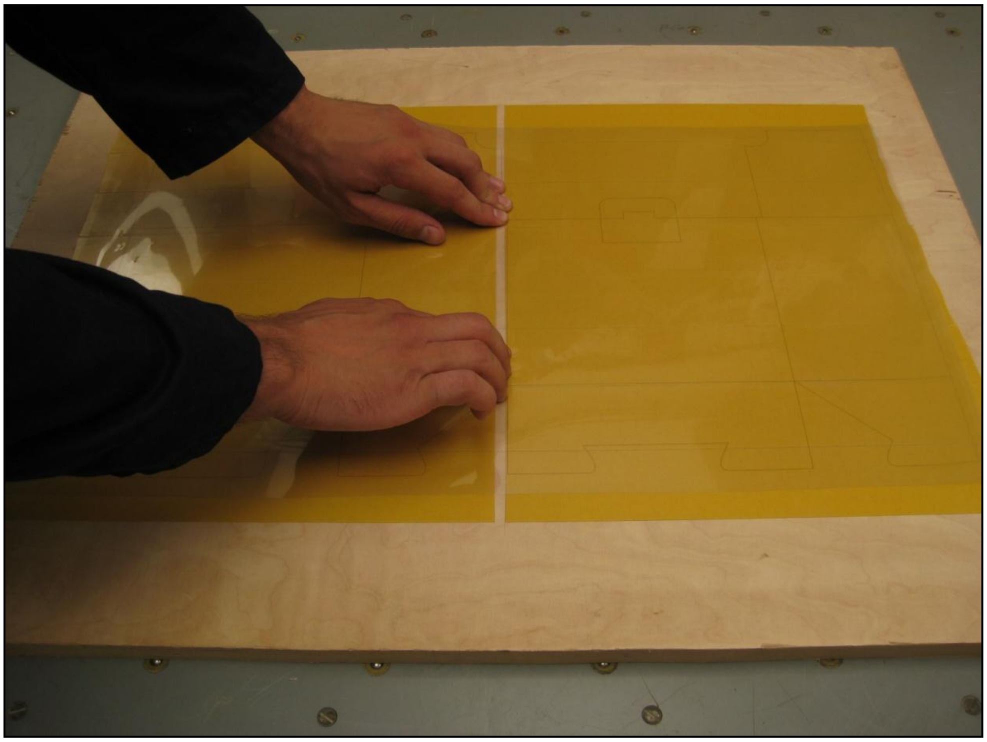


When working with films first glue the adhesive tape on the plywood, then remove the strip and glue the film on the plywood. But before removing the entire strip it is best to make a small 5mm wide line cut in the middle of the treated surface. This will help you position the film on the board.

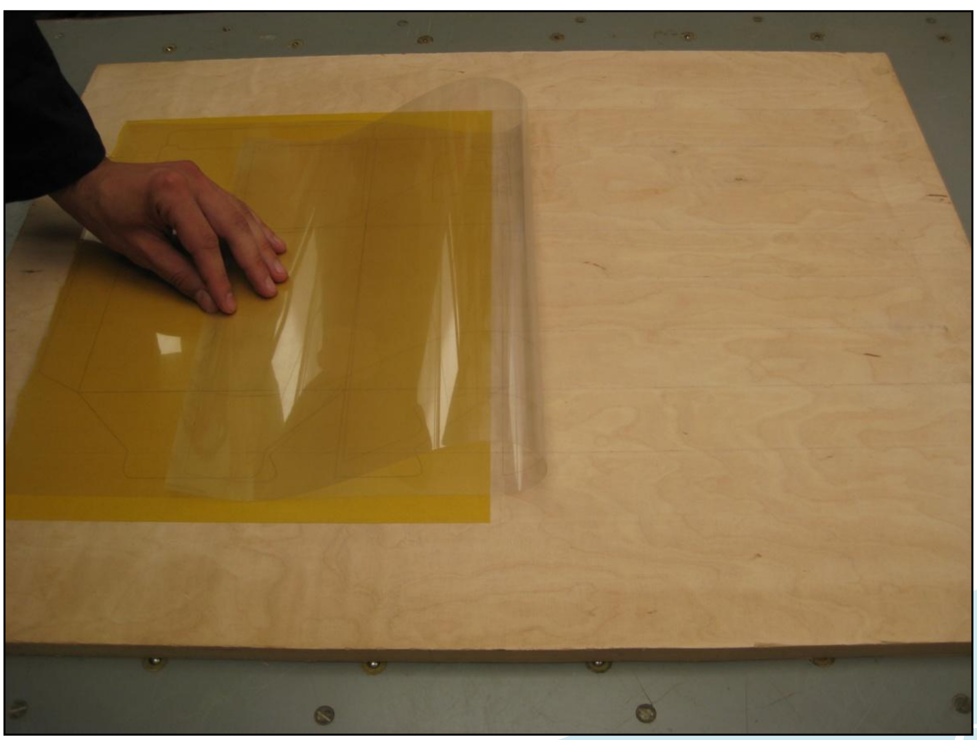




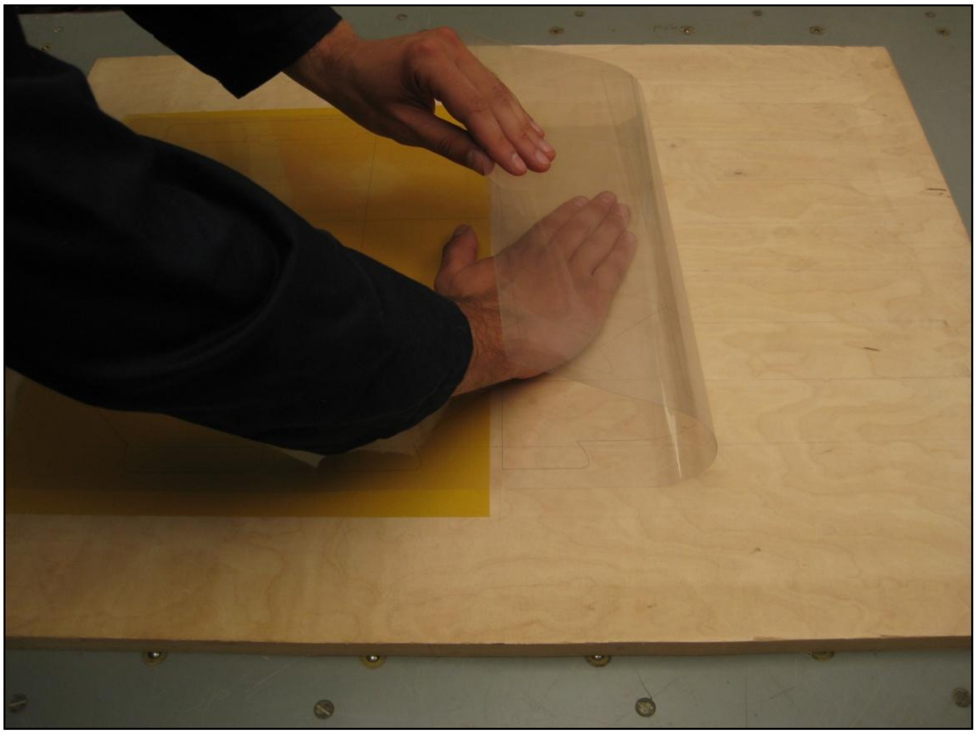


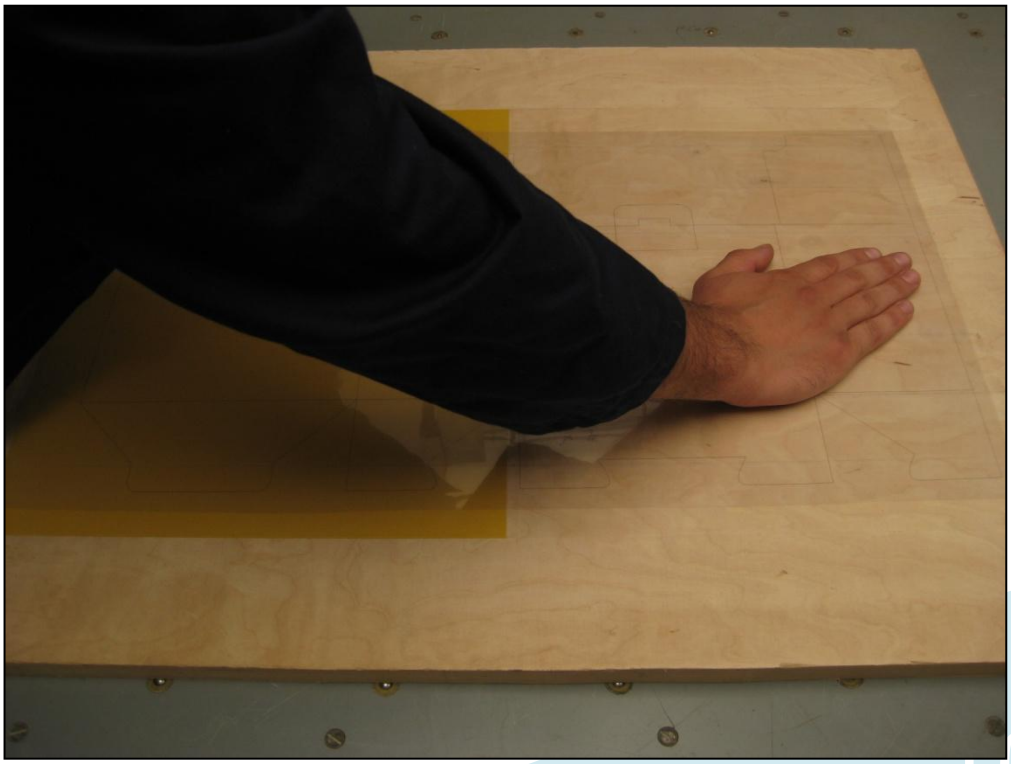


Glue the film only in the middle section and then remove one side of the strip.

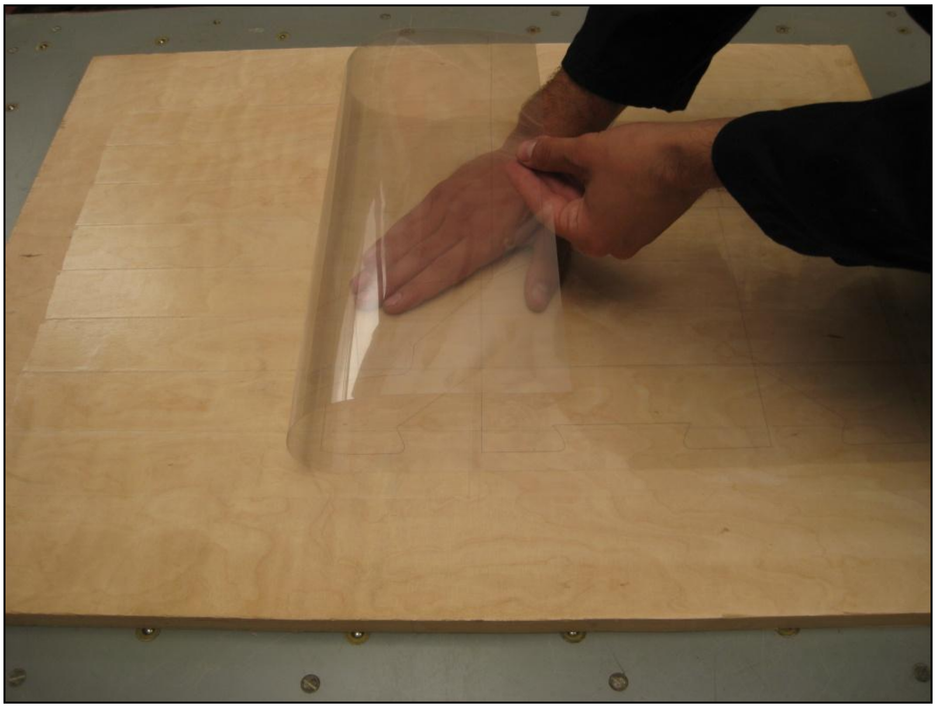


Then glue the film going from the middle to the end.

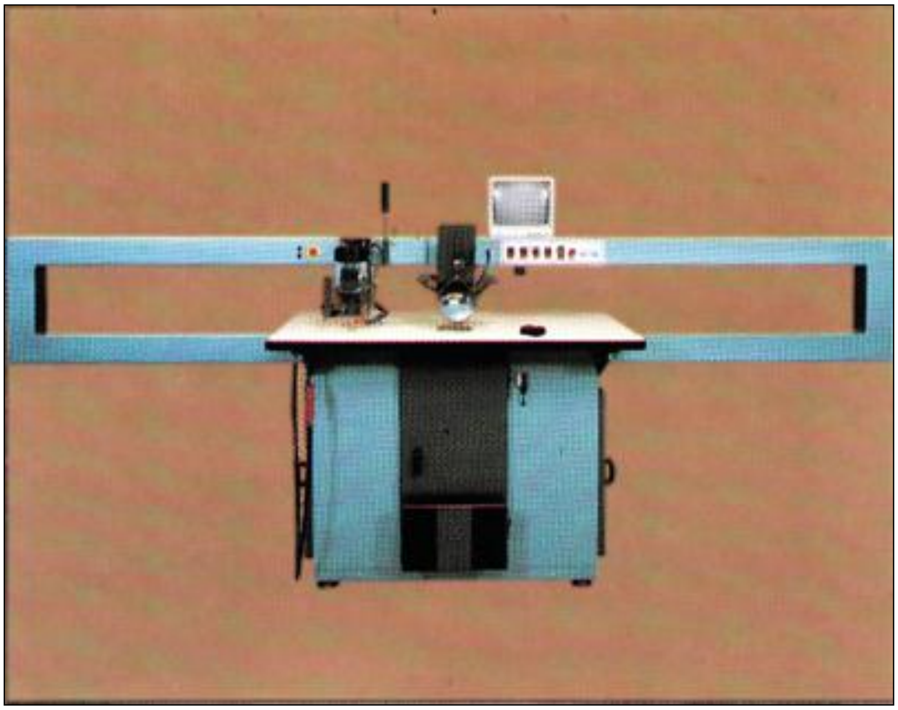




Do the same with the other side

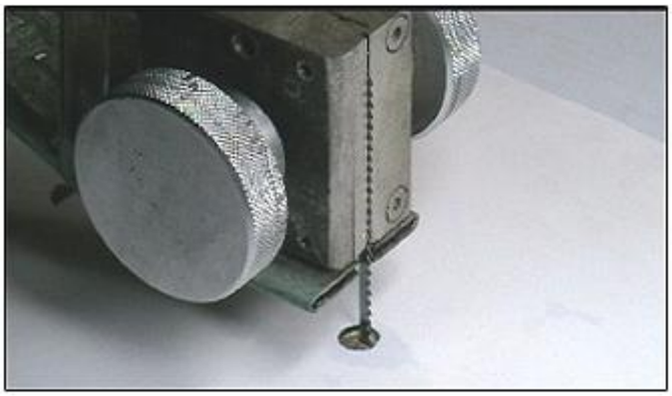


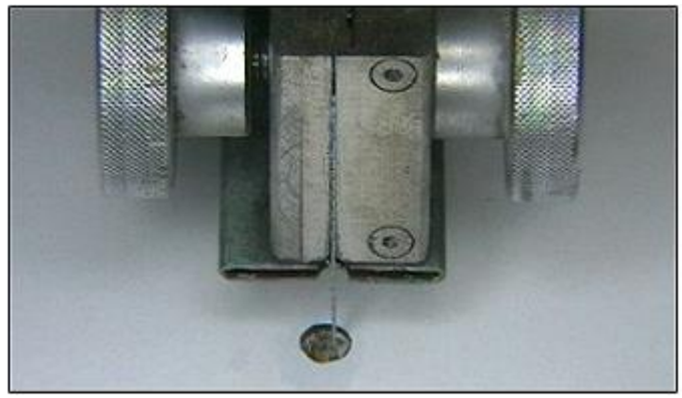
The plywood with netting drawn in this way is cut by jigsaws. A jigsaw is a tool used for cutting curves or other custom shapes. However, these are not classical circular saws.



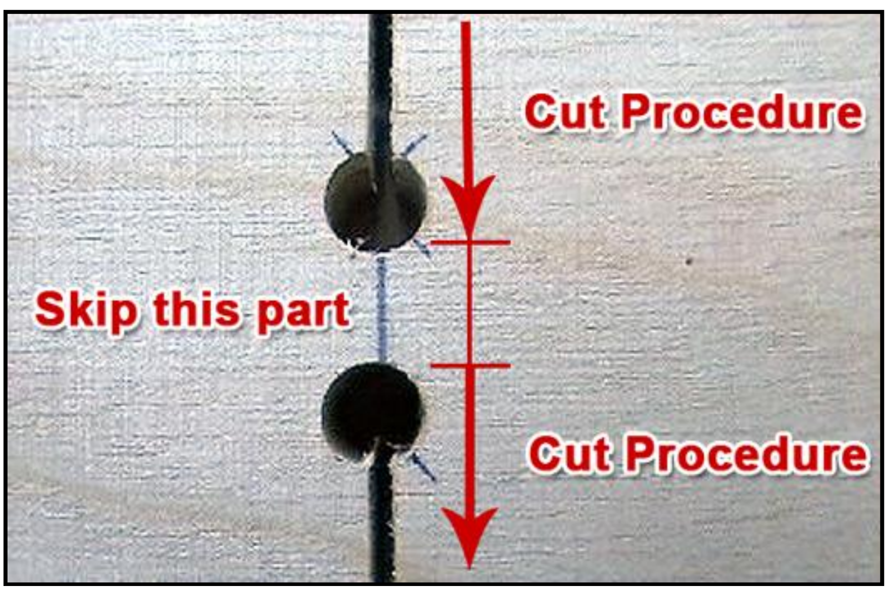
These saws consist of strong and stable stand on which the working table is. There is an electric motor under the table in a stand, by which a small saw is driven. More advanced types of these saws have also (usually pneumatic) device for lifting and lowering small saw under and over the level of working table, which is done by hand or foot switch. The "socket" (arc) comes out of the table, which carries on its ends, or in the middle, depending upon construction, a lamp for magnification, boring machine and upper saw holder.

A small saw already has two holders, one on the socket and the other under the table and they serve to fix the work of the saw at one point. This increases the precision and speed of cutting. The thickness of the small saw corresponds to the thickness of the blades that are used (2, 3, 4 pt) and the length is from 130-150 mm.

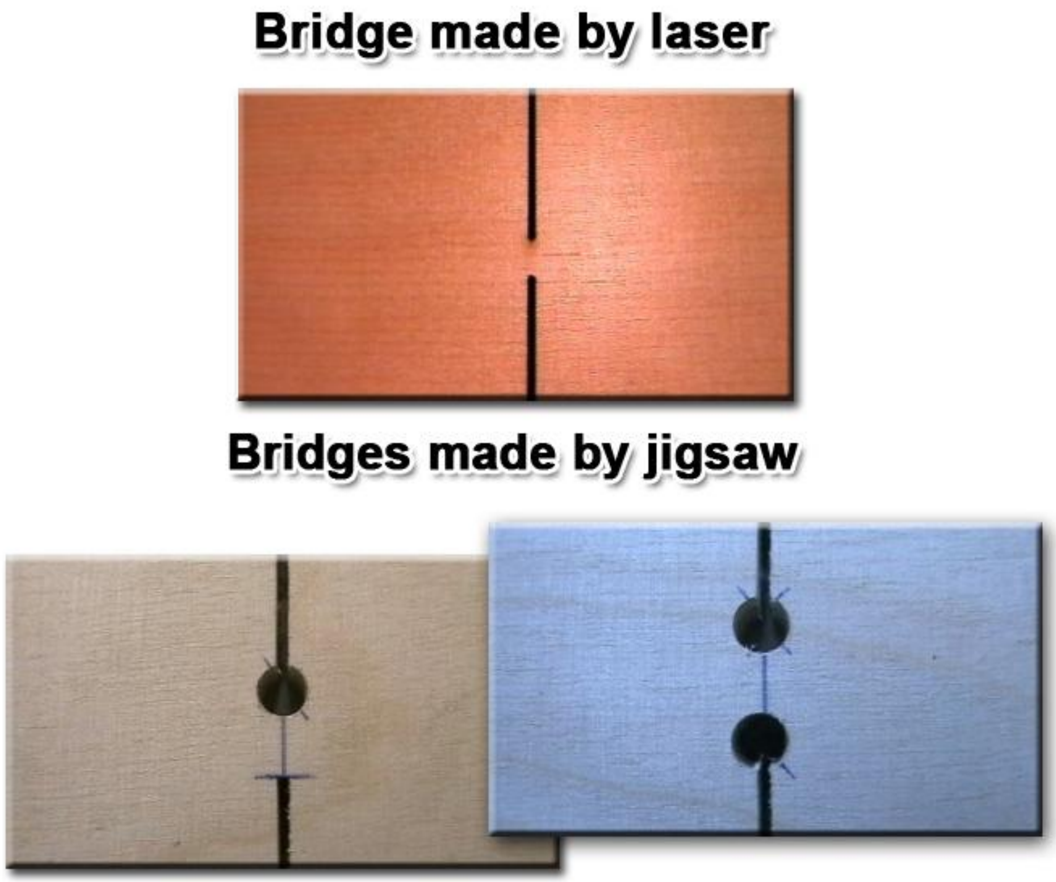




Boring machine serves to bore “pilot” holes through which a small saw is pulled and at the same time the bridges are made. Bridges represent a place where plywood has not been cut and they prevent plywood, and the tool itself, to fall apart.

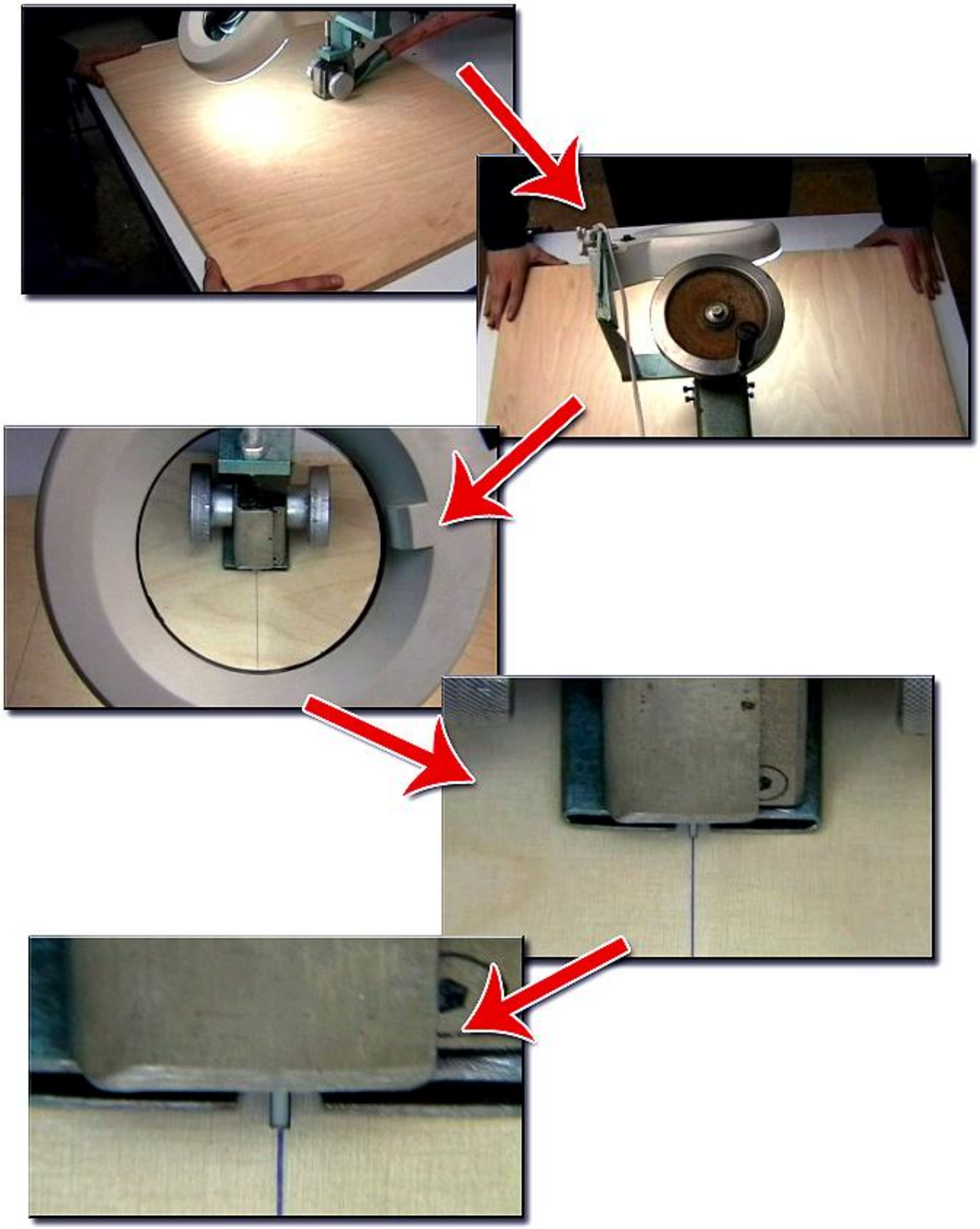


For straight cuts, bridges should be left at every 100 to 150 mm. You should avoid placing bridges in curved sections, but if it is necessary, place them at every 80 to 100 mm, but do not place them where rules intersect because this diminishes the strength of the joints. The size of these bridges is around 4 - 6 mm.



The jigsaw also has built-in exhauster to exhaust scrapings under and over the cutting point, as well as on the boring point.

Cutting is done manually, using both hands and following the lines of drawn netting. Precise cutting is enabled with the lamp with magnifying glass, through which the cutting point can be seen very clearly.



Cut going from one pilot hole to the next in line with skipping the bridges. When you reach one hole, stop and pull down the saw then position the next hole above the place where the saw is supposed to come out and activate the switch to pull out the saw.

Positioning the hole above the place where the saw is supposed to come out is in the beginning hard but it comes easier with practice, which in this work is eminent.

Even cutting a straight line is not such an easy thing to do in the beginning. Pushing the board with both hands can be tricky. Getting a 100% straight line can be hard even for a skillful die maker. Not to mention cutting curves. Biggest number of mistakes in die making using this method comes from board-cutting. Practice brings the number of mistakes to a minimum.

In cases of large and not so complicated dies, if the deviation left and right from the cut line is around jigsaw thickness, it is not so bad. You could say it is in the tolerance limits. But when it comes to cutting boards for small packages like pharmaceutical packages than these deviations must be kept to a minimum.

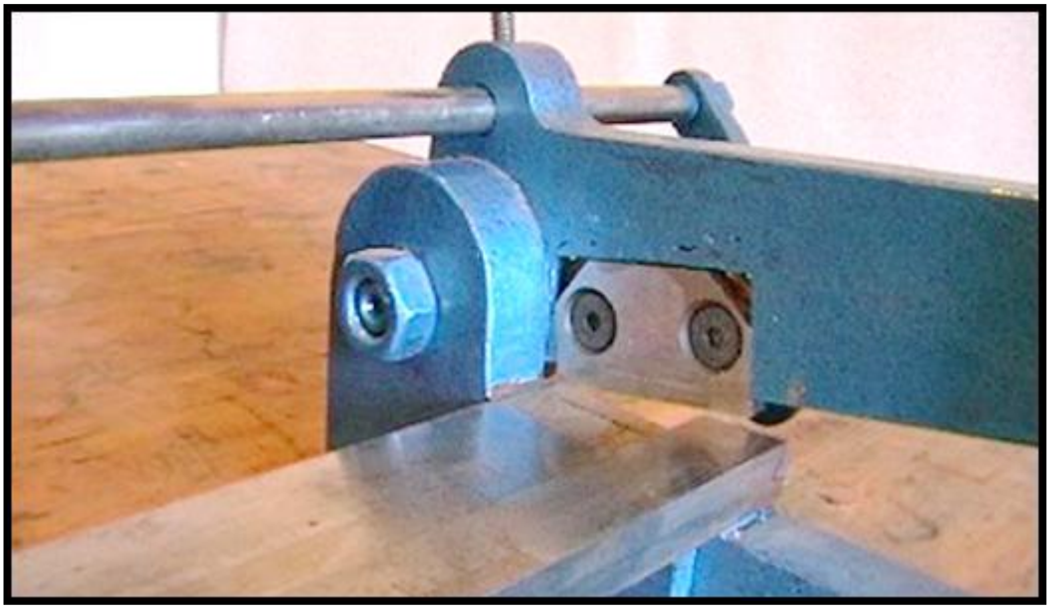
Upon cutting, checking up of dimensions is done again. If in some stages of copying the design or cutting comes to faults beyond limits of tolerance, processes should be repeated or in the case of copying the design on the board with carbon paper or by drawing, only correct the design on the board.

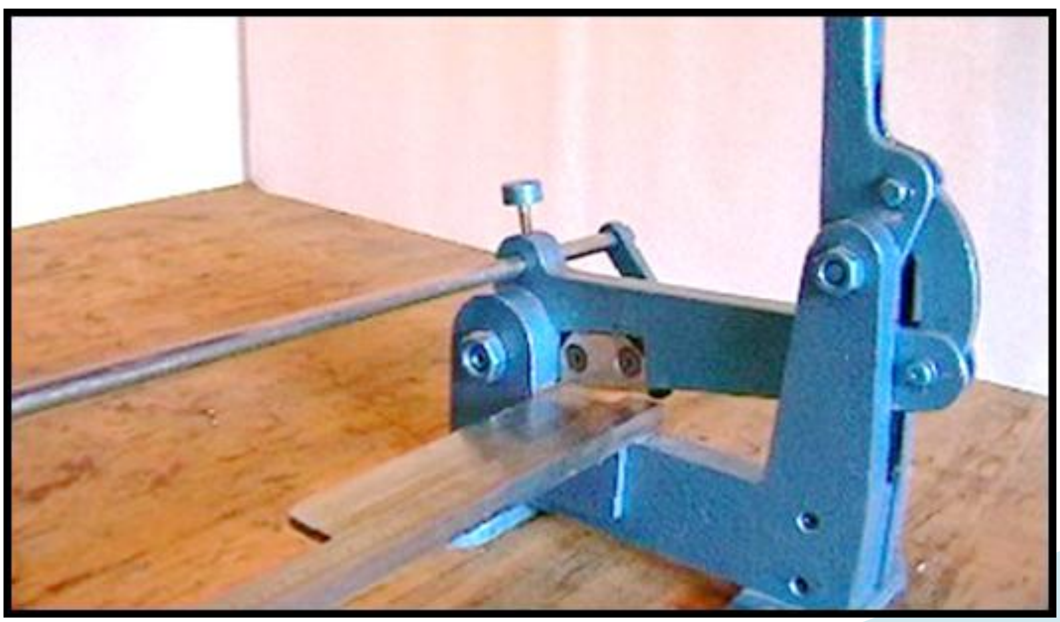
LESSON 45 – RULE PREPARING BEFORE PLACING

Rules are cut and bended to certain measure, before they are set. This is done by machine sets especially for these operations. They can be manual or automated. If they are automated, either electric motor or pneumatic cylinder driven. The basic operations of these machines are cutting, bending, notching, mitering, placing nicks, broaching. Some complex machines combine more than one operation.

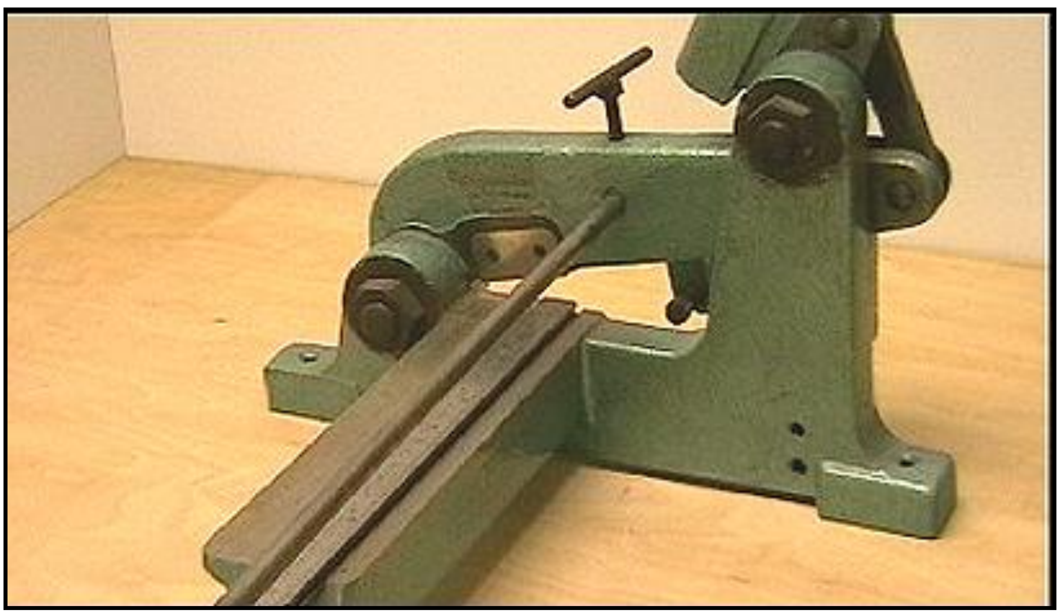
Hand rule cutters:

Model 1

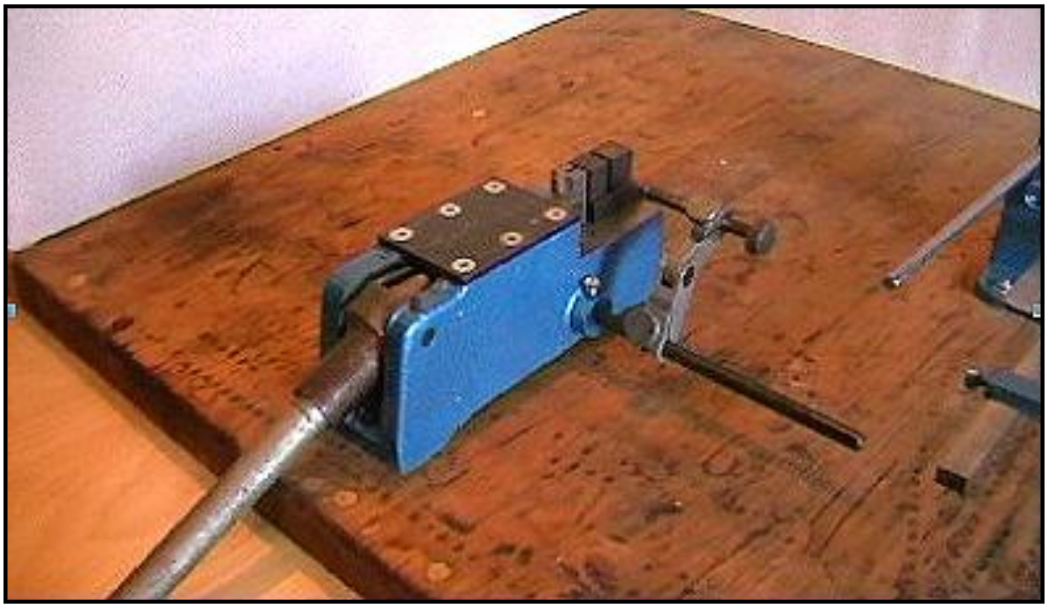


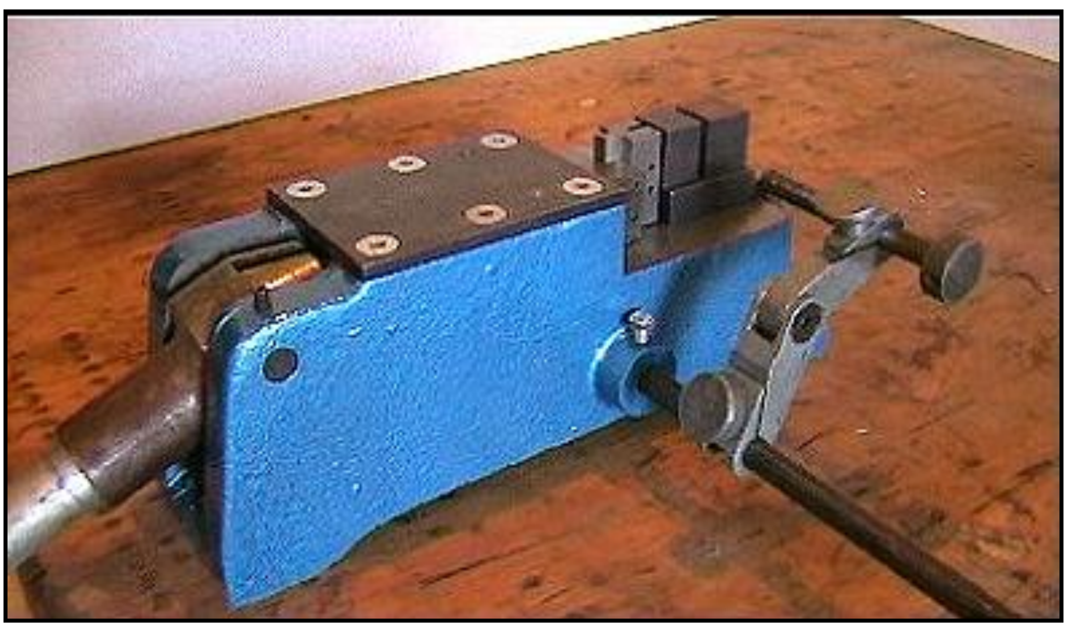


Model 2

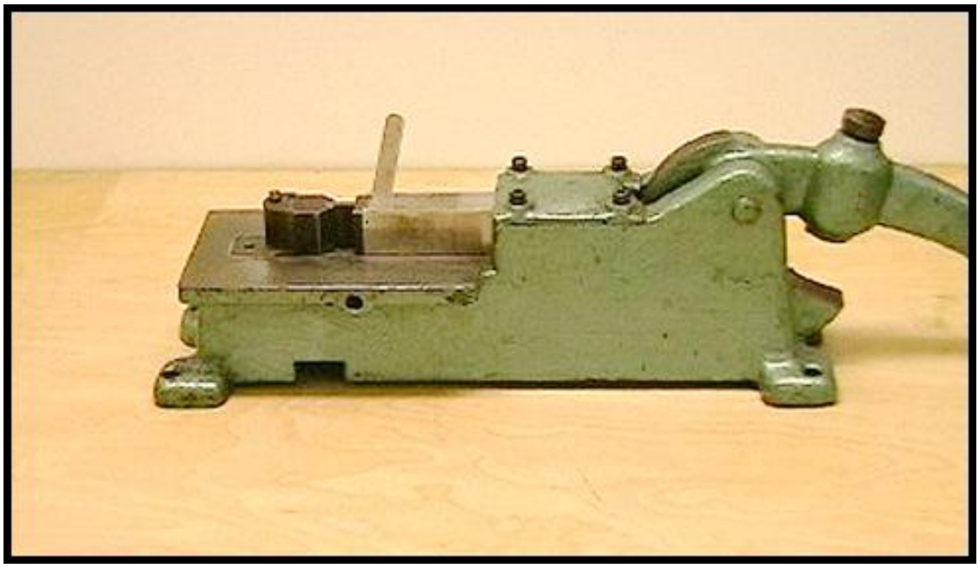


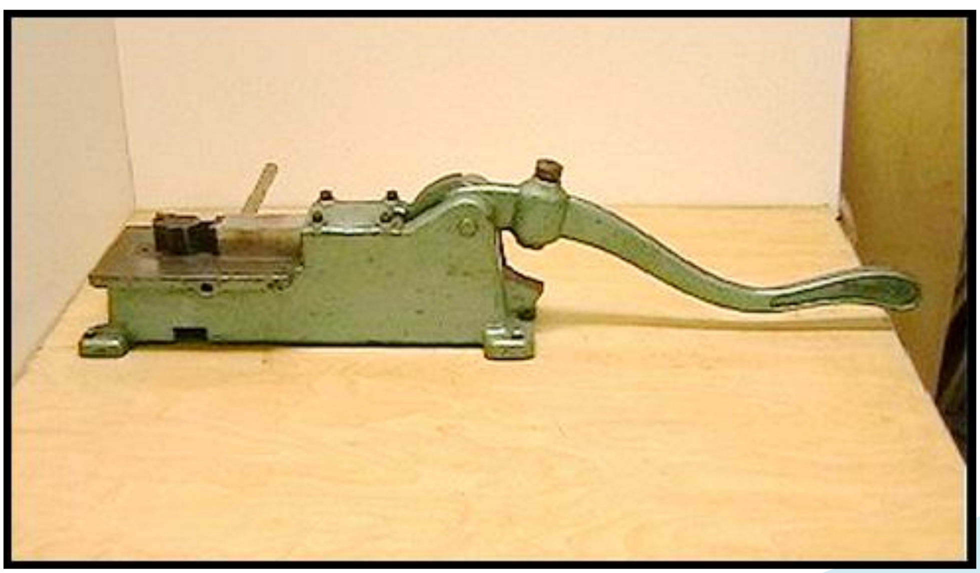
Hand notcher



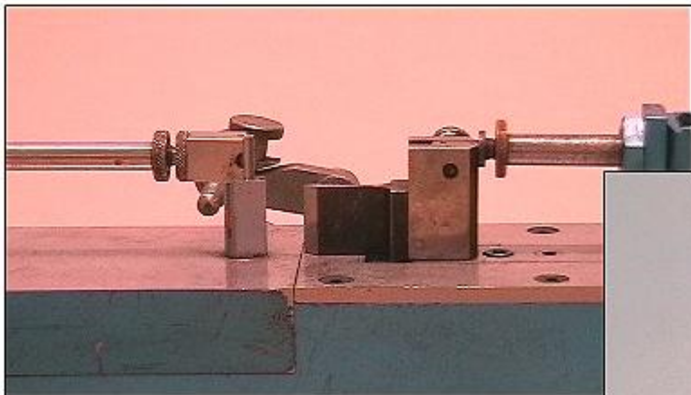


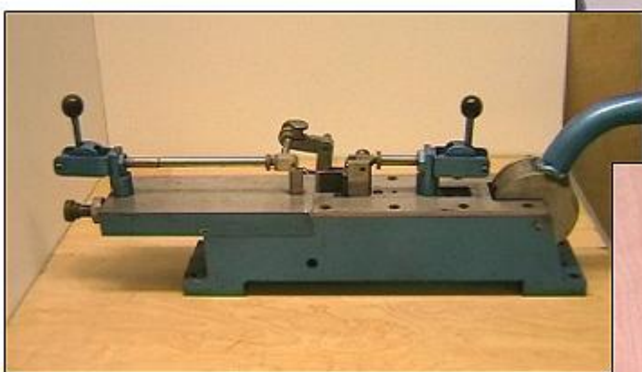
Hand rule benders: Model 1

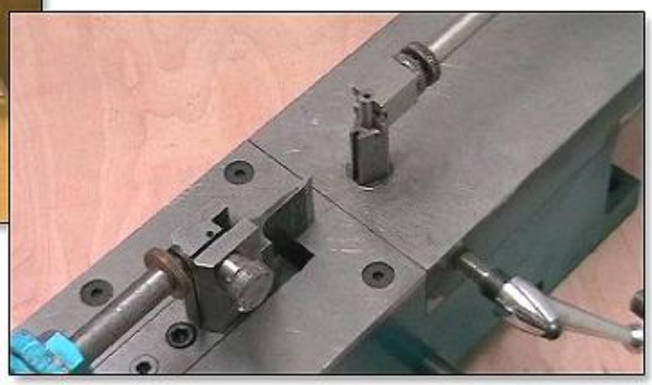




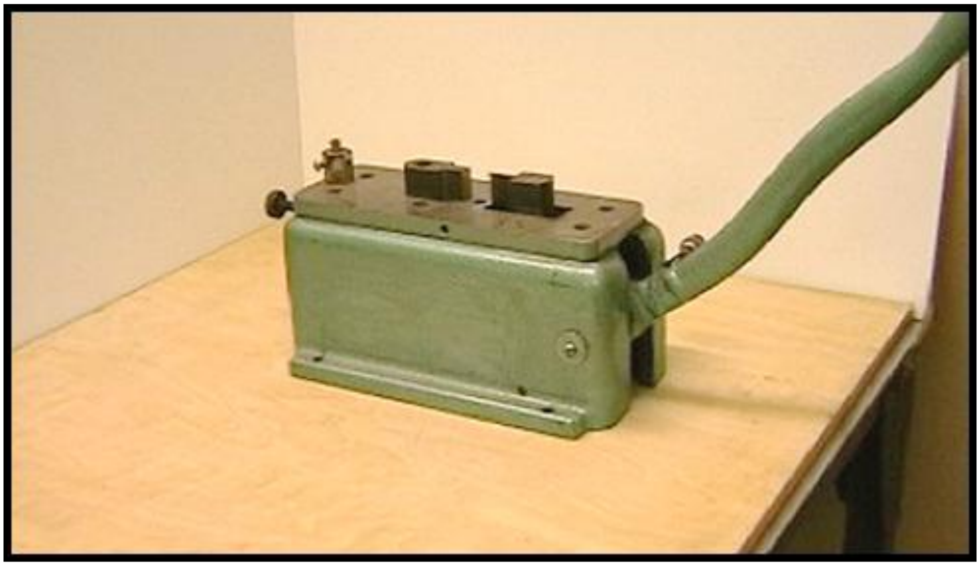
Model 2

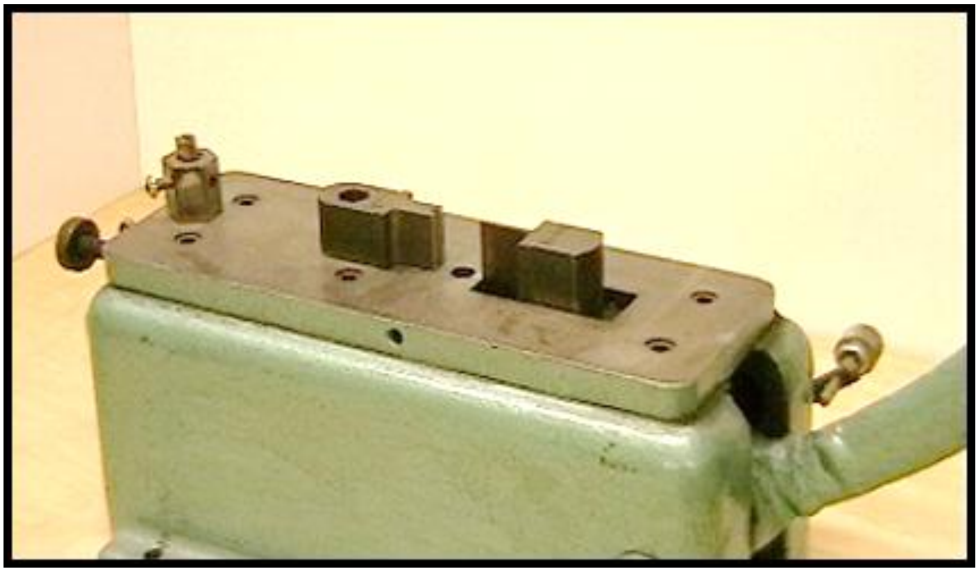






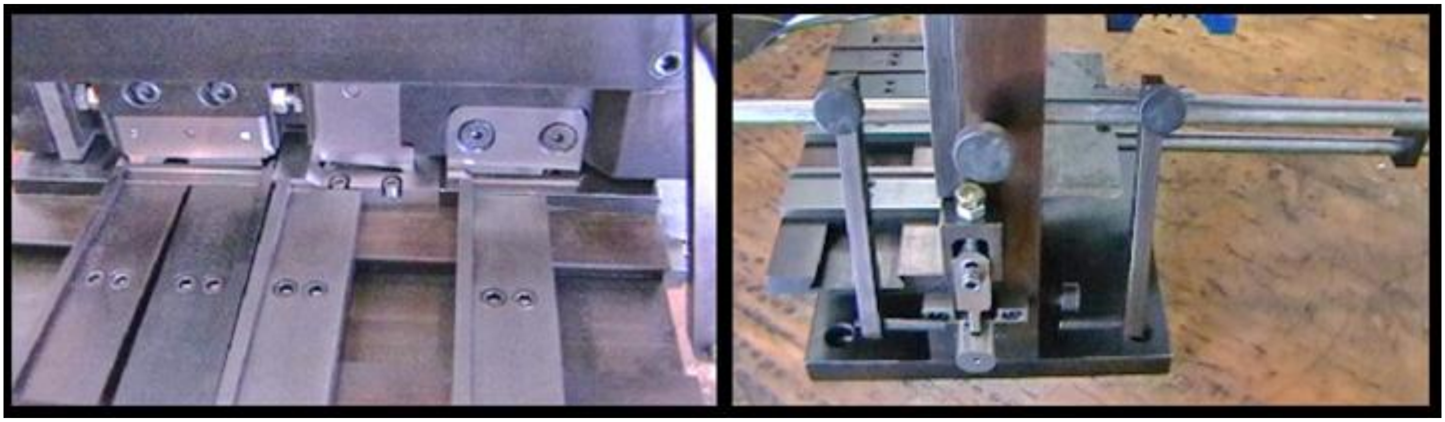
Model 3





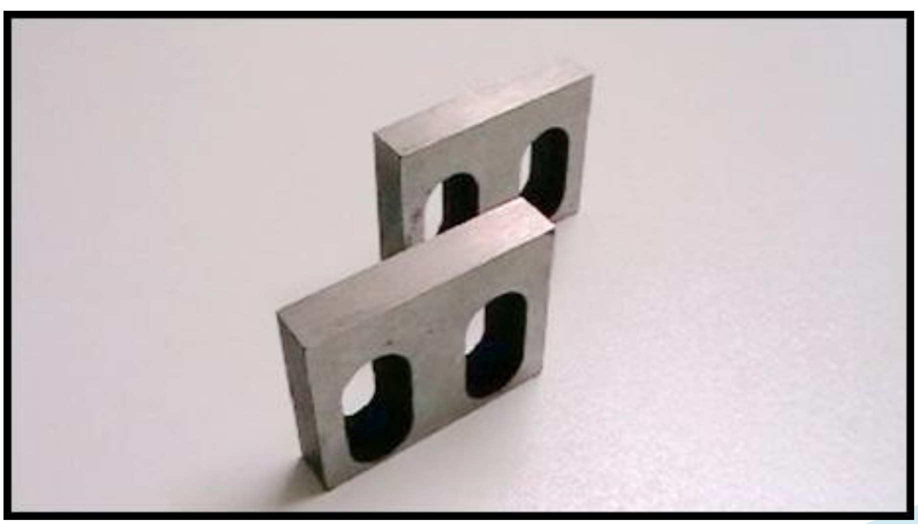
Combined cuter and bender

Automatic combined cutter, notcher and miter

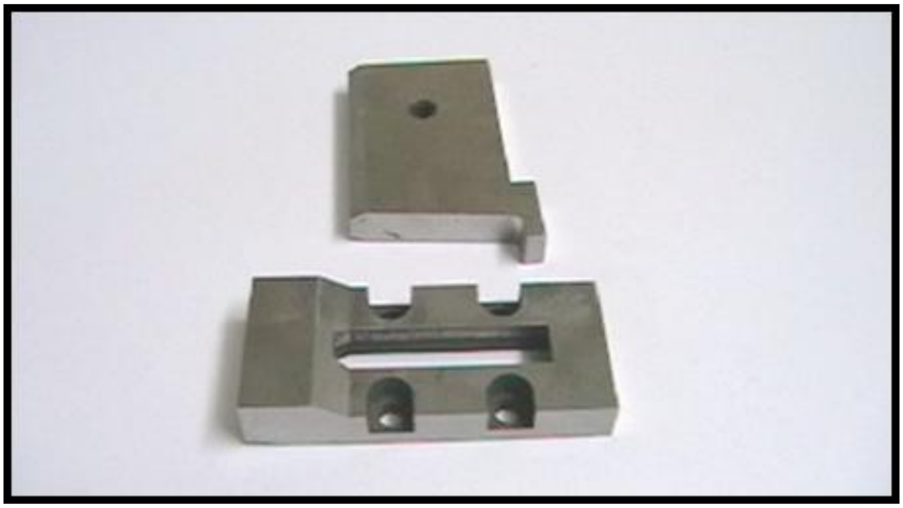


Each of these machines has its parts, tools, made of steel, which have much higher hardness than rules, so that they could process them (with the exception of nicking machines). These tools represent special type of tools (dies) made for metal processing. For each machine the producer labels the thickness of rules that can be processed with it in order to avoid damages during work (breaking of a tool). For example the machine in the picture above can only process 2pt rules. Thicker rules can damage the die parts of the machine, or in long terms, the engine powering the machine.

Cutting dies

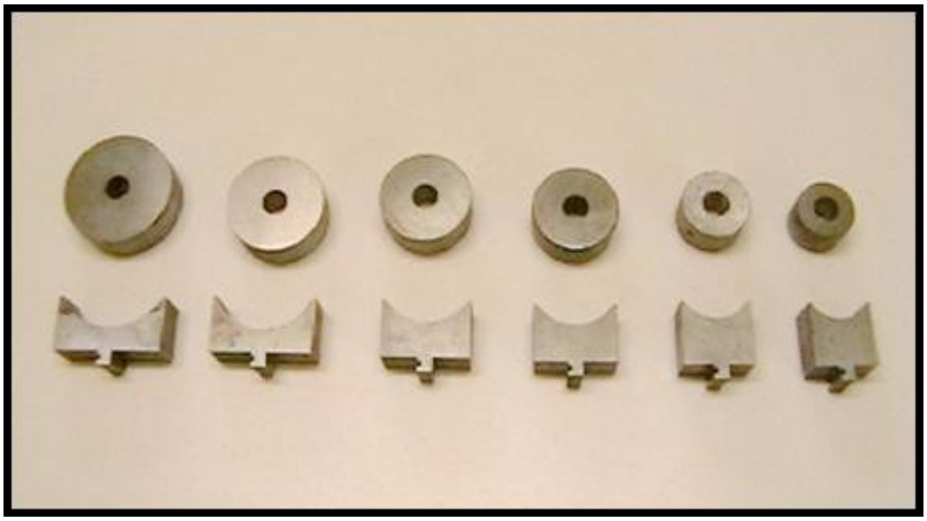


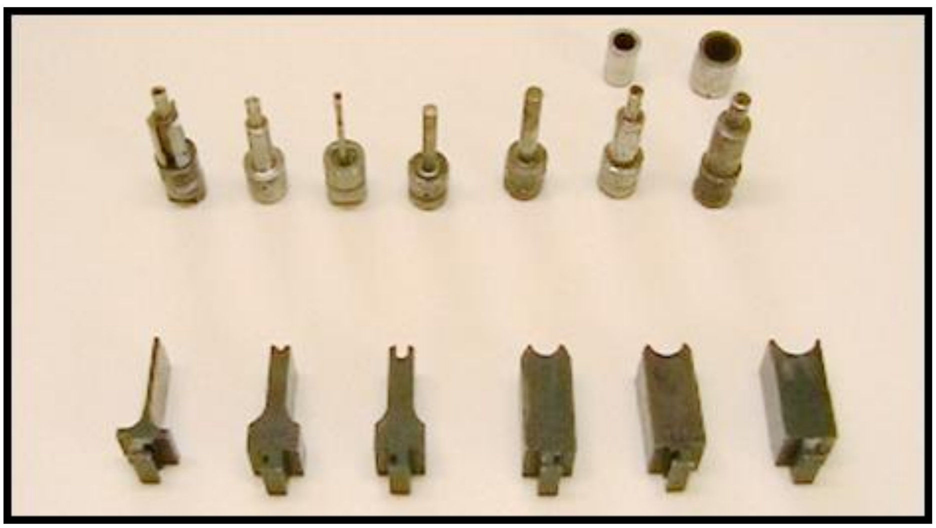
Mitering dies (upper mail, lower female)



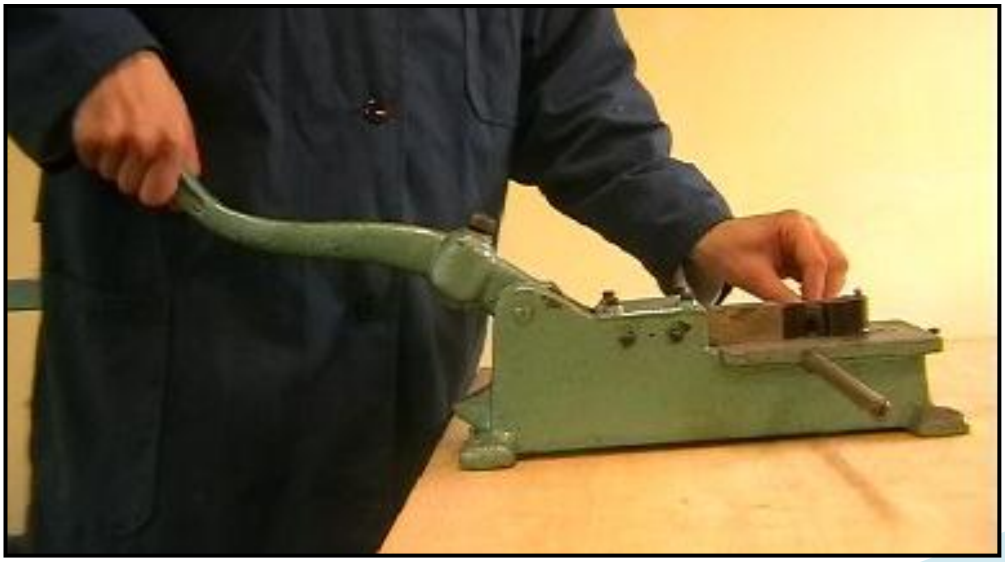
Notching dies (left female, right male)

Sets of bending tools for different bending machine models

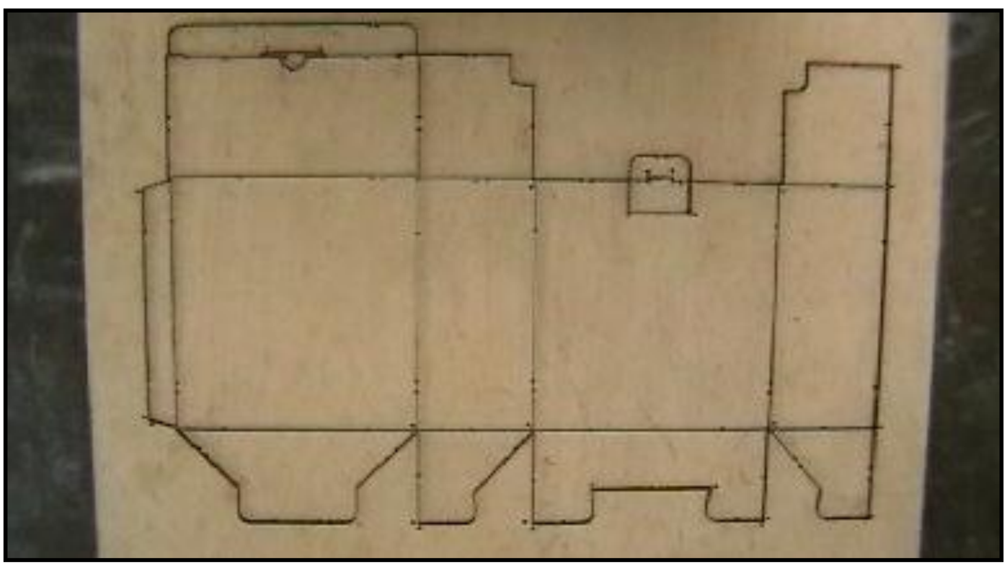




Operating hand machines is very simple. With one hand hold and position the rule between the two dies meant to cut, bend, notch or miter it and with the other hand push the handle downwards to execute an operation. Do not hit the rules when operating, use just enough straight that is needed. Using too much force may damage the dies. All hand machines should be firmly attached to the working desk.

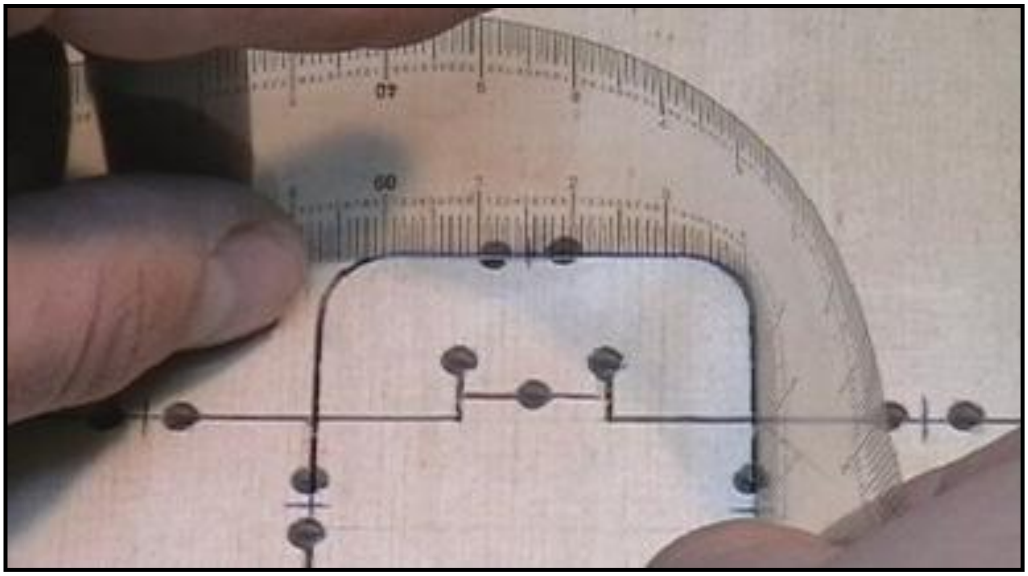


Cutting tools are used to cut the rules to a measure. Cut out parts of rules are then lined in the gutters of the board so their ends fit perfectly, and in the end they look like one long branched rule that looks like the net of the package.



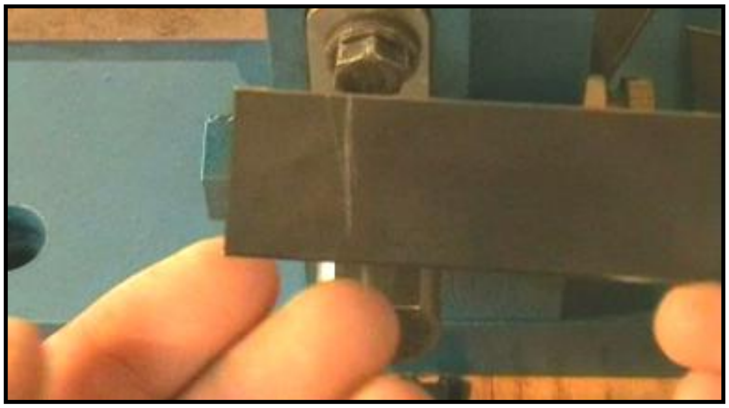
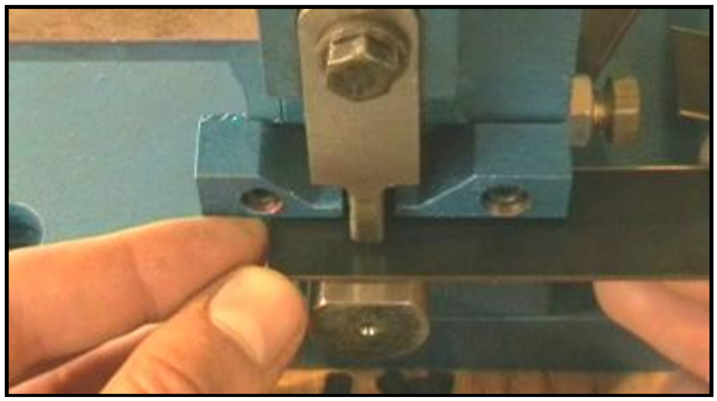
When you have to make rules for sections where there are a lot of curves, or curves generally speaking, try not to make parts that have more than one radius. This will reduce distortions and make it easier to position the rules in the board, as well as make time required to fit the rules shorter. If the length in a curved section is not known, measuring can be harder. For this use rulers printed on a plastic foil.

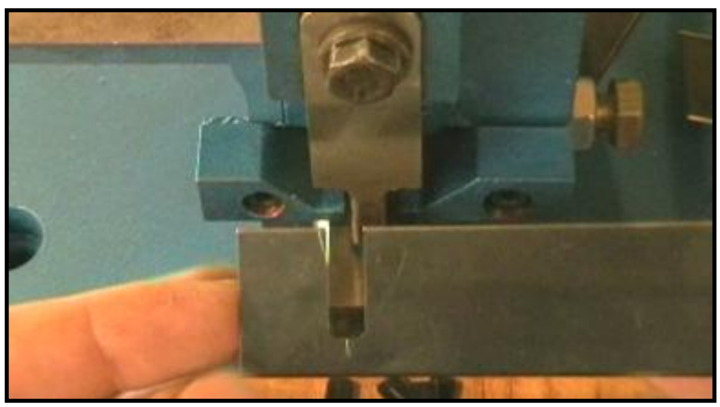
When placing rules you should place first the cutting rules and then the creasing rules. Also if the die is more complex and there are cutting rules in the inside area as well as outside, place the inside ones first. During the rule placing you can cut yourself on the rule bevel, this way reduces that chance.



NOTCHING

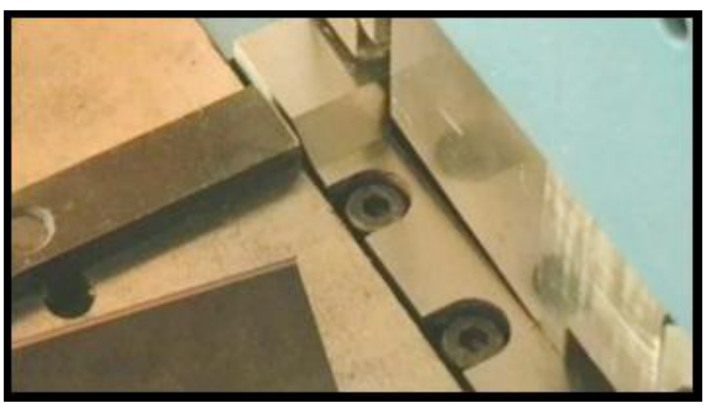
Flat cutting is not the only operation that needs to be done before placing the rules. At the places where there are bridges on the board, notches must be made on the rules. Height of the notches should be 0.5 mm higher than the thickness of the wooden board in order to take account of the thickness variations in the wood. This allows you to see the positions of the bridges when you make the notches for the nicks. While the height depends on the thickness of the board, the width of the notches is generally 5 mm to 8 mm.

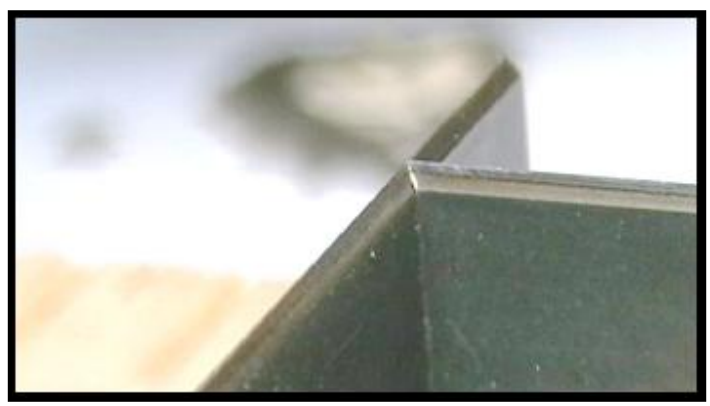



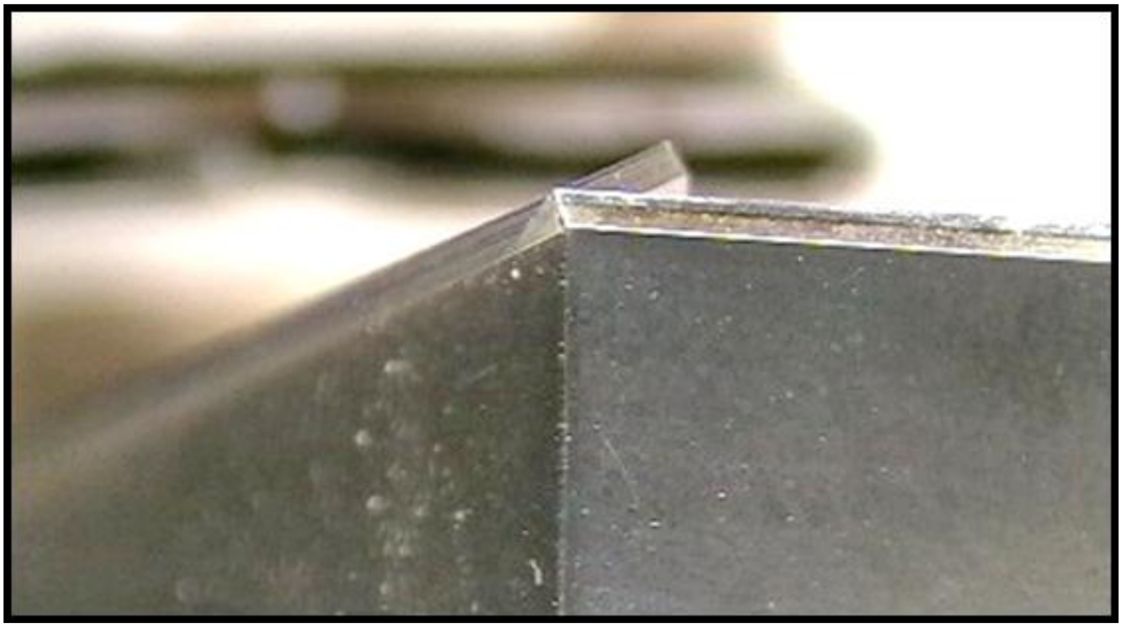


MITERING

To join two rules at a right angle, a joined mitre has to be made on one of the two rules. This mitre will allow the rules to be adjusted so that the cutting edges fit each other perfectly. The shape of the mitre should correspond to the profile of the rule.





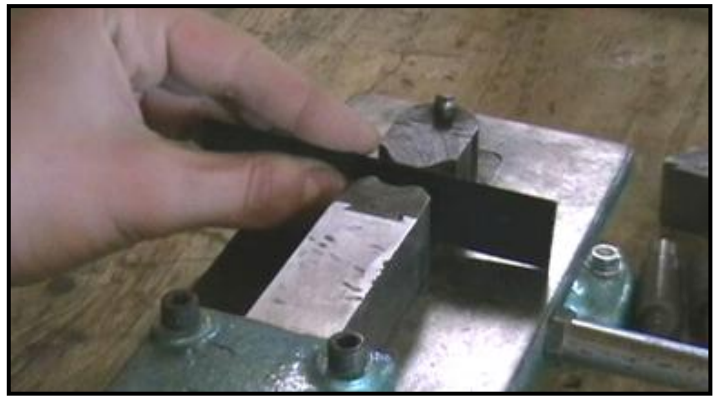


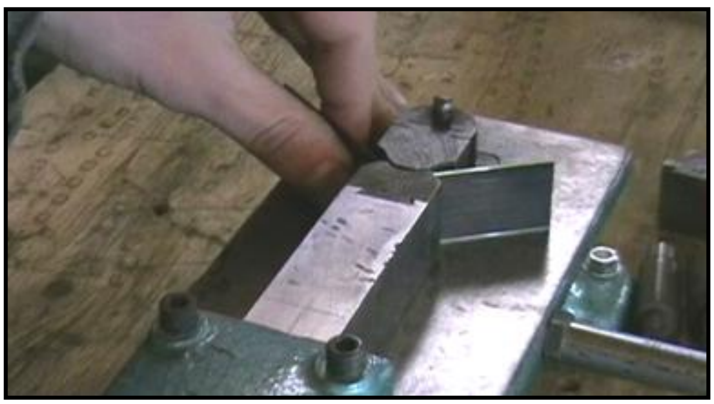
Creasing rules don't need mitering. They are lower than cutting rules and they don't have a bevel.

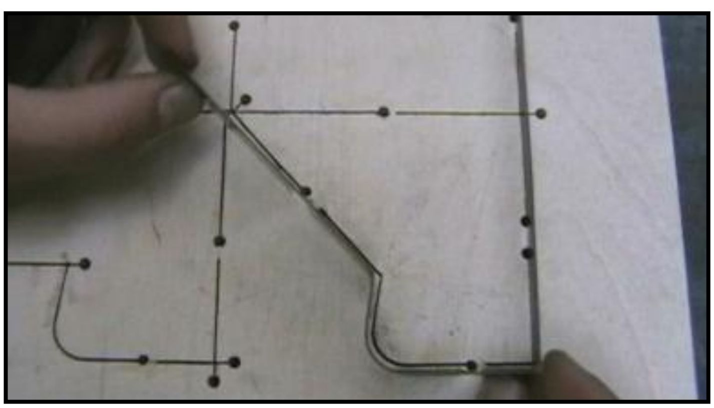
BENDING

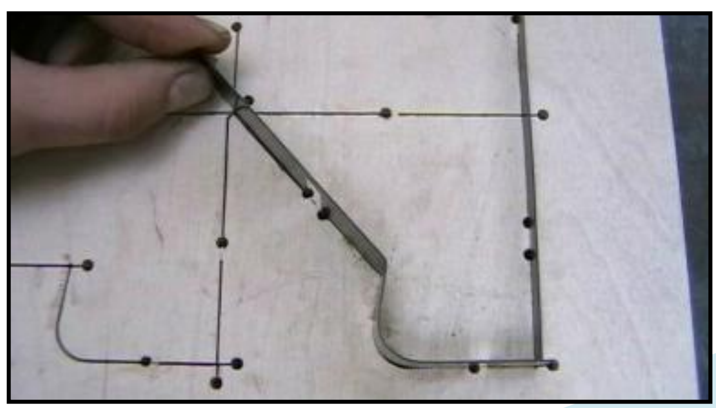
If you are making a rule for a section that has a curve (bending operation) that rule has to be bended at the exact same place and radius as the curve. This way the peace of the rule has the same shape as the section with a curve and placing it will be a lot easier and quicker. Bending operations should be done last, after cutting, notching and if needed mitering.

In cases of small sharp corners if you make a mistake in bending (bent part does not match the grove), and decide to straighten that part; advice is don't. After bending the rule at the same place, or near it, more than once, the rule becomes weaker and could break. Or it will not have a straight and nice form. It is better to just repeat the operation using a new piece.



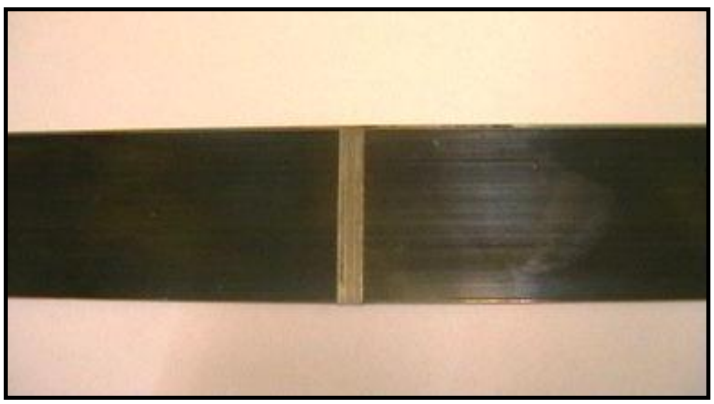


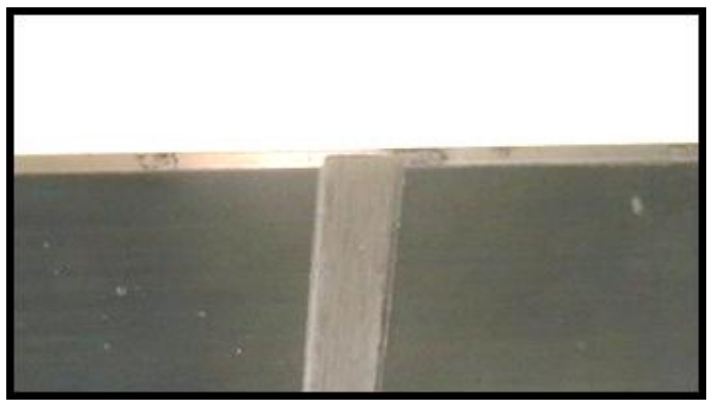


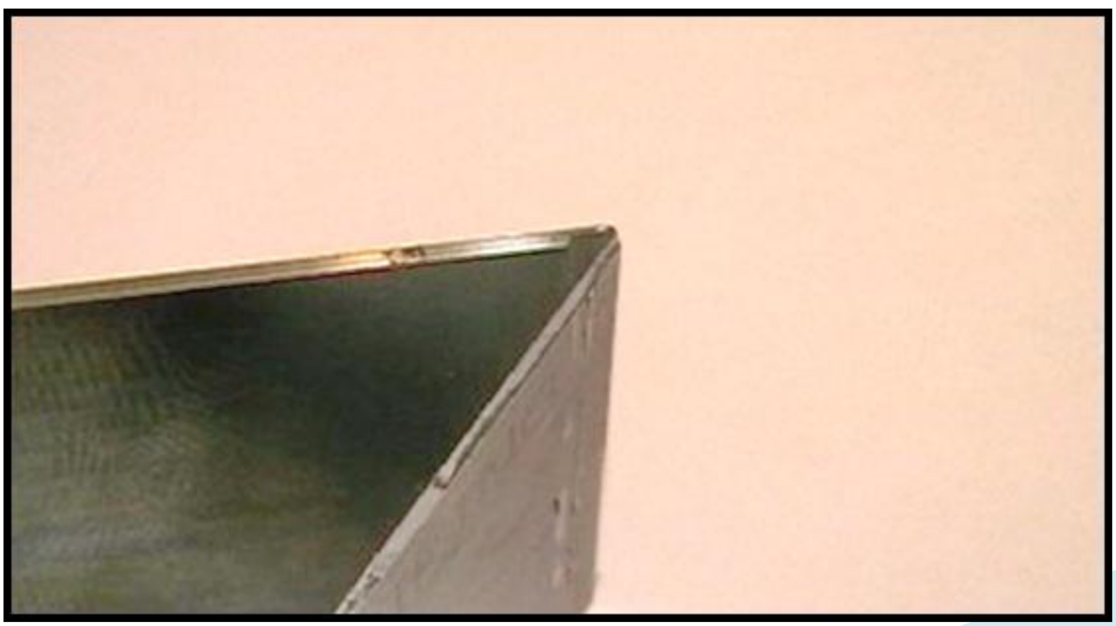


BROACHING

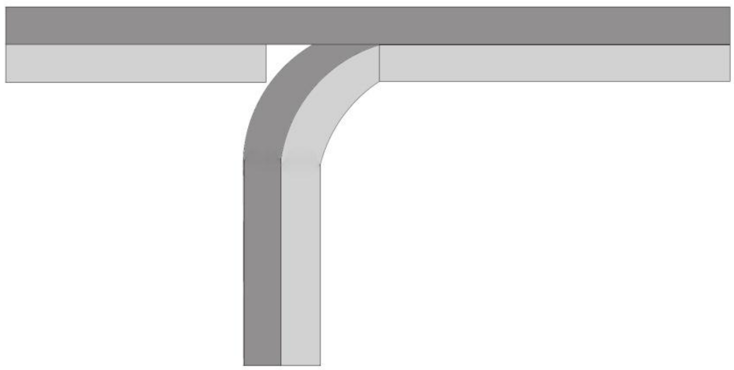
When you have to bend a rule to a very small radius, it is best to use broaching to make it easier. Broaching is a method of removing material. At the place where a rule needs to be bended, the rule is being “scraped” on the side which makes the rule weaker at that place. The bevel is, however, not harmed and this procedure gives the advantage of: fitting rules easier, faster, more accurately, constant height of the rule after bending, accurate adjustments of joints, high bending angle.







Joint of two rules, strait-curved

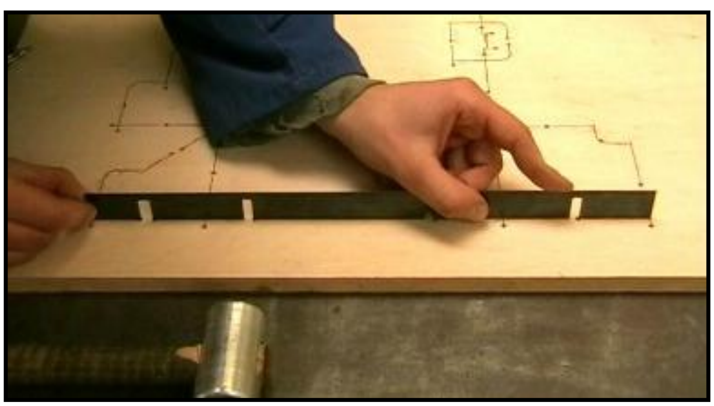


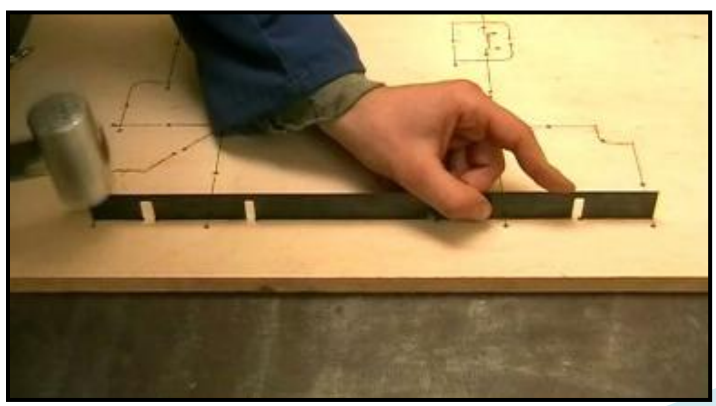
LESSON 46 - PLACING RULES AND RUBBERS

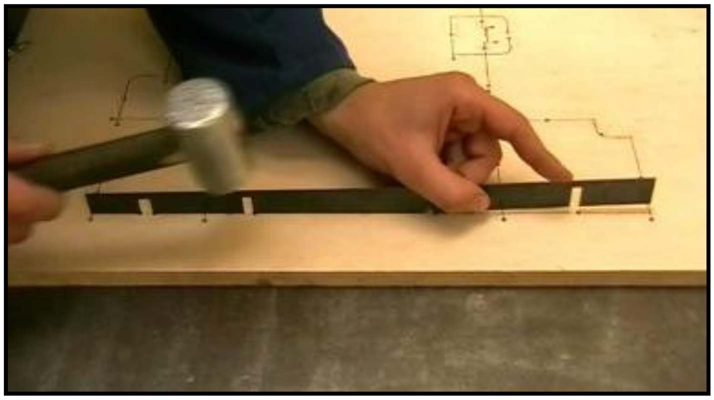
All die-assembly operations should be done on a die-makers table. This table is made out of metal and it has a perfectly flat surface. It is preferable that all the die makers tools and machines are near the table in order to make the assembly time shorter.

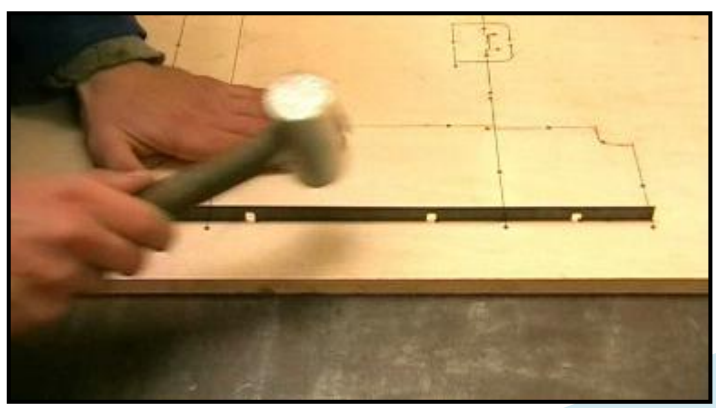
After they are finished, rule pieces are then hammered in the sections they are meant for. This is done by hitting the rules vertically at a straight angle with a die makers hammer. This hammers have rubber heads or in some cases aluminum. Rubber and aluminum are materials that have a lot smaller hardness than the rules so that when you hit the rules no damage would happen to them, like breaking the cutting rules bevel.

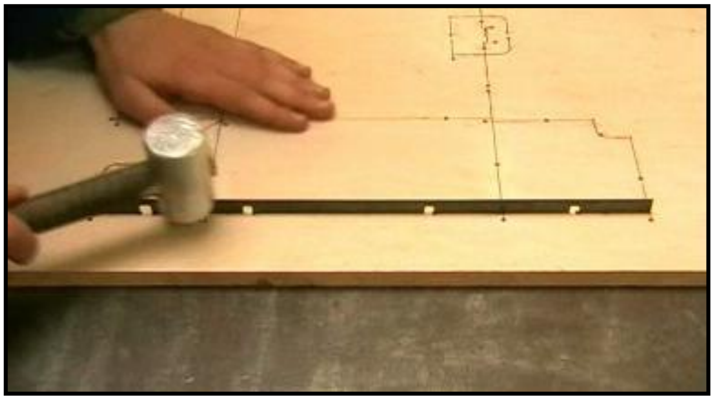
Placing the rules is done hitting them from one end moving to the other.

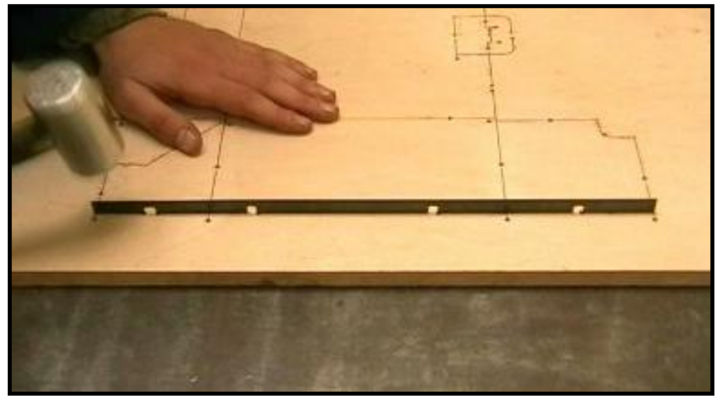


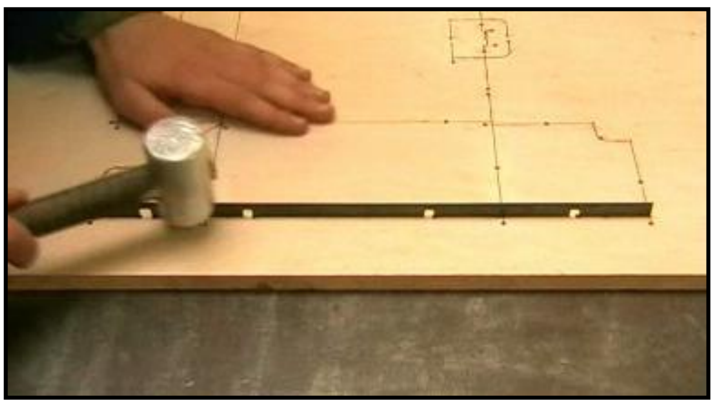


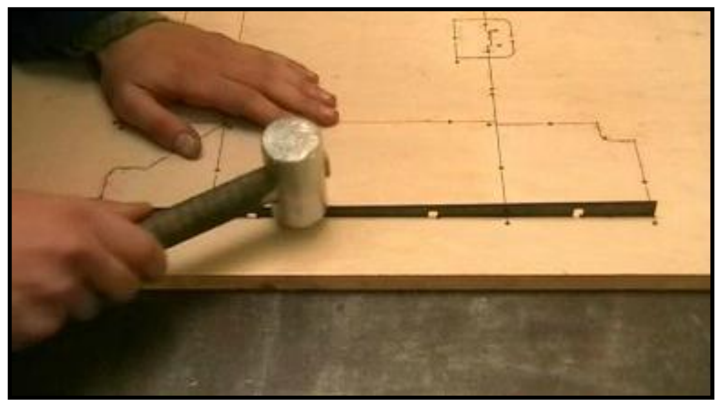


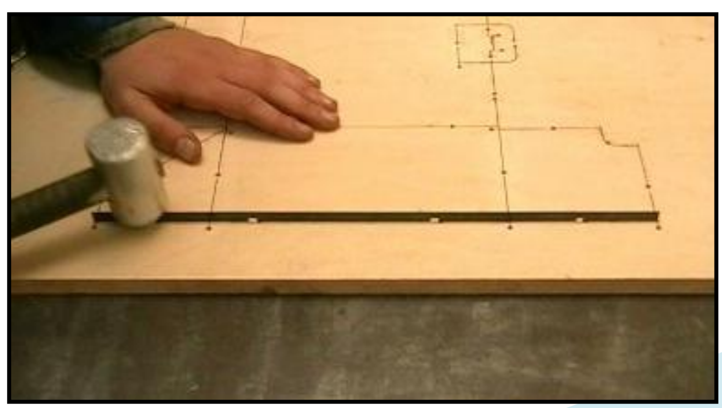










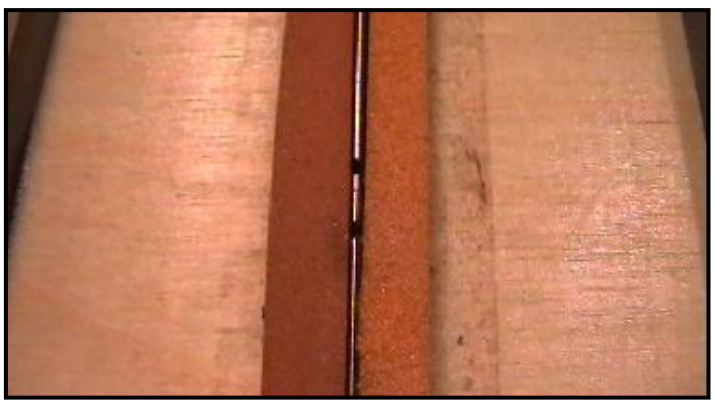


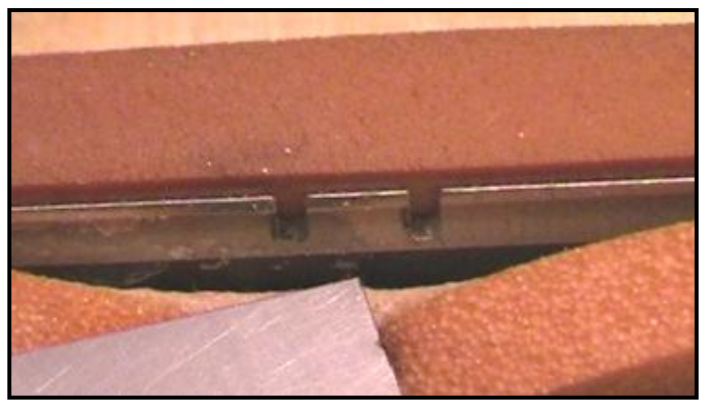
Rules should not be hit with too much strength particularly when working with aluminum hammers. Even though they are not as hard as the rules they are still strong enough to make damage to the rules if hit little too hard and at a bad angle. Which is why, it is better to use rubber hammers.

PLACING NICKS

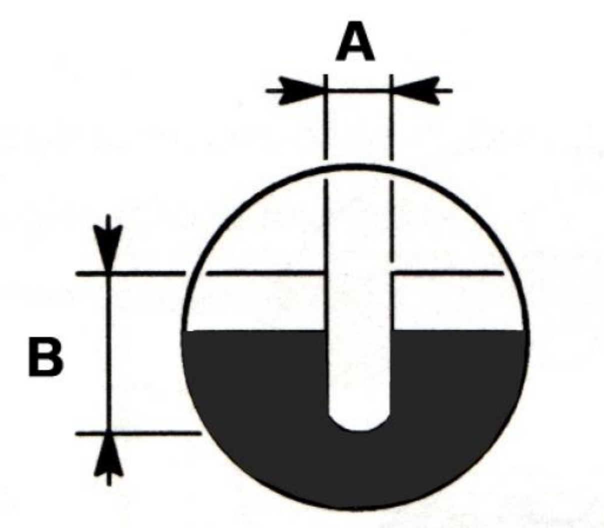
After placing all the needed rules in the board and before placing rubbers nicks have to be made on the cutting rules. Nicks are notches on the bevel of the cutting rule and their purpose is to stop the waste, which comes from the board of the material being die cut, to pile in the press.

Nicks on a faced cutting rule (grinder):





Dimensions of the nicks are determined by the material thickness.



Material thickness	A	B
0.1-0.6 mm	0.3-0.8 mm	e+0.5 mm
0.6-1.5 mm	0.8-1.6 mm	e+0.5 mm

When placing nicks, the minimum distance between a nick and the end of a rule is 4 mm and for sections were large pieces are cut out and one nick isn't strong enough add a second nick 6-10 mm from the first.

Do not place nicks above bridges. Doing this will create a weak cutting point.

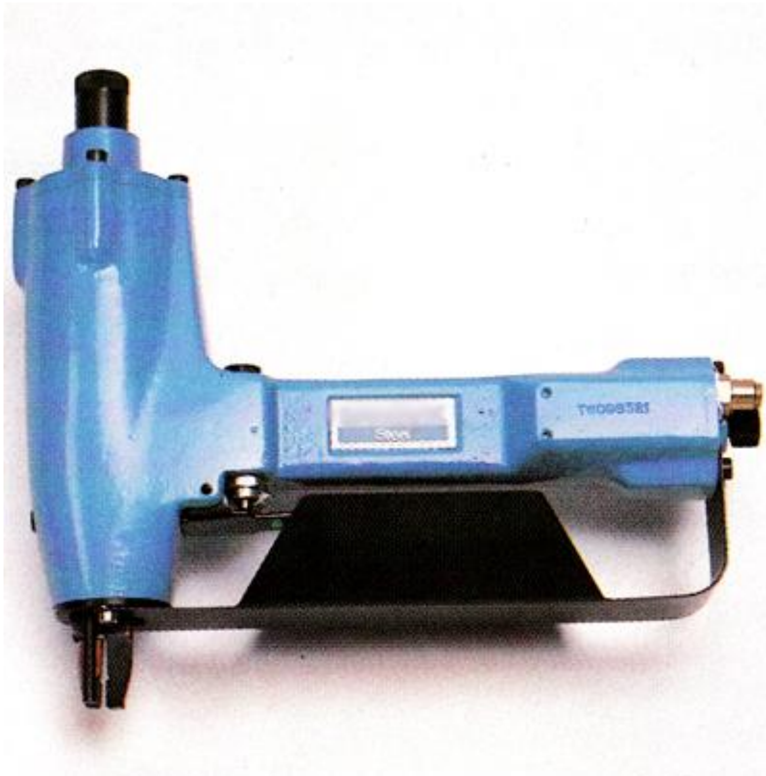
For placing nicks use nicking tools, grinder or chisel. Using grinder requires wearing safety glasses.

RULE PULLING

If during placing rules one of the rules got damaged or all of the cutting rules on a die are dulled from too much work, those rules need to be replaced. This is done by pulling out the rules out of the board using various tools made especially for this operation (rule extractors, steel rule jack clamps, rule pullers). While these tools are made to make the pulling out process easier the principal is the same and will best be explained on this example using pliers.

Rules are pulled in the same way as they are placed in: starting from one end and going to the other.

It is important to pull the rules as vertically as possible in order to prevent any chance of damage to the die-board and rule. Broad base of the pliers makes it possible and also provides greater pulling power with less chance of slipping of the rule. The problem with using pliers for pulling rules is that after (pulling) to much rules you could get pain in your arm and wrist and blisters on your fingers. This is why it is better to use more modern tools for automatic pulling:

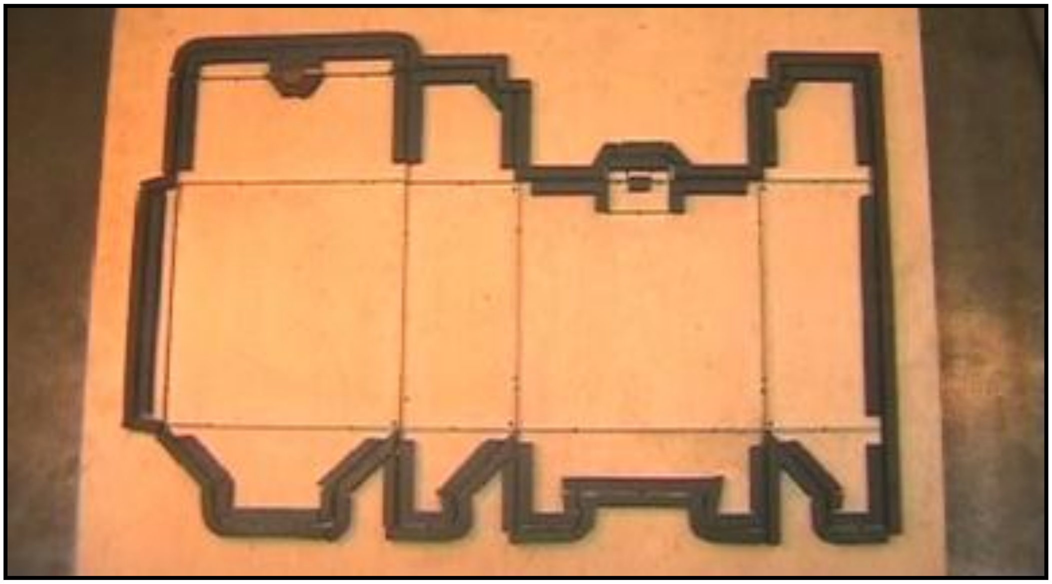


PLACING RUBBERS

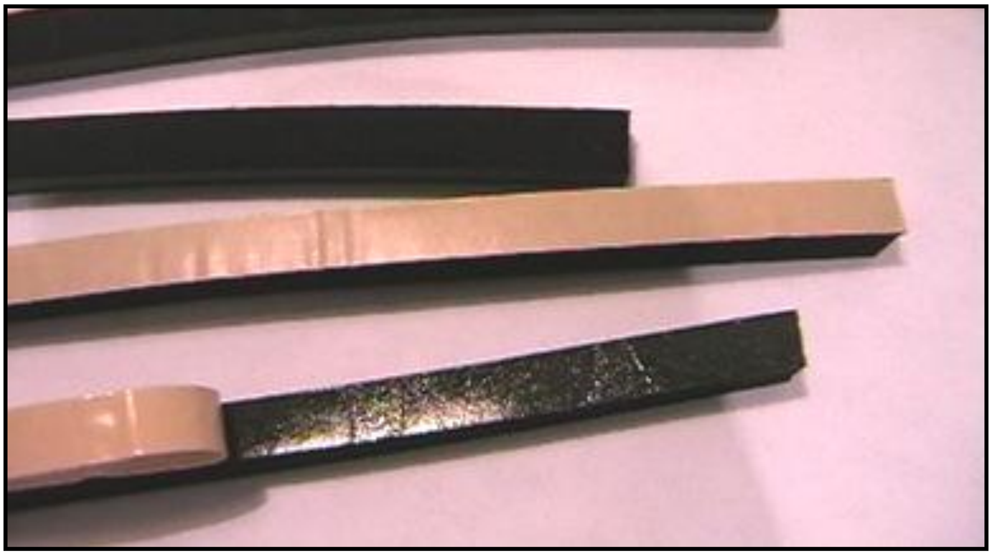
Rubbers are placed on the cutting die at the end of all operations concerning placing rules in the die-board. The purpose of these rubbers is to hold the board that is being die cut during the cutting process and bounce the board from the die after cutting. During the cutting process the board gets stuck around the cutting rules. Therefore the rubbers are only placed around these types of rules and not around creasing rules. Placing rubbers around creasing rules would also make it impossible to place the counter parts for them.

Rubbers used for these dies are solid and foam rubbers. They can be sheet or stripe shaped. Stripe shaped rubbers are directly glued on the die, rubber sheets are cut in shapes of the required sections and then glued.

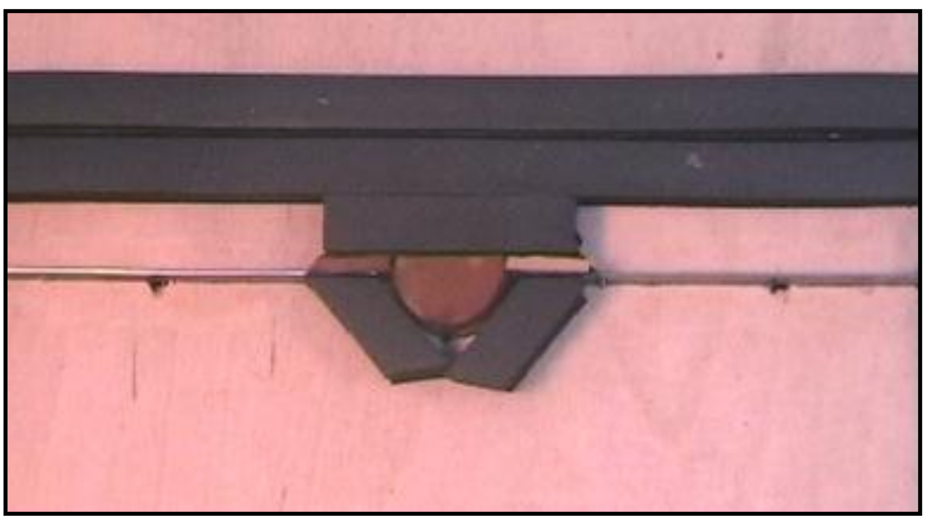
After placing rubbers on our example die:



The black lines around the cutting rules are stripe like foam rubbers of 20 to 30 **shores**.



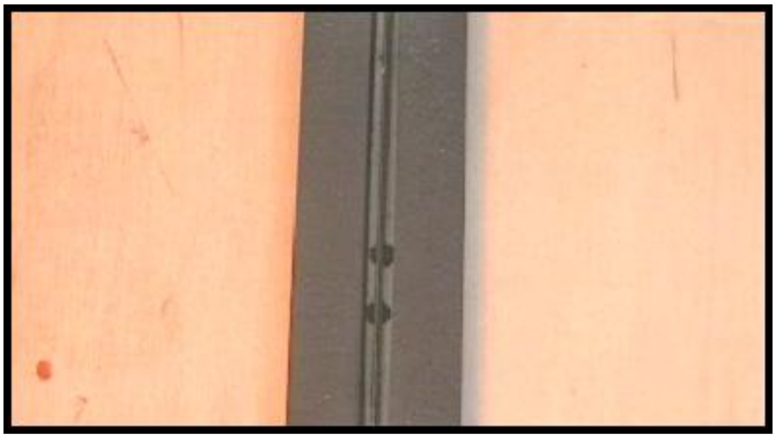
These rubbers have an adhesive which makes their placing on the board easy. They can easily be cut to a wanted length and shape using scissors. Because these rubbers are too soft they should not be used in small and tight sections. For these parts using harder rubber is required.



This is an example of such a section and rubber on our die. This orange color rubber is solid rubber of 50 to 60 shore and it was cut out from a rubber board.

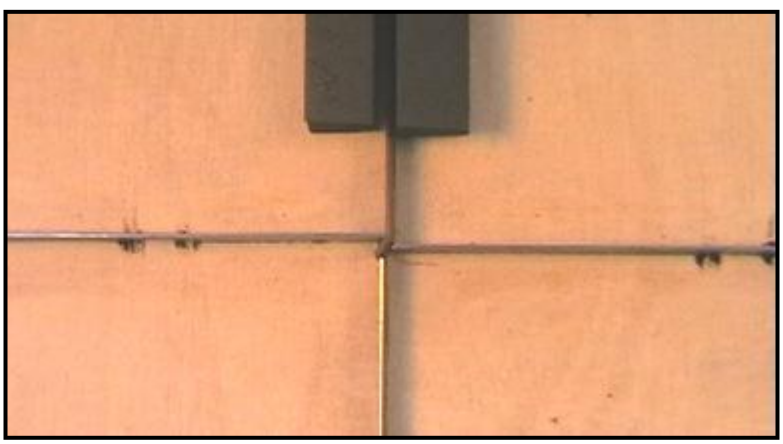
Softer type of rubber should be 1 to 2 mm higher than the rules, harder type should be 0.5 to 1 mm higher which since cutting rules have a 23.8 mm height means their height depends on the board thickness.

When placing rubbers, leave a 2 mm space between the cutting rule and rubber.



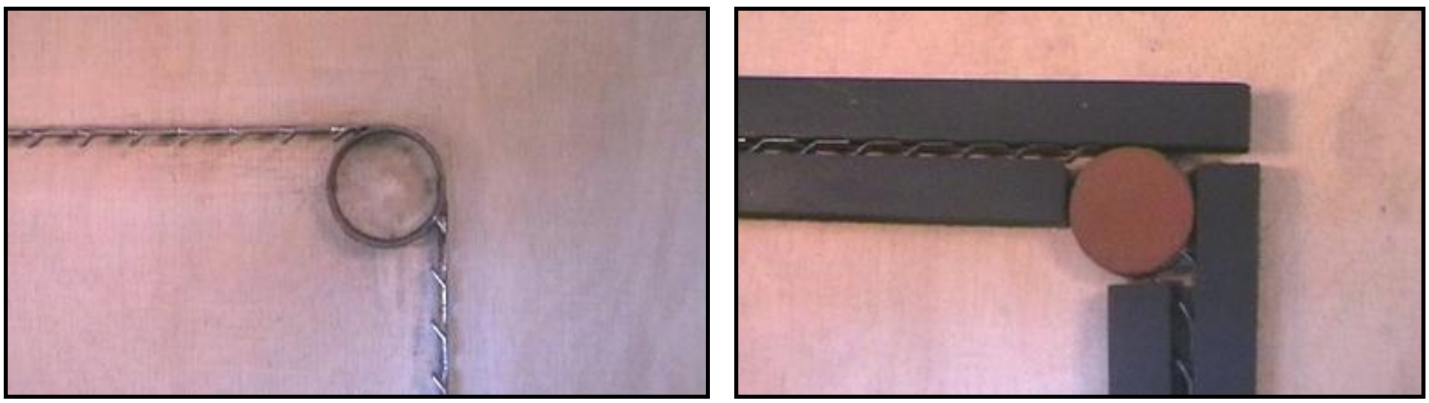
Placing rubbers with the cutting rules will, during work in press, because of rubber compression generate opposing forces which tend to push the blanks apart and break the nicks. The distance also reduces the static charge between the rubber and rule.

When placing rubbers next to cutting rules that intersect creasing rules, rubber should not be placed next to the creasing rule but 8-10 mm further from the rule.



Perforating rules often have solid rubber glued next to them in order to achieve better bending in cases of corrugated carton; solid rubber presses the waves around the rule.

Here is an example of a "before and after":



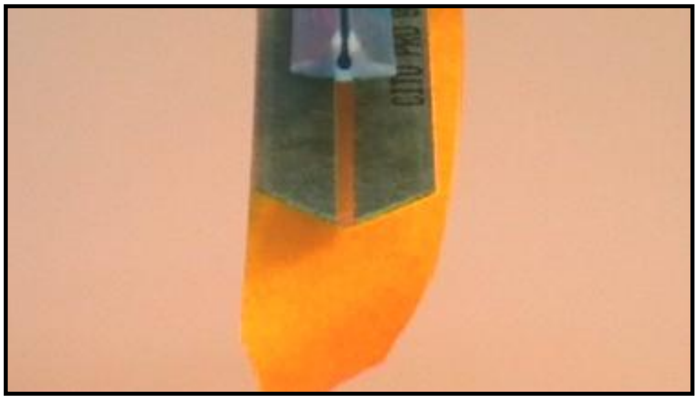
And another example of a well done section:

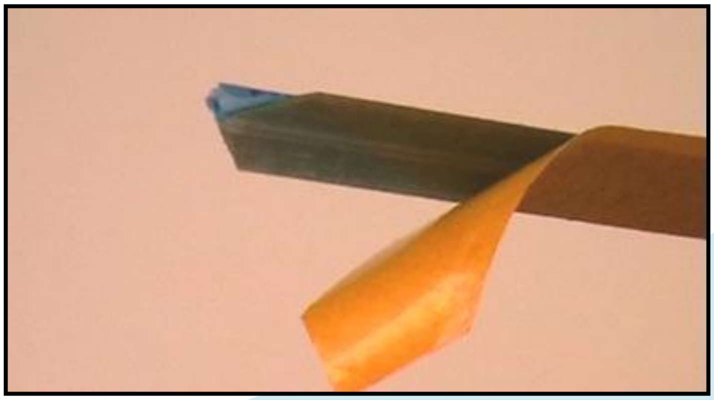
LESSON 47 - MAKING THE COUNTER-FORM

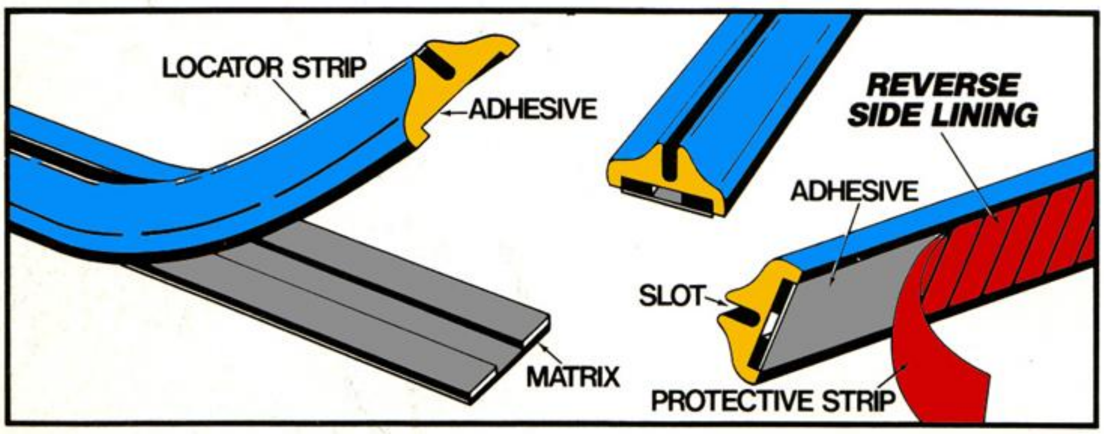
After placing rubbers, the cutting-die-form is done, but this is one half of a complete tool. The other half is the counter-form for this die. A die still needs proper creasing counterparts in order to make creasing possible. Since creasing rules are smaller by material thickness they don't have a proper effect on the material.

Counter-form consists of creasing counterparts and the cutting plate. Here we will show the making of a counter-form using CITO-lines (matrix) for counterparts.

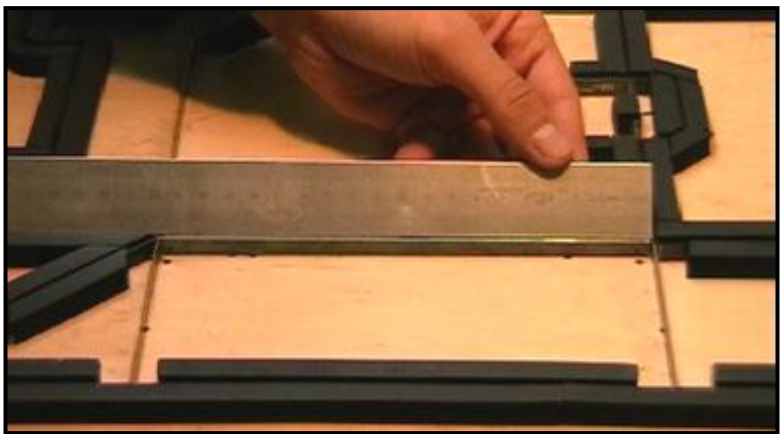
Using CITO-lines (matrix) is very simple; they provide top creasing quality; easy settable; long lasting; high creasing precision; easy to replace.





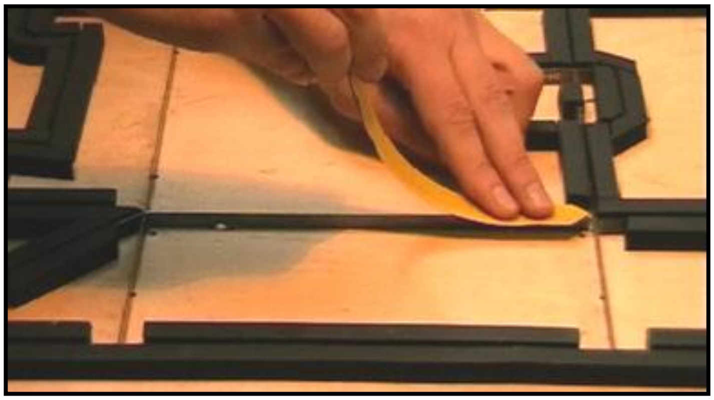


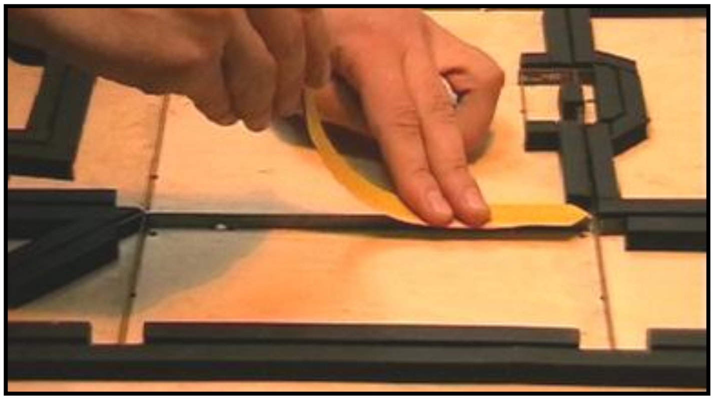
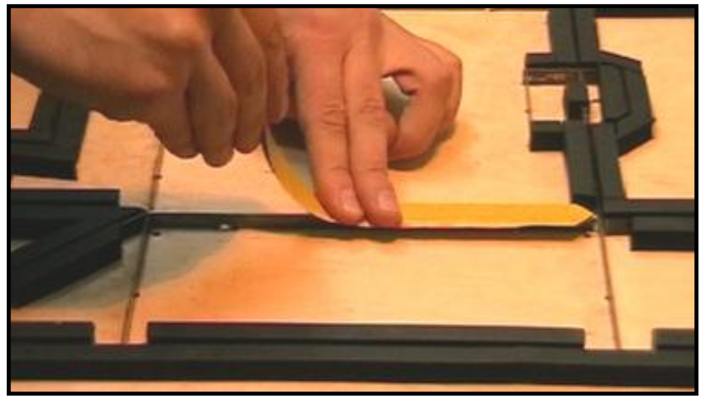
First you need to determine the number and length of lines by measuring the creasing rules.

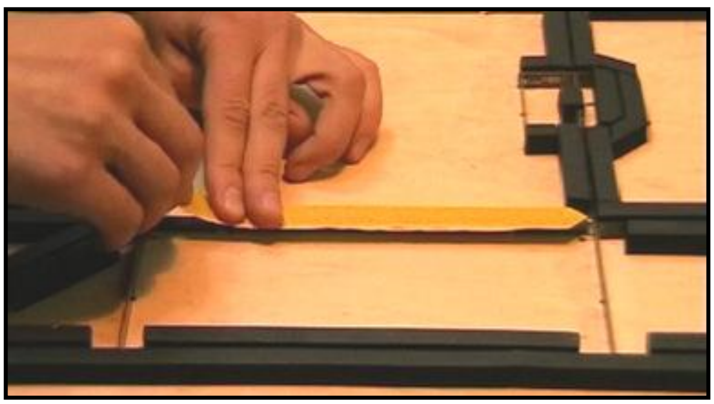
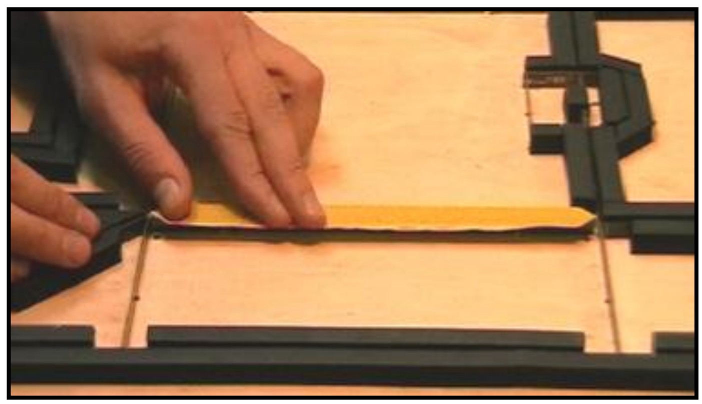


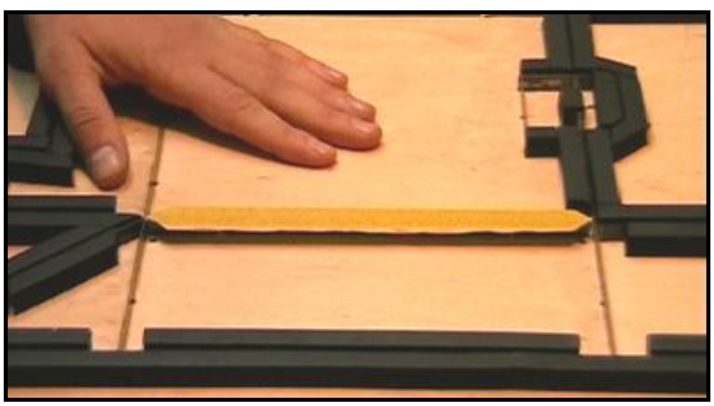
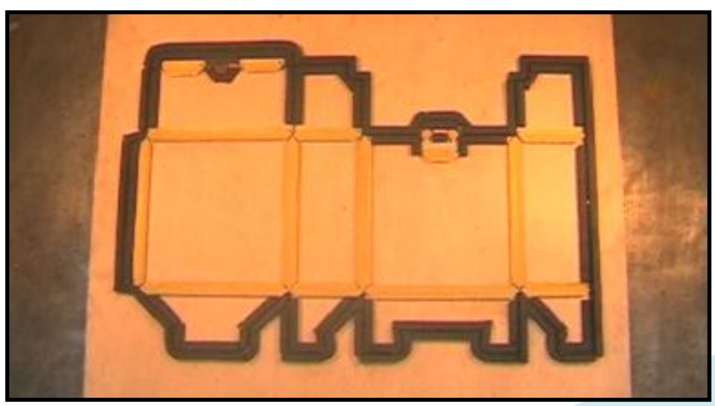
Then by using mitering pliers or mitering bench press cut the lines to a measured length.

Place the locator strips on the creasing rules.

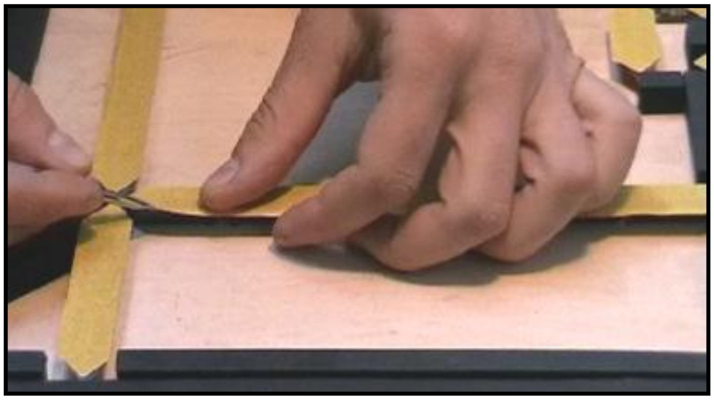


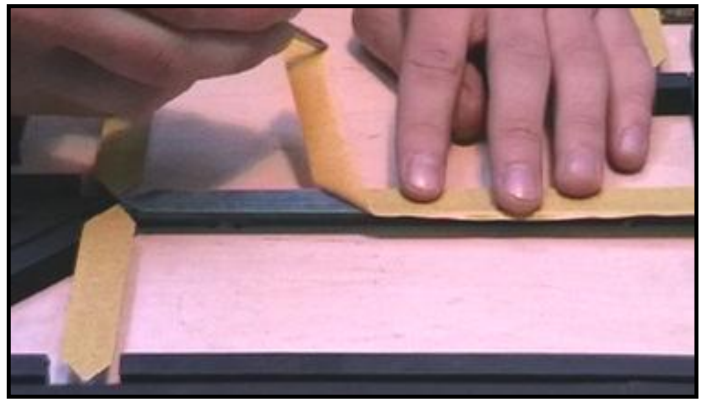



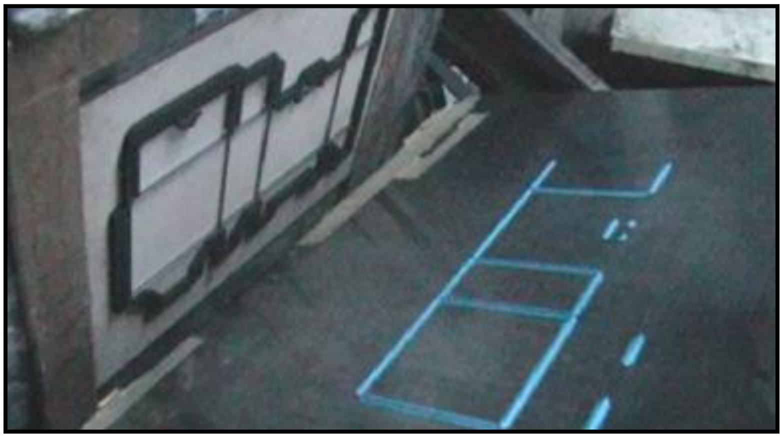



When all the counterparts are placed, put the die in the press. Then remove the protective strip to expose the adhesive. You can also remove the strips before placing the die in the press.

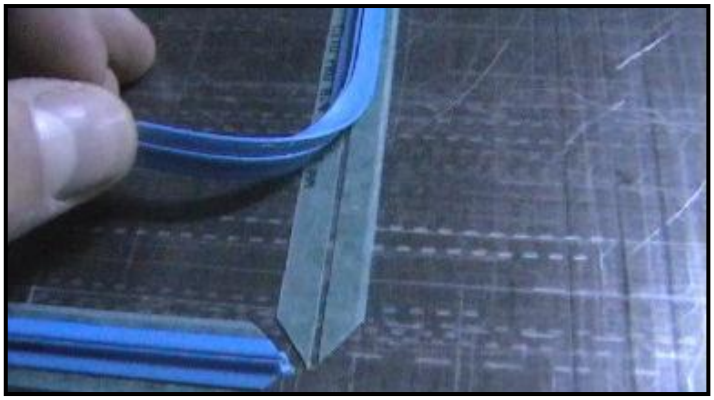


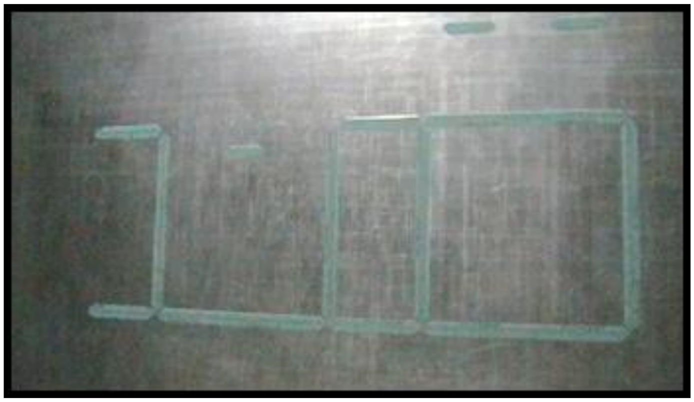


Then operate the press for one complete cycle. Thanks to the adhesive, the counterparts will be transferred (glued) on the cutting plate.

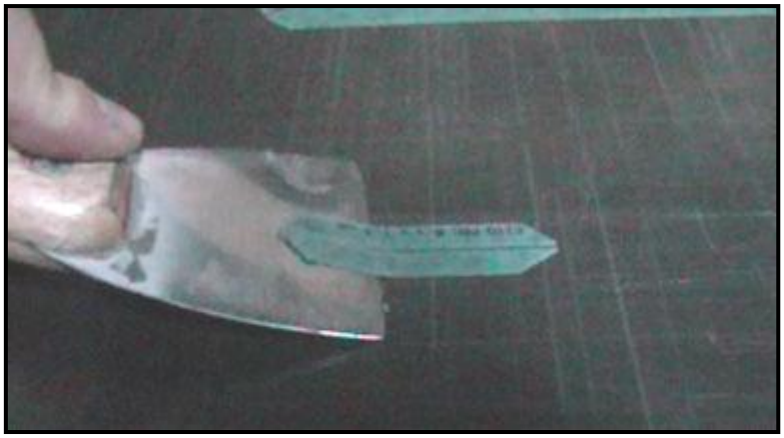


After removing the locator strips, matrix are ready to run in accurate register with the creasing rule.





Removing the matrix after use is easy using a spatula.



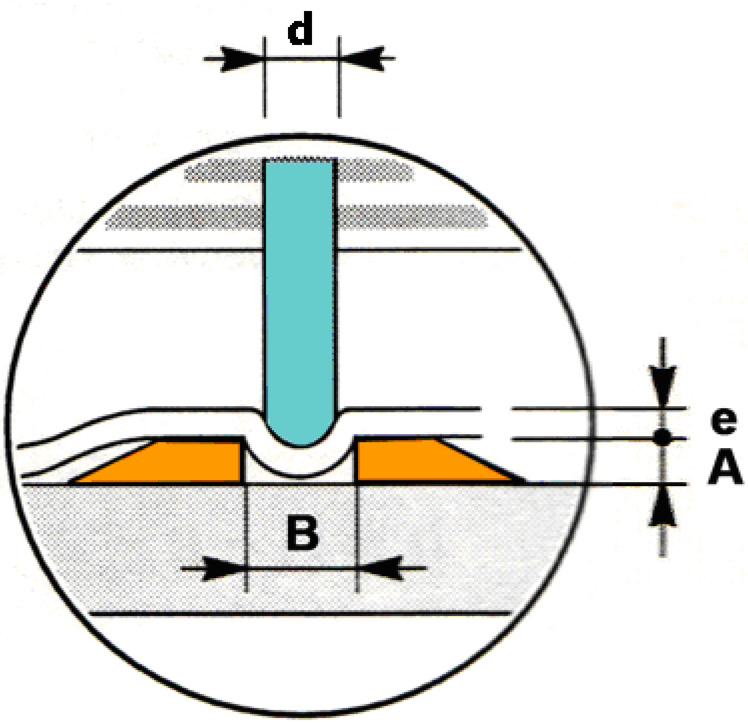
When making a counter-form you have to choose the right type and dimensions of the counterparts. Dimensions depend on the material thickness and creasing rule thickness and they are calculated using these formulas:

$$\boxed{B=2\times e+d}$$

$$\boxed{B=1.5\times e+d}$$

$$\boxed{B=1.3\times e+d}$$

$$\boxed{A=e}$$



B-width of the grove

e-thickness of the material, in case of corrugated paper and paperboard minimum thickness.

d-thickness of the creasing rule

A=height of the grove

The first formula defines the width of the grove for corrugated boards, the second for paper perpendicular to the board fibers and the third for papers parallel to the board fibers. When creasing a board perpendicular to its fibers, the width should be 0.1 mm bigger. The forth formula defines the height of the grove which should be the same as the material thickness; for softer creasing lower the height for 0.1 mm or use IK type.

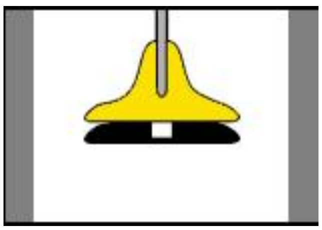
Matrix producers in their offer have a wide range of sizes, as well as types. Different types have letter marks on them for recognition. Here is a list of some of them:

RY-standard matrix lines

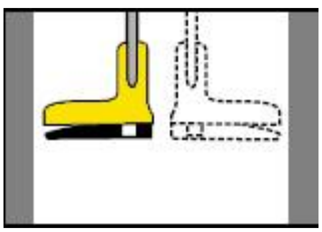
IK-lines for softer creasing, prevents material breaking

CMR-lines that come in rolls

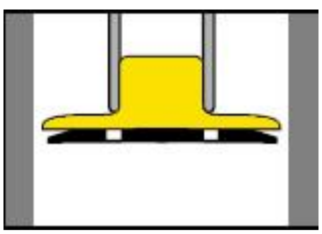
DR-lines with double and triple groves



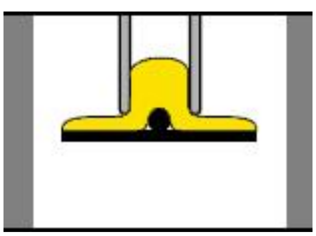
Center matrix-most widely used for regular creasing.



Off center matrix-used when two creasing rules are used close together to produce a double crease or when creasing rules are as close together as 4 mm so using normal center matrix is not advisable.

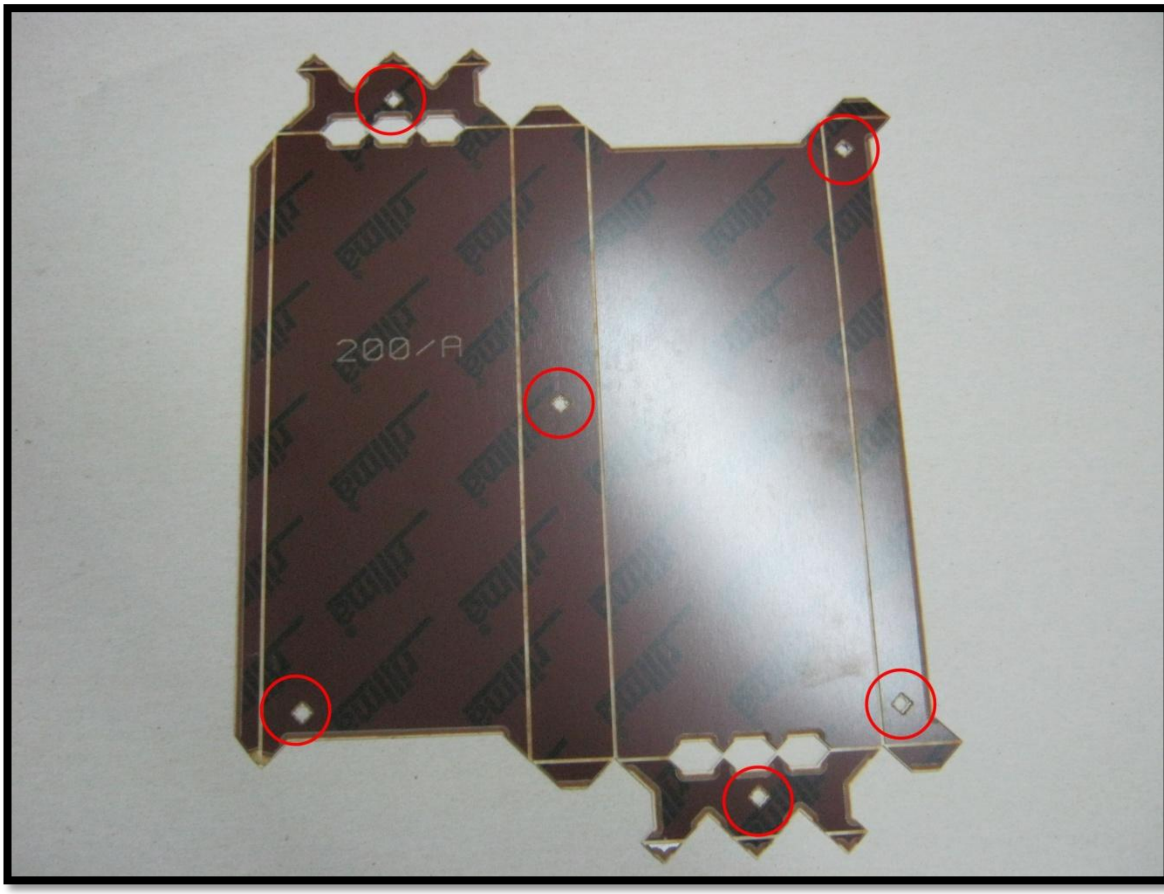


Double creasing matrix-used to achieve a double crease 3.5 mm from center to center.



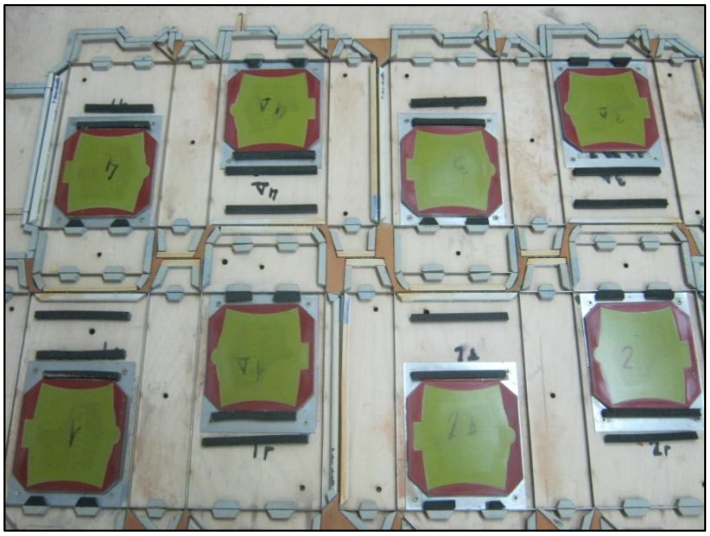
Reverse bend matrix-used when creasing on both sides of the board is required. Two creasing rules are inserted in the die to form a channel and the ridge on the matrix acts as a creasing rule. Often used for corrugated cartons.

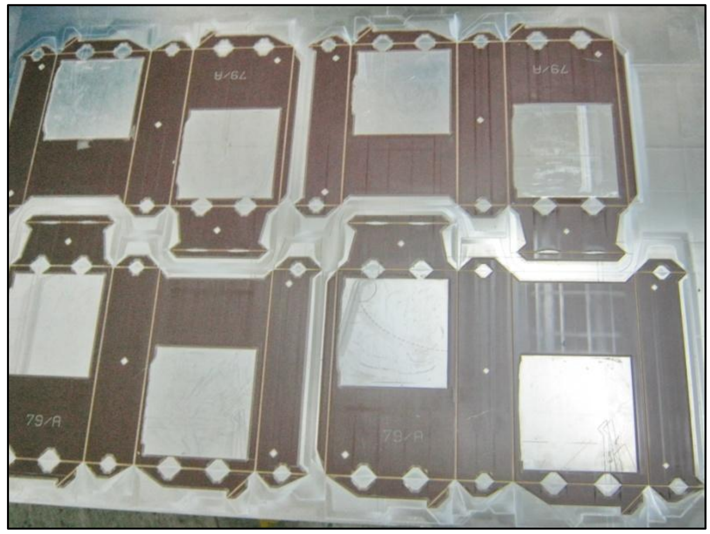
Another group of counter plate dies is the one that is becoming more popular with the usage of CNC machines. These plates are made from hard thin materials that have groves grinded on their surface. These groves correspond to the position of the creasing roles of the die. This allows the plate to be used and used many times over. This type of counter plates was used before CITO system but it was difficult to craft since it was done by hand. Today with the usage of plotters it has become very easy and precise.



This is an example of such a counter plate (phenolic counter plate) for a different die, for a different package. This type of plates is built in the process of using CNC machines in every step of die making, beginning with die designing. The same design goes to lasers for board cutting and to plotters for counter plate building. And in the only way to join the one with the other, in the cutting press, is with locating holes (red circles) which you can see on this plate. The same holes, but in mirror image view, exist on the die board, and using pins, they are joined together before entering the pres. So for the die that we made the old fashion way this plate is somewhat useless, because fitting both of them is very difficult, and never precise enough.

Here is an example of a die board and die counter plate, made using CNC machines (male-left and female-right) with one detail- the counter plate is already glued to a metal sheet which is for there for the press requirements. Not all die cutting presses are the same and some require counter forms already glued to the bottom side plates. The calculations for this type of counter plates are the same as described for CITO matrix, concerning the thickness of the plate, width of the groves…





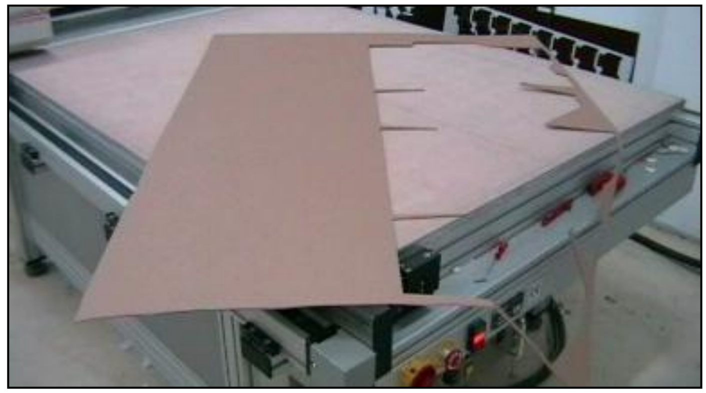
LESSON 48 – INTRODUCING NEW TECHNOLOGIES

Today, worldwide, more and more new means of making dies are used since they provide greater speeds, accuracy and flexibility. Even thou in essence die making hasn’t changed, the process just got a lot easier thanks to computers and automated machines.

Today it all starts in a program that works with vectors. Most commonly used programs are CAD/CAM systems, and they require taking courses and training in order to fully understand them and learning how to use them. Using this program is a job for a die designer; a person that in today’s packaging industry is only one of many included in the die making process and does only that. This die design is the starting point for all automatic machines that follow, so it has to have all the parameters defined (notches, joints, groove width, additional machine requirements, etc.).

In modern day die making, all off the stages are connected, weather by LAN or wireless. Automated CNC machines today work with very “user friendly” programs, and learning to operate with one is not hard with basic computer knowledge. The only problem is that every producer of a CNC machine uses his own program, so explaining how to operate with one here would probably not help. But there are some general actions that all same type machines have. Also the file type that CNC machines use is no longer CAD, but CF2 and DXF. These are special types of file formats used, and all others have to convert so CNC machines could read them.

After making the design, it moves on to the next in line; prototype making. Plotters are machines used for this and they provide a variety of possibilities.



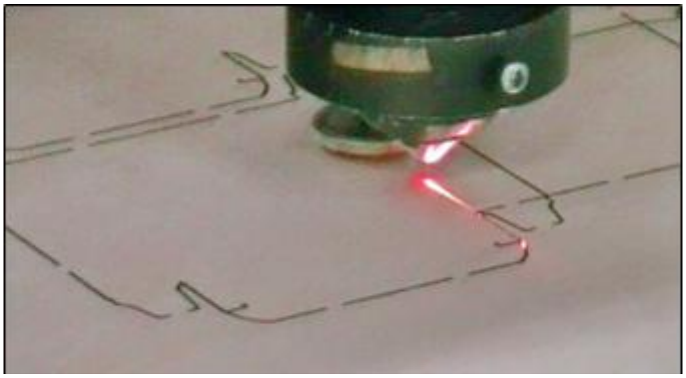
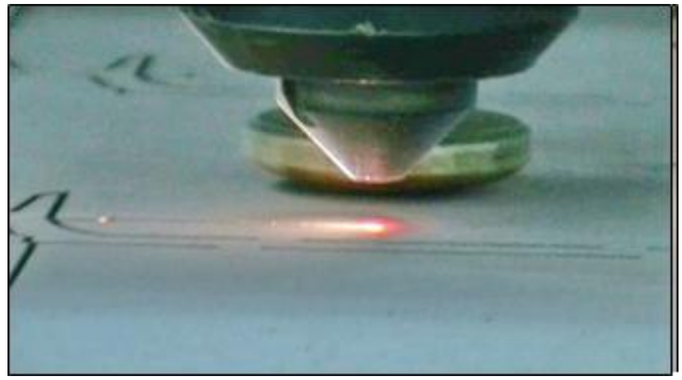
When the computer operating plotter receives the image, it is up to the operator to define all the factors required. For every line in the design, the operator has to set which operation will be performed. If it's a cutting line, operator has to mark that line and set the command for cutting; for a creasing rule, height and width have to be defined; for a counter plate: depth and width, with consideration of parallel and perpendicular creasing's. Every operation on every CNC machine has to be defined since this machines act as giant printers. So if you leave something undefined, unmarked or not placed, it will not be done. The machine does not now that what you are crafting is a package, it just moves left and right and performs operations that you told it to.

All of the operations required to build the prototype are possible thanks to the diversity of the head mounted on the supporting arm. This head contains dies for every operation required. For cutting there are cutting dies that cut by oscillating at high speeds, for creasing there are wheals of different width. Possibilities vary from one producer to other, giving you more options. For example some can even print the prototype, emboss… This type of machines, and all similar, work in the (X,Y) axis. The Z axis in this case determines how deep the creasing, cutting or other pressure type operations will be. This machine provides a great way of making not only prototypes but also producing small series, canceling de need for die making. After setting all parameters the operator starts the machine by marking the (0,0) staring point. From this point the starts operating. This point also important for lasers.

Laser machining is a new, very flexible process in die-making especially, for the machining of fine and complex structures. Principles of laser effect date Einstein who gave the theory, and exists since the 1960's, when it was first experimentally confirmed.

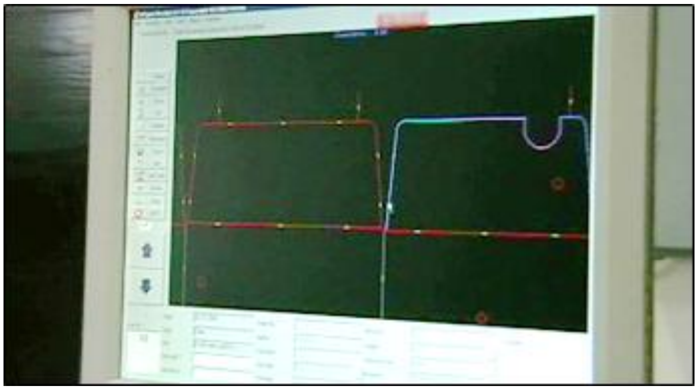
Today, the application of lasers is numerous and they can be found almost everywhere. Laser cutting is a technology that uses a high temperature laser to cut materials, and is typically used for industrial manufacturing. Laser cutting works by directing the output of a high power laser, by computer, at the material to be cut. The material then melts, burns, vaporizes away, or is blown away by a jet of gas, leaving an edge with a high quality surface finish. Industrial laser cutters are used to cut flat-sheet material as well as structural and piping materials. This process is suitable for processing difficult-to-machine materials, like ceramics, carbide and hardened steel with excellent productivity, surface quality and cost efficiency.

The CO2 Laser creates a beam of light that cuts through the plywood, so there is no part of the laser system in contact with the material. It is amazingly precise, 99%, following the pattern of the die, it gives the best solution for plywood cutting today. When receiving the die design, the operator has to set the laser for cutting. Marking the lines to be cut, marking their width which tells the laser amount of power to apply. If for some reason the design does not have notch marks, operator can add them. If there is a special text that has to be laser drawn on the board, or other requirements, all of the parameters have to be set before the cutting. In their memory CNC lasers may contain data for die specifications required by certain types of automated diecutting machines. These specifications refer to, for example, plywood size, grooves, holes for Die placing, holes for counter plate guiding… These requirements are different from one machine to the next, and since producers make new models, the data base has to be updated regularly. After all the settings, operator can start the machine and watch the laser do the task. The speed of lasers varies, but it’s around 1-2meter/min. The progress can also be seen on the screen. The laser head moves in the (X,Y) axis and Z axis is the beam power.

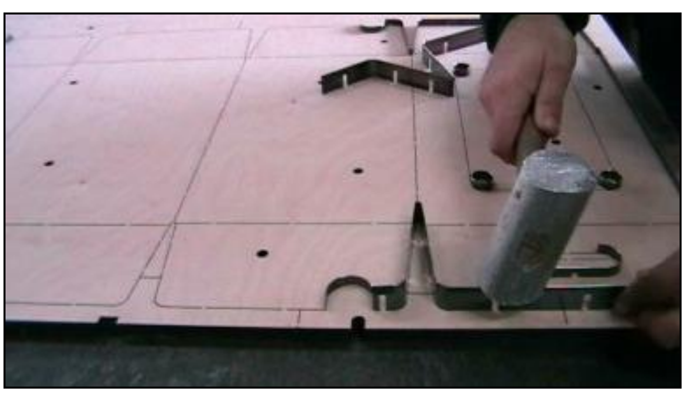
 

Automatic rule processor is a machine that automatically cuts, notches, bends, broaches and miters a broad range of rules. This is the machine most favorite to die makers. Rule preparations is the part of die making that takes many working hours and ever since this machine was developed, that time got a lot shorter.

Rule processor operates somewhat like other CNC machines presented so far. The image is also visible on the monitor, and the lines and commands can be chosen with a mouse or keyboard. Rule processor holds in him all the operations possible of doing like with the old methods. Except now you have one big machine instead of lots of small ones with even more dies for different angles, cuts and joints. But in order for the operation to be performed, the right command must be told. Operator marks the part of the design that he is making and tells the machine to fabricate it. Machine program recognizes the curves and operations required and it is up to the operator to select them. So even thou someone is a great computer expert, without knowing the ways of die making, he would be useless here. The machine fabricates parts of rules with all the necessary operations performed on them going from section to section, and in large companies it is operated by a person that only makes these parts. Even thou the machine can fabricate large sections at once, because of its greater precision and the fact that rules used in this machine come from a rule roll that has a great length, it is not advised, and generally not done for the reasons already explained (hard to place large sections, hard to replace).



Finished parts are then placed in the die-board already laser cut. These operations can even be performed simultaneously, since this are separated machines and sections from the rule processor can just be set aside while the board is being cut. Placing rules is done the same old way using rubber or aluminum hammer.



Rubbers can also be manufactured using CNC machines, but not with plotters or lasers. Plotters can't cut that deep and lasers would burn the rubber. This is done with another type of machines called water jets. Programs using the die design calculate the surface and shape of the rubber necessary for a certain section and give suggestion how it should look like. Operator chooses if he wants a section like that or not and cuts the peace out from a large rubber sheet.

CONCLUSIVE NOTES

Since the process of die cutting is infiltrated in all industries, as well as other aspects of the economy, many experts will be trying to design new die cutting presses for packaging manufacturers or tools adjusted to new materials that follow technological process, to achieve better results considering precision and speed of the process. The process of die cutting is finding wider application with time and new ideas.

This e-book has been intended for those interested in either making die cutting tools or packaging paper and paperboard die cutting, or designing patterns of packaging in small businesses.

Larger companies require special trained personnel since the automated machines cost a great deal of money, and inadequate operating could lead to damaging them. That's why CNC operators go thru special training, before working with them.

But even thou these technologies are new, even newer and better are yet to be invented. And handling new ways of die making can be really hard if you don't know the old ways and reasons why certain operations are done or not. There are things called "tricks of the trade" which computers can't teach you, only experience can. The methods of die making haven't changed, the means did.

GLOSSARY OF TERMS

ADHESION
The process of attaching objects with adhesive materials.

ASEPTIC PACKAGING
Sterilized containers made of plastic-lined paper (foil and plastic lamination).

Die Cutting and Die Making Guide

ADHESIVE, PRESSURE SENSITIVE
A type of adhesive which in dry form is aggressively tacky at room temperature. It has the capability of promoting a bond to dissimilar surfaces on contact, with pressure.

AIR HOLES
Air escape holes are often required in a die blade or at the back of the die to allow the built up air in a die cavity to escape during the die cutting process. If air holes are not provided the captured air in a die cavity can impede the die cutting action and hinder the ejection of the die cut piece from the die after the die cutting cycle. In clicker and high dies, the die maker will often grind several grooves in the back of the die to allow air to escape from the die. Also used on auto platen stripping & blanking dies.

BLANK
A folding carton after die-cutting and scoring but before folding and gluing.

BACK UP PLATE
A plate normally placed on the back of a die.

BRIDGING
the placement of notches in steel rule blade so that the blade can fit into its relative place in a die board which leaves an equal bridge of die board along the knifed path.

CALIPER POINTS
A measure of paper thickness expressed in units of a thousand of an inch and usually written in decimals.

CHIPBOARD
Recycled paperboard.

CHISEL
A die blade that creates a slice or tear cut in a die cut piece. It can be anywhere in a die configuration where a separation is needed or could be outside the die to help break away the web of material to relieve cutting pressure to aid in improved die cutting techniques.

CHOPPER KNIVES
Steel rule in a die to cut up scrap in smaller pieces.

COMBO DIE
A die layout consisting of more than one box design – multiple cartons of different types in a single layout.

CUTTING PRESSURE
This refers to the amount of pressure that a cutting press exerts in the downward stroke of the cutting press. The pressure is normally identified in tons of cutting pressure. Generally a common rule of thumb states that it takes about 500 pounds per lineal inch of blade to accomplish a clean die cut, but that figure varies according to the material being cut and other conditions.

DROP TEST
A mechanical procedure used to test the safety of package contents during shipping; determines the resistance of a filled box to shocks caused by dropping it in certain ways.

DIE SIDE
The view looking down on the sharp edges of the knife, also called the “inside view” in paperboard cartons.

EASELS
Supports attached to a box to hold it upright for display.

EMBOSSING
A process in which paper is pressed between metal dies to create an image in relief.

FLUTES
The wave shapes in the inner portion of corrugated fiberboard. The flute or corrugation categories A, B, C and E indicate flutes per linear foot.

GRAIN
The direction in which the fibers in paper line up.

INNER PACKAGING
Materials or parts used in supporting, positioning, or cushioning an item.

IN NICK
A nick or small “V” shape, half round shape or square shape, put into the edge of the die which cuts out a small section of the die cut piece. It is used as a location device to align various die cut sections for assembly.

KNOCK-OUT
A knock out is any device that knocks out the scrap from a cut out in a die.

LASER
A device that produces a very narrow beam of extremely intense light; used in industrial processes, medicine, and detailed die-cutting.

MATRIX (WASTE SELECTION)
The face material and adhesive surrounding a self-adhesive label, usually removed after die cutting.

PAPERBOARD (CARDBOARD)
A material made from laminated layers of paper in sheets of 12 points or more.

PULP
Basic cellulose fibers resulting from the disintegration of wood, rags and other organic materials by chemical or mechanical processes used to make boxboard.

PERFORATING RULE
A cutting rule that produces perforations in the material to be die cut The perforations can be an aid to better glue adherence in the folding and gluing process of folding cartons.

PNEUMATIC PRESS
An air operated cutting press.

POWER STRIPPERS
A pneumatic tool that pierces into a stack of die cut blanks to strip away the excess materials from the finished die cut parts.

Pt (POINT)
Derived typographic unit of American system based on inch (pt=0.0351mm)

PUNCH
There are a wide variety of cutting punches used in the die cutting process. Different types of punches are used in different types of cutting dies to cut out round holes, ovals, squares, rectangles and other shapes in a die cut piece.

REPEATABILITY
The ability of cutting a die to reproduce an exact duplicate cut part after each cutting action.

RE-RULING
Re-ruling refers to the re-knifing of a steel rule die to replace a dull or worn steel rule blade so that the die will be sharp again for continued effective use.

ROTARY DIE
A curved cutting die, used in a rotary die cutter. It can be constructed in several methods using curved steel rule blades more being machined by CNC or EDM methods from a solid cylinder blank. Flexible etched magnetic rotary dies are turned around a magnetic cylinder.

RUBBER EJECTION
Rubber used to eject the finished product from a cutting die.

RULE, PERFORATING
Steel rule die blades that make perforated cuts in the material being die cut.

SCORING RULE
Steel blade that leaves impression in blank without cutting – usually a fold line.

STATIC
Electrical charges generated in handling materials which cause materials to cling together. Can jump to humans or equipment causing shock or fire if solvents are present. With reference to films, causes them to cling to one another or to other insulating surfaces.

STROKE
The upward or downward action of stroke of a cutting press.

SET-UP PAPERBOX
A pepperbox or rigid construction that has been formed or set up and is ready for use.

ISBN 978-86-916807-0-1