Project Report on

Design and development of Arduino based 2D Wire Bending Machine

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[2021-22]

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'येथे बहुतांचे हित ।'

C E R T I F I C A T E

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have successfully completed the project-II entitled **“Design and development of Arduino based 2D Wire Bending Machine”** under my supervision, in the partial fulfillment of Bachelor of Engineering - Mechanical Engineering of Savitribai Phule Pune University.

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PROJECT COMPLETION LETTER

S. S. ENGINEERS

MANUFACTURER OF PRECISION MACHINED COMPONENTS & JOB WORKS

IN ISO 9001:2015 CERTIFIED COMPANY

PROJECT COMPLETION LETTER

This is to certify that, development of special purpose machine is successfully carried out for us by students enlisted below. They have designed and manufactured the machine which is working as per desired expectations. Development cost and infrastructure required for the project has been provided by S. S. Engineers.

Project Title: Design and development of Arduino based 2D wire bending machine

Start Date: 05-07-2021

Actual Manufacturing Date: 25-12-2021

Completion Date: 15-04-2022

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ABSTRACT

The use of a bending machine acquired a high level of importance because of increasing the level of the industry. This project aims to develop a more accurate and precise bending machine. The proposed bending machine has achieved brilliant output products, in which three main manufacturing parameters have been examined to produce an equilateral triangle, bending angle and bending radius. The main point depends on the proposed algorithm, which has been developed based on separating the process, in which the central controller is responsible mainly for controlling the sub-controller, it is programmed using Arduino IDE to control the entire mechanism of feeding and bending separately and ensure that the outcomes of these mechanisms are compatible with the input data from the central controller.

Keywords: Feeder, Bender, Proximity Sensor, Limit Switch, Arduino NANO, Machine Controller, Arduino IDE, Easy EDA

INTRODUCTION

In different sectors of industries and medical fields, automated machines spread widely nowadays. In several countries, automation has been used in agriculture in a way that has made life easier for millions of people around the world by combining production machinery with control systems. The industries are still considered to be seriously, more expensively and erroneously manufacturing complex engineering products with hand machines, though incorporating automation has made them simpler and more economically effective. However, challenges in the global economy and the industrial section developments exacerbated as a result of a lack in the automated wire bending machine industry. It has proven that the use of bending machines is necessary to include during a linear or rotating movement with different industrial processes. For regular operation, the automated bending systems required precise control loop tuning with an excellent dynamic response to simplify commissioning and avoid control errors. Therefore, this project devoted is important in the process of bending machine in the forming and reforming industries nowadays.

Fig 1.1 Manual wire bending process by hand.

All of these urges a deeper research and development of the equipment and processing which is used to bend the wires. At present, the advanced equipment for wire forming in India is mainly imported from the technology developed countries such as Germany, France and Japan. While most customers give up this way due to the fancy price and inconvenience of maintaining. Currently, Some Indian manufacturers have also created such equipment, but they all did not invest in improvements in these fields about the quality, the efficiency and the level of maintenance.

Fig 1.2 Manual wire bending process by hand.

At the same time, the high manufacturing cost makes it lack of market competition. The common Automatic wire-bending machine includes storing mechanism, straightening mechanism, cutting mechanism, feeding mechanism, bending mechanism, etc. But we don’t have equipment with a higher integration and automatic production lines with high and production efficiency at present. The specific reasons are as follows.

Firstly, the traditional bending mechanism uses single head to bend, but the production efficiency is slow. Currently, there is some bending mechanism with doubleheads in the market. But it cannot achieve asymmetric bending, meanwhile, its efficiency is low and maintenance is inconvenient.

Secondly, the wire-bending machine needs to be equipped with the clamping mechanism which is used to clamp and whirl the wire. However, the existing clamping mechanism is complicated, results in difficult maintenance, unstable powertrain, and lower rotational accuracy. Finally, in the process of the mechanism which is used to feed the wire, the wire will be pushed, or the tension will be building up when the feeding speed is different from the receiving speed of the processing equipment. In this situation, the mechanism which is unable to reset by itself needs to be adjusted manually. This way not only reduces the production efficiency, but also increases the labor costs. In order to solve above problems, the research is based on the wire-bending process to develop a wire-bending machine which is used to bend the wire to any angle. It is a fully automatic machine with storing, straightening, cutting, and feeding and wire-bending mechanism to improve the integration, automation and precision.

1.1 History and Development

The need for a reliable automated bending machine in the industrial sectors is still rising, it did not reach the required precision for the use of bending and cutting operations. However, some traditional bending mechanism tried to implement the machine with more accurate and precise measurement. Some applications attempted to overcome the problem of machine efficiency and accuracy. Presently, not many researchers have paid attention to higher integration and automatic bending production with the computer aided technologies. The growing scope for AI and ML can prepare the complex design to solve the complex problems and these complex designs require the advanced manufacturing machines. We are heading towards Industry 4.0 and Information technology driven world where the human up skilling is imperative in modern era industries. India can increase its exports under Make in India initiative and grab the world markets as swift manufacturing processes are available.

2D wire forming or wire bending is an advanced technique used to manipulate metal wire into standard or customized shapes for the manufacturing of products. Consisting of various shapes and sizes, wire forms are fabricated with machines through heat treatment, cutting and bending. 2D wire forming machines operate by using standardized tooling to alter the shape of the wire in size and dimension to create complex two-dimensional and three-dimensional parts.

Wire forming in general is instrumental in several industries automotive, aerospace, construction, military, medical, commercial, and electrical sectors to name a few. Wire forms are fabricated from a variety of materials, including steel, stainless steel, copper, aluminum, and a number of alloys. 2D wire forming offers benefits such as custom design, less setup time, reduced development time for introducing new or modified product parts into the market, and lower per-piece costs even in small to medium size production runs.

PROBLEM STATEMENT

2.1 Statement

- To Design and to develop wire bender and feeder for 2D wire bending machine considering following requirements.
- Type of material: - High bounce MS wire.
- Wire Diameter: - 1.5mm – 5mm.
- Bending Angle- 0-270 degrees.
- Feeding rate- 1.8mm in 1 RPM
- Maximum Bending Moment- 150 NM

2.2. Objectives:

- The aim of the present project is to Design, and develop an Arduino based 2D Wire Bending Machine which is controlled by Arduino and used to manipulate metal wire into standard or customized shapes for the manufacturing of products in cost efficient way.
  To achieve this aim, we need to implement the following tasks:
- To design a bending machine used in different wire bending processes.
- To select the cost feasible components.
- To develop an algorithm, which is utilized with the bending machine and produces more accurate and precise products.
- To verify the accuracy and precision of products.
- To make the bending process automated and less complex with sufficient efficiencies.

2.3 Methodology-

Once the topic was selected and problem definition was cleared, we started searching for the research papers online. We found many works which is done on this topic. After reviewing those research paper and market surveys we found 2 major problems related to the wire bending machine.

First problem was till recently wire bending operation is perform manually which creates too many errors as it is done by the human operators and the accuracy and efficiency is too low as manual wire bending has a huge tendency to create errors. Also, it parallelly increases treatment time.

Second problem was there are machines available for bending the wire, but they are too expensive to afford. Small scale workshops cannot afford these high-tech machine as it will also increase their maintenance cost and they will have to hire skilled operators to operate those machines.

After Reviewing all the details, we decided to manufacture compact site 2D wire bending Machine whose main objective will be to increase production with high efficiency and high accuracy at Low cost. To make our project Reality we started by designing the model on CATIA V5 software which is a best software in his field. After designing, we now knew how our project was going to look like. We procured the OEM parts easily available in market such as gears, and algorithm is designed as per the requirements compatibility.

To make the 2D wire bending special purpose machine the following steps were taken under consideration

- Problem Definition.
- Study on Related Research Paper.
- Analysis of Research Paper.
- Industrial Survey.
- Project planner.
- Testing and Verification.
- Design and Drafting of CAD Model.
- Manufacturing.
- Procurement of OEM parts.
- Introducing automation.
- Assembly
- Concluding Remarks and Submission

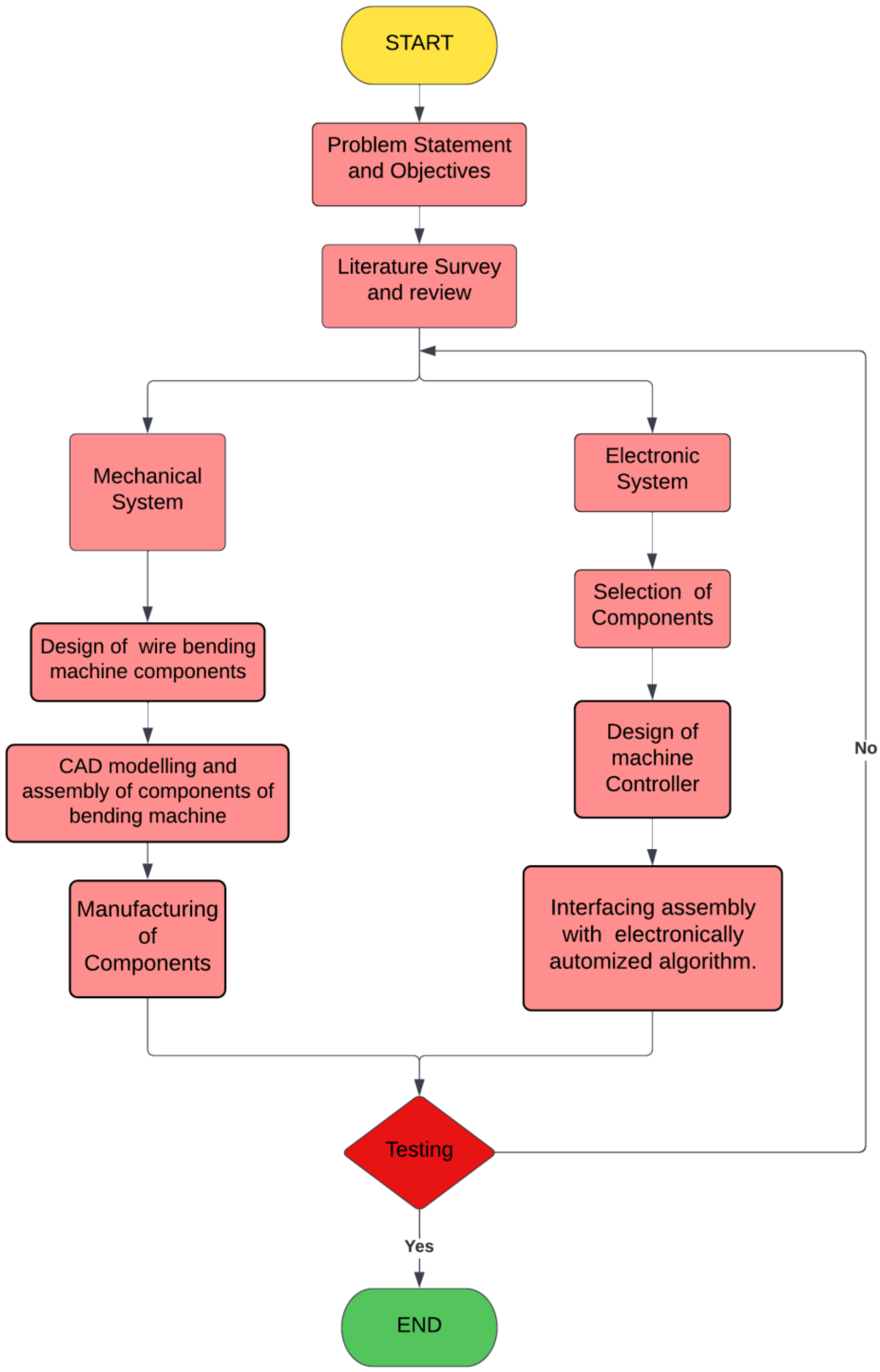


Fig 2.1 Process Flowchart.

2.4 Scope

Wire forming is vital in the production of numerous components for countless applications. 2D manipulation of wire forms provides an extensive range of products motor mounts, wire baskets, power transmission applications, pins, clips, springs, wire screens, grills, coils, guide wires, The agricultural industry uses computer numerical control bending machines for the production of accessories for vineyards, agricultural springs, soil anchors wire-stents, tubes, carts and filters.

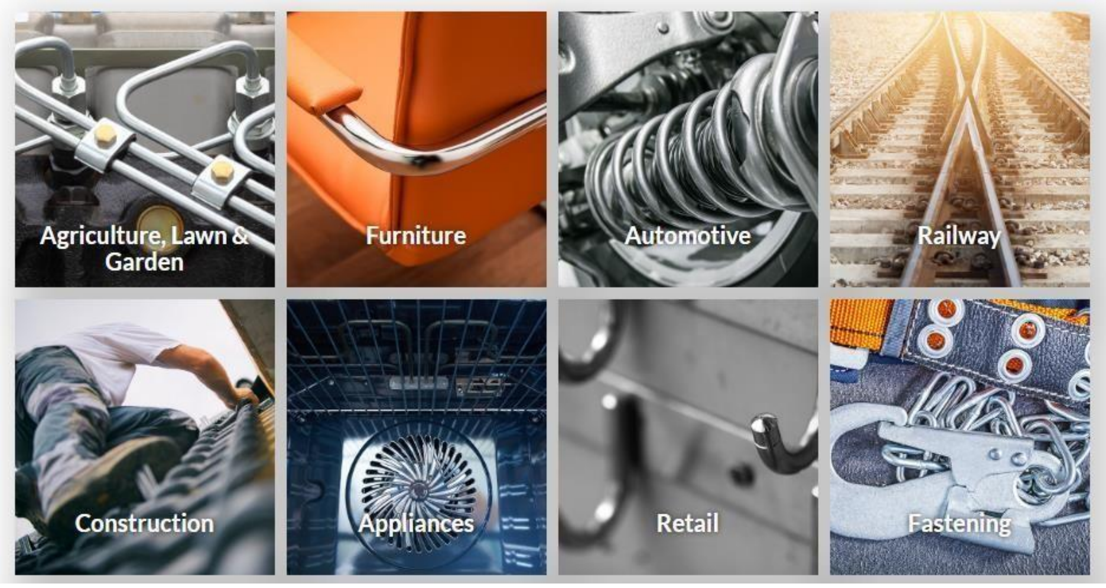


Fig 2.2 Applications

The agricultural industry uses computer numerical control bending machines to produce accessories for vineyards, agricultural springs, soil anchors, tractor parts, etc. Vase holders and levers for lawn mowers are some of the most produced items for the gardening industry. 2D bending machines meet the demands of the furniture industry

Fig 2.3 Applications

thanks to the production of chair frames, details for lamps, decoration accessories, etc. Industries like the automotive use 2D wire forming in suspension applications compression coil spring and volute spring. 2D wire forming is used to manufacture products used in sterilization procedures and standard components like metal baskets for washing equipment. Other healthcare products range from simple gauged tray to hand-held pliers. Electronic and electrical fittings are produced through 2D wire forms. Household products from mouse traps to screen doors to clothes hangers are made from wire forms. The list goes on in commercial and retail, construction and hardware, aerospace, energy and agriculture, all sectors rely on 2D wire forming in the production and manufacture of products vital to their industries.

LITERATURE SURVEY

3.1 Present Research and contemporary developments

- **FaizF. Mustafa(2020) [1]** –This research have been concisely summarized asfollows:

  1. Design and development of wire bending machine have been achieved successfully, in which the machine is able to create any frame shapes such as hexagonal, recant angular and circular frames depending on the set point of the structure. This machine has been practiced to implement an equilateral triangle using a wire with a 1.2 mm diameter made from mild carbon.

  2. Development of the algorithm programmed with this machine has proven that this algorithm is necessary for obtaining accurate products. The product accuracy has improved, the parameters of bending angle and bending radius witnessed an increase in its accuracy with respect to error rate from the standard measurements.

  3. The precision of the product shows a high record, in which the proposed algorithm has helped to decrease the error rate in each parameter for all industrial operations. The overall accuracy has improved to be 98.85228 % after carrying out the proposed algorithm if compared with other machines that do not use the proposed algorithm.

- **Dr. Amol Kakde (2020) [2]-** The most important outcomes of studied research have been concisely summarized as follows:

  1. The present methods for bending rod, pipe and metal strips are of great significant for modern job order type production workshops. The situation where the workshop owner can't afford different machines for such workshops it is viable option.

  2. "Automatic Bending Machine" is affordable to them at optimum cost and it will able to bend both rod as well as pipe. It also helps to reduce shop floor area as it can assemble and dismantle easily whenever required.

  3. After observing the results obtained from machine study, we are able to know that how to reduce the cost significantly.

  4. This machine also has the advantages of less cost, multi functioning, easy assembly and dismantling according to need, optimum accuracy, easy to use, no slipping action of pipe etc. in short this is very useful for small scale workshops having less investment.

- **Tawanda Mushiri (2017) [3]-**
  1. The rod to be bent is placed in between the two Jigs mounted on the circular plate. The motor is attached with the circular plate. The power from the motor is transferred which rotates the circular plate in anticlockwise direction.one Jig is connected to the motor and the other Jig is rotated due to the rotation of circular plate. Since the rod is kept in between the two Jigs, the rod would bend.

  2. Problems associated with the bending machines
     a. They huge hence not portable, they cannot be moved from one place to another once mounted. So, we need to design the most possible compact framework.
     b. They are operation specific each type has a specific type of operation it achieves for instance, having two machines, one which can bend solid

rods and the other one which can feed the beams. So minimum number of components cannot be minimized or multifunctionality is challenging to achieve.

- **Han, G. (2010) [4]-**
  Design and research of the rotary head numerical control bending wire machine. Xi'an University of Architecture and Technology.

- **Liu, L. (2011) [5]-**
  The design and implementation of 2D system for the 5/12 automatic steel bending hoop machine (Master dissertation). Yanshan University.

- **Lu, C. (2013) [5]-**
  Research and design of key mechanical structure of the 3d numerical control bending wire machine

- **Marcus Paech (2008) [6],** "Advanced semi-automatic straightening technology"**-**
  1. In 2008, he describes the power requirements for the process material deformation process based on the working principle and the main characteristics of the straightening process. A simulation program is available to support the assessment of the power requirements. Simulation in turn is based on a theoretical model of alternate elastic/plastic deformation and the relationship between bending moment and curvature during bending operations. This article describes advanced semi-automatic straightening technology. Advanced straightening technology uses process simulation to determine optimal spacing and maximum straightening range. shows the geometric factor like roll diameter, wire diameter, spacing between rolls etc. affecting on the position of straightening rolls. Hence we extensively used the CAD software like CATIA V5 and ANSYS to ensure the space constraints, strength and failure analysis.

2. Optimization of spacing is based on the level of finished product quality that the customer wants as well as the material characteristics. Advanced straightening technology features a modular design, minimal component count, a user-friendly Human Machine Interface and the availability of process and setup data prior to the start of the process. So, to make the machine cost efficient and minimally complex we are for time being skipping the straightening mechanism.

- **Marcus Paech (2001) [7],** “Roller straightening process and peripherals”-
  1. He uses the principles of pneumatics as working mechanisms but due to higher compression ratio required to achieve desired force the energy requirement is also. We calculated that using pneumatics would be redundant for our design objectives.

- **A.S.Patel (2011) [11]-**
  1. The present article has been authored with the intention of focusing on the latest advances and to highlight the opportunities provided by the implementation of innovation in wire straightening cutting machine.
  2. Straightness of wire is depending on various parameters such as wire diameter, die spacing and helix angle, material properties (like tensile strength, yield strength, geometry etc...).
  3. Below 3.15 mm wire diameter for Mild steel, rotary Arbor straightening method and stopper cutting off mechanism are used. Additionally, the reviewed approaches, which are attempted in the context of the present paper, may lead to some valuable conclusions as stopper less flying shear method is to be adopted to innovate the machine. More over simulation between the flying shear and straightening method is made for implementation of this machine in industry successfully.

- **M. Nastran, K. Kuzman [12]** –

  This research describes influencing of the material properties of the wire to allow stabilization for bending or straightening process. As per paper, experimental work proves that it is possible to change the yield strength of the wire by an appropriate pre-setting of the filler in the roller straightener. It also describes numerical analysis of straightening process. This work obtained results are used for developing a numerical system capable of defining the inter meshing of the roller so that the yield strength of the material is optimally constant. So, we arrived at conclusion to use the HSS and ONHS materials for critical components.

- **Amirul Farhan B Mohd Salih, (2010) [8]-Existing bending machines**

  1. **Press brake bending machine**

     Press brake bending machine use die and punch to bend a sheet metal. The die and punch of the bending machine have a variety of shape. Some of the common press brakes bending operations are bottoming, coining, air-bend, etc. Press brake bending machine is a machine that use air pressure to operate the bending machine. In addition, the Press brake bending machine comes with big size and use a lot of space. And in this design, there is possibility of cracks.

  2. **Roll bending machine**

     A roll bending machine uses roller to bend a metal. The roller of bending machine can be two rollers, three rollers, or four rollers. The common product of roll bending machine are tube bending, plate bending and a coil. All modern roll bending machine are power driven and some of the bending machine equipment with electronic controller. So, we decided to assembly and code the controller

- **C. Anbumeenakshi (2018) [9]**–

Investigated about Design and Fabrication of Multi-rod Bending Machine. The multi rod bending machine is an electrohydraulic unit, where the electrical power supply causes the motor to run, and the hydraulic power pack provides the necessary force that is required to bend the rods. But due to leakage complications we arrived at conclusion to select electrical motor drive to power the bending process.

- **P.N.Awachat (2015) [10]**–

Investigated about Design and Analysis of Re-Bar Bending Machine. For portable machine, they are making rebar bending machine works on motor and microprocessor, which eliminates the need of storage tank or compressor.

- **Thokale Manoj (2017) [13]**–

They have worked on Design and fabrication of pneumatic bar bending machine. But we yet select the motor drives to reduce the cost factor.

DESIGN OF MACHINE

4.1 Mechanical part

The second important part named as a mechanical part, in which five parts are accomplished together to complete the bending process is represented as follows.

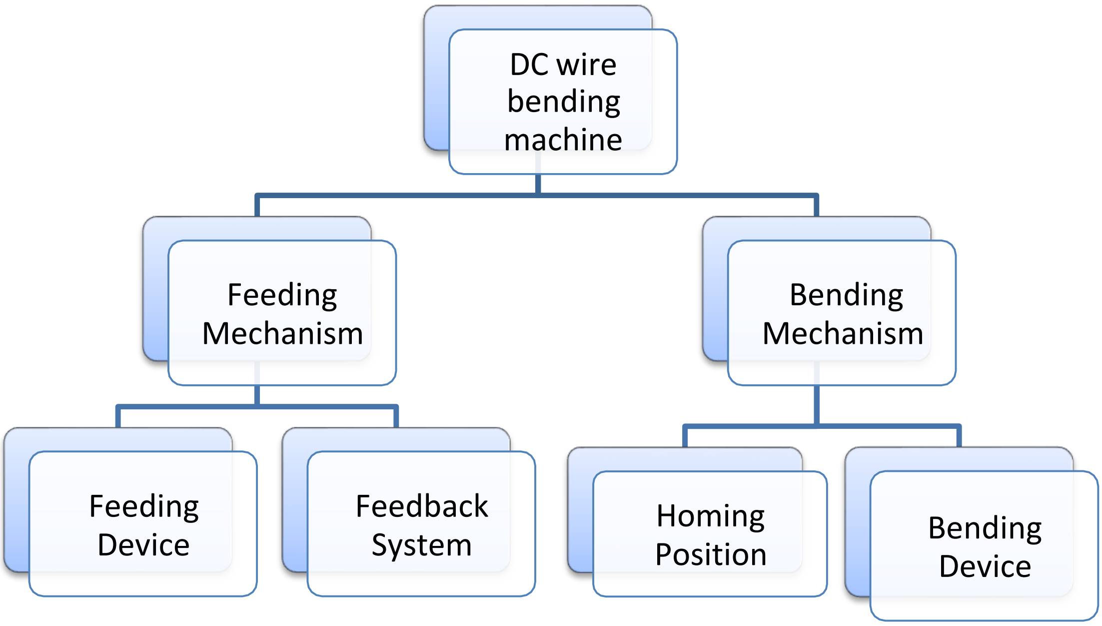


Fig. 4.1 Mechanisms Distribution.

4.1.1 Wire feeding mechanism

The central part of the wire feeding mechanism consists of a cylinder and pulley. It is responsible for the wire feeding for the machine. The cylinder has a rough surface to prevent the wire from slipping during the feeding process. This cylinder is mounted on a gearbox coupled DC motor. At the same time, the pulley rotates around the fixture via ball bearing. In contrast, the pulley freely rotates around the installation via ball bearing. The function of the pulley fixture is to push the wire against a cylinder to prevent slipping, using a strong spring. The pulley surface has a groove to prevent the cable from escaping out vertically during feeding. The function of the feeding device is to push wire to bending mechanism. The value of torque at roller after reduction is 9.4 N-m as reduction ratio is 2 and the diameter of the pinch roller is 60 mm. According to calculation, the design information can be achieved: Torque: M=9.4 N-m, Revolving speed max: n=19.1 n/min, we can adjust the speed by controller and get the required distance travelled by wire. The pushing power of each wheel: FS=150 N. Therefore, the stepper motor whose rated current is 24.0 A is the best choice and hold the torque at 4.7 N-m.

Fig 4.2 Wire Feeding Mechanism (Front View)

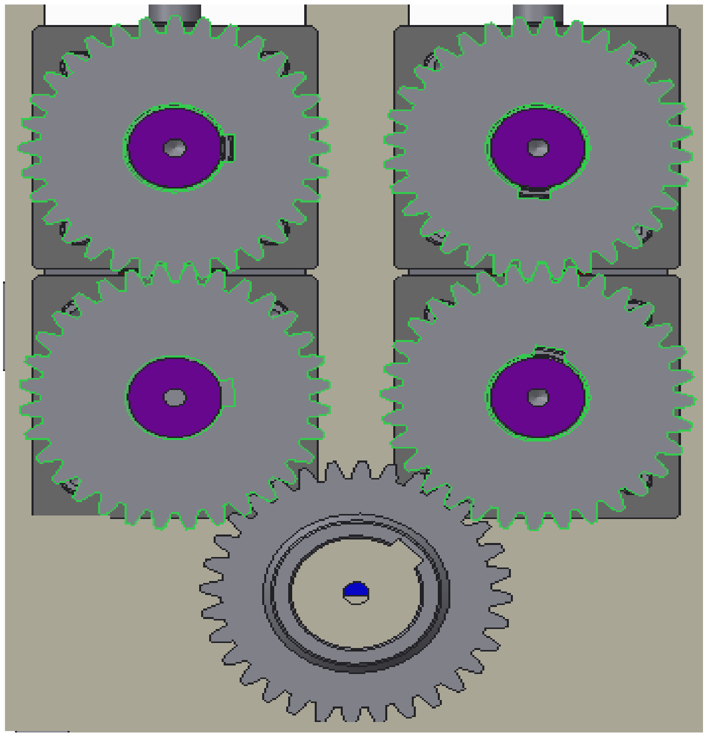


Fig. 4.3 Feeding Mechanism (Back View)

It has 2 gears connected to each other. Where in the main feed gear is connected to gear box output shaft. The connections are made such that two gears rotate in one direction and the other two in opposite direction, so that Feed rollers connected to the other end of shaft are able to pinch wire and feed it in the desired direction. Wire is guided throughout its path in a wire guide made especially for each section type of wire, this is done so that the wire does not repel back or divert from its path up to its forming station.

4.1.2 Wire bending mechanism

Bending machine is defined as a machine that is able to bend single pieces as well as small batches with the same precision and efficiency as series-produced parts. A group of combined parts which integrates for the reason of the bending process. The work piece consisting of a metal wire [1] is fed through the split die [2] adapted with bending pins suited for the bending shapes. The rotary bending tool [3] bends the wire around the die resulting in plastic deformation. Then, the wire is moved up to the next bending position. The entire bending anvil [4] can be rotated about the wire axis, and thus enabling bending in all directions. Finished part is released by cutting the wire in the desired location. Many bending machines can switch between different sets of bending tools to be able to vary the bending radius or allow other complex bends.

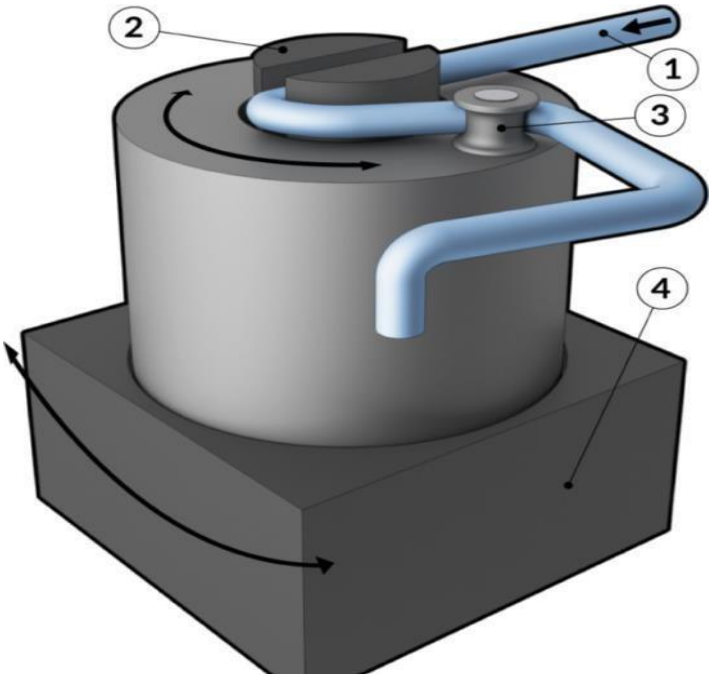


Fig. 4.4 Wire bending mechanism

4.2 Calculations

Motor Torque for bending of Following wire Specification

Given:

Table 4.1 Wire Specifications

Wire specification	
Material	**HB (High Bounce) MS Wire**
Diameter	**2-5mm**
UTS	**450 N/mm2**
Yield Stress (Syt)	**415 N/mm2**

- M= bending moment
- I=Moment of inertia of the area of cross section.
- σ=Bending stress
- y=distance of extreme end from the neutral axis
- E=Young's modulus
- R=radius of curvature.

Syt = 415 Mpa

$$I = \frac{\pi D^4}{64}$$

$$= \frac{3.14 \times 4^4}{64}$$

= 12.56mm^3

$$\sigma = \frac{MY}{I}$$

$$M = \frac{\sigma \times I}{Y}$$

$$Y = D/2 = 2mm$$

$$M = \frac{415 \times 12.56}{2}$$

$$= 2606.2 \text{ N-mm}$$

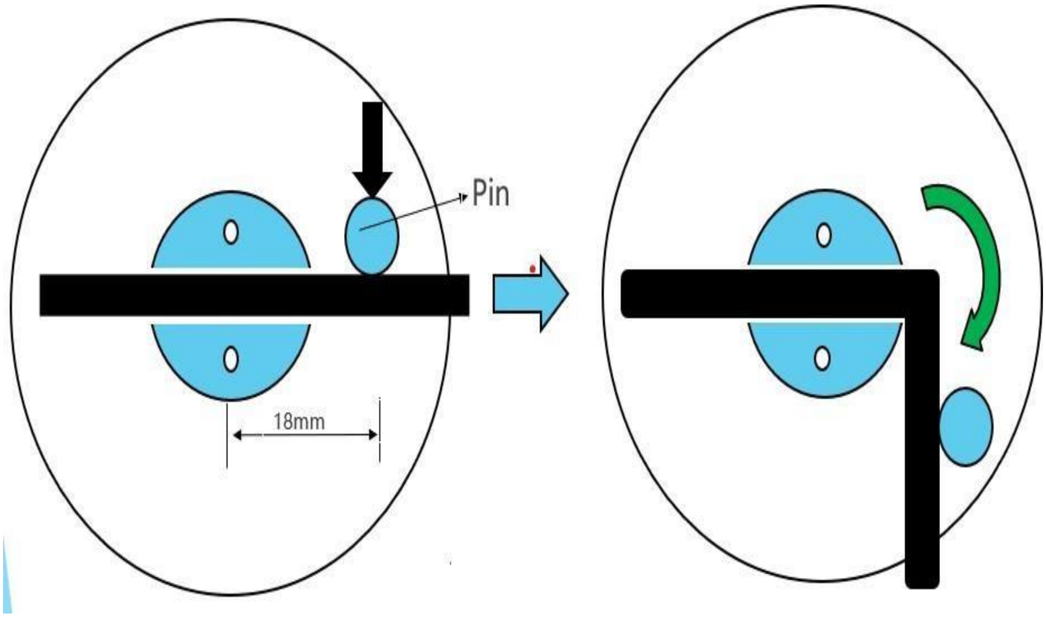


Fig.4.5 Free Body Diagram

It is same as cantilever beam

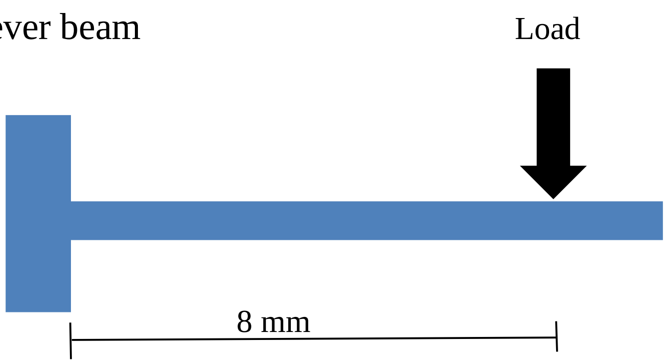


Fig.4.6 Free Body Diagram

Force required to bend the wire= Moment (m)/Distance of pin

= 2606.2/8 mm

= 325.775N

Torque required to bend the wire = Force X distance of the bender from center

= 352.775 x 18 mm

= 5863.95 N-mm

To deform the wire, we need to manifest the stress more than yield stress.

Critical Point in bending operation

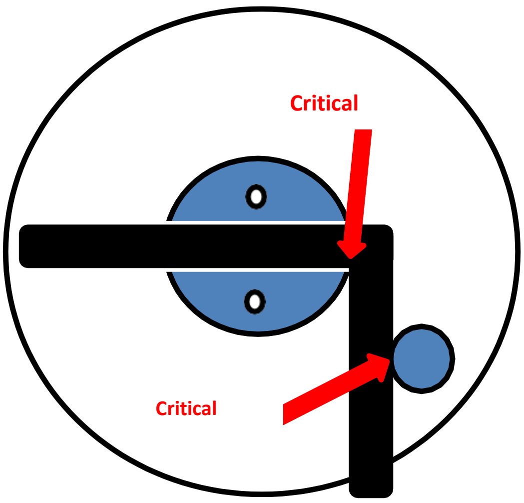


Fig 4.7 Critical Point in bending operation

Critical Points in bending operation:-

a. Split Die b. Bending Pin

Syt of bending pin=1000MPa (HSS)

Syt of split die=10Pa00M (HSS)

Syt of wire= 415MPa (MS HB)

Stress in Wire < Yield Strength of split die and bending pin.

Factor of Safety (FOS) =1000/415=2.40

The critical component of the machine is bending pin and split die is durable with FOS is **2.40.**

Motor torque = **87 kgcm = 8.531 N-m**

Reduction ratio:

$$Gear\ Ratio = \frac{Torque_{out}}{Torque_{in}} = \frac{Teeth_{gear}}{Teeth_{\ pinion}}$$

$$Teeth_{gear} = 50 \qquad Teeth_{\ pinion} = 14$$

$$Torque_{out} = \frac{8.531 \times 50}{14} = 30.467\text{Nm}$$

As, 30.46 Nm > 5.86 Nm

Maximum Torque of Motor > Torque required to bend wire

The setup and motor selected are compatible with each other and capable enough to bend the wire with required angle of bending and bend of radius also we can machine the materials stronger than taken examples by controlling the motor torque with the help of motor driver.

Feeding Mechanism: -

Roller Diameter = D

Circumference of Roller = ∏ D

Total Feeding Length of Wire in 1 Revolution of Roller = Circumference of Roller

= ∏ D

=3.14*60mm

= 188.5mm

Therefore, 188.5 mm of wire is being rolled in 1 revolution.

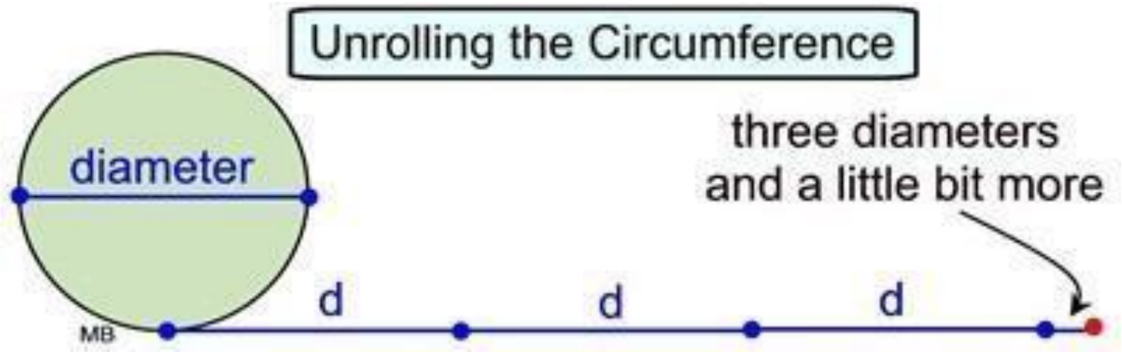
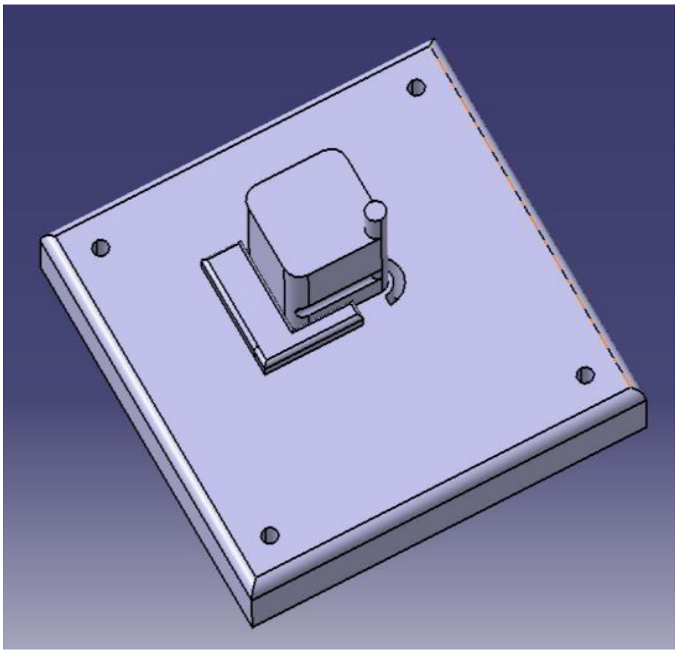


Fig 4.8 Circumference of roller

4.3 CAD Modelling and Assembly



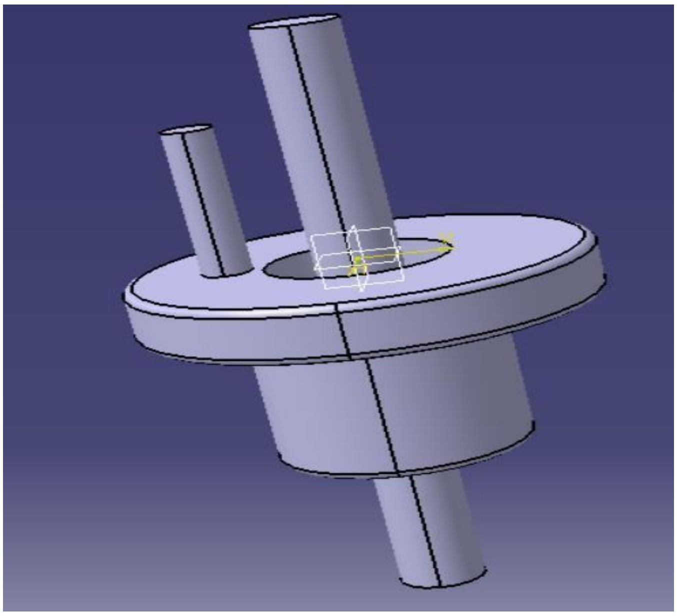


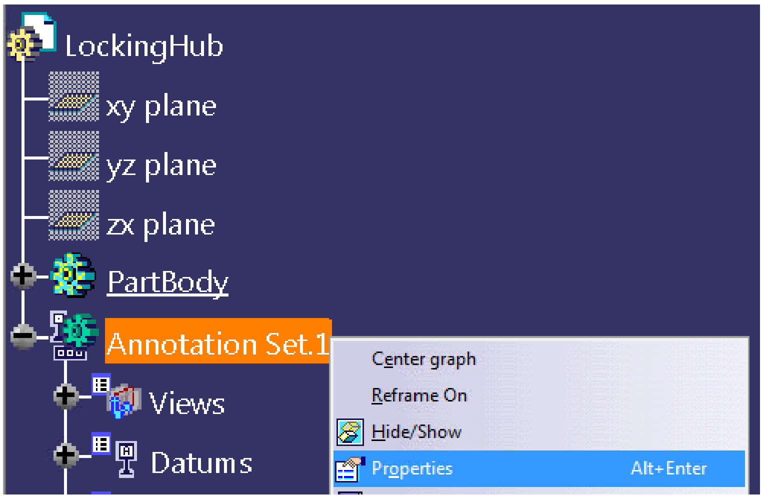
Fig. 4.9 Prototype CAD model of bending mechanism

CATIA V5:

We have got a model displaying dimensions, tolerances, notes, and annotations in 3D, it can be used to create a 2D drawing view with the same information. (More information on creating these 3D annotations can be found in the CATIA V5.

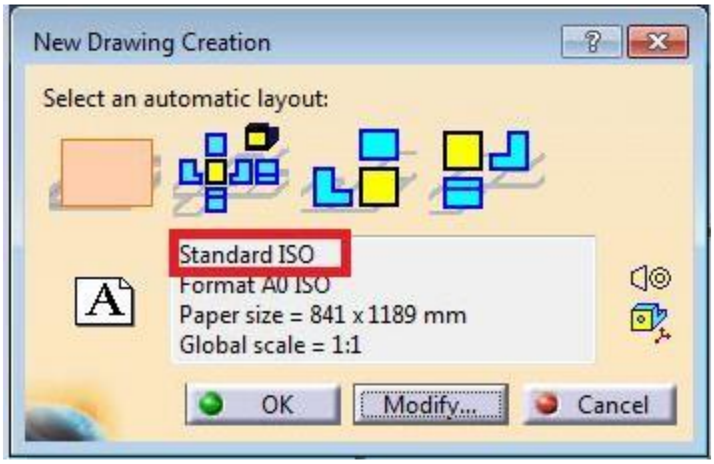
Setup

Now, to get this information into a 2D drawing, you'll want to create a new drawing using the same standard as the 3D data. To check the 3D annotation's standard, find the Annotation branch of the tree and give it a right click.

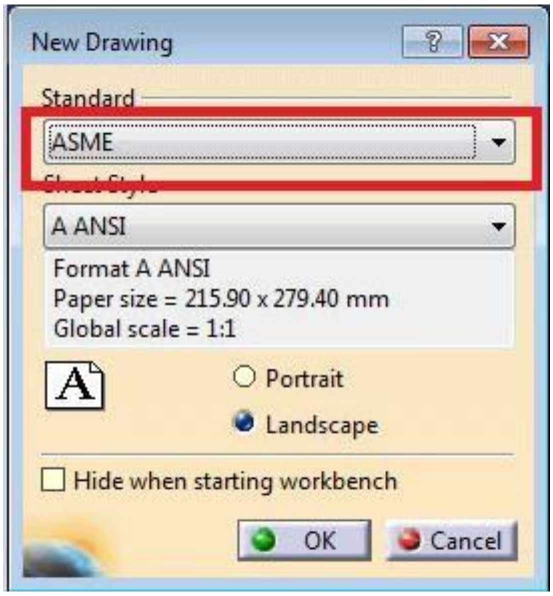


Pick Properties and in the new menu and head to the Standard tab. Take a peek at the current standard. In this case, it's set to ASME. So, the drawing must also use the ASME standard.

Next step: Head to Start > Mechanical Design Drafting (or File > New and choose Drawing).



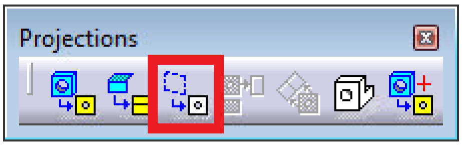
Check the default drawing standard. If it's different, click the Modify button to change it. Currently, the standard is set to ISO, so it will need to be set to ASME to match the 3D model in our previous screenshot.



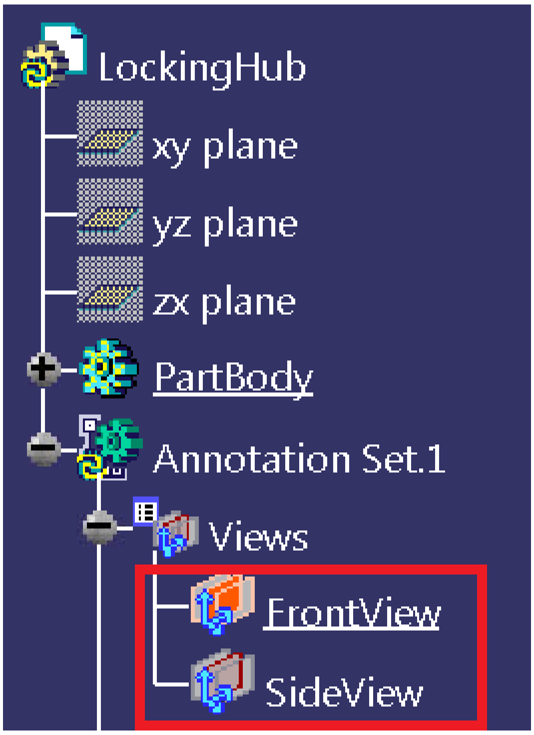
Press OK and create the new drawing.

Creating the View

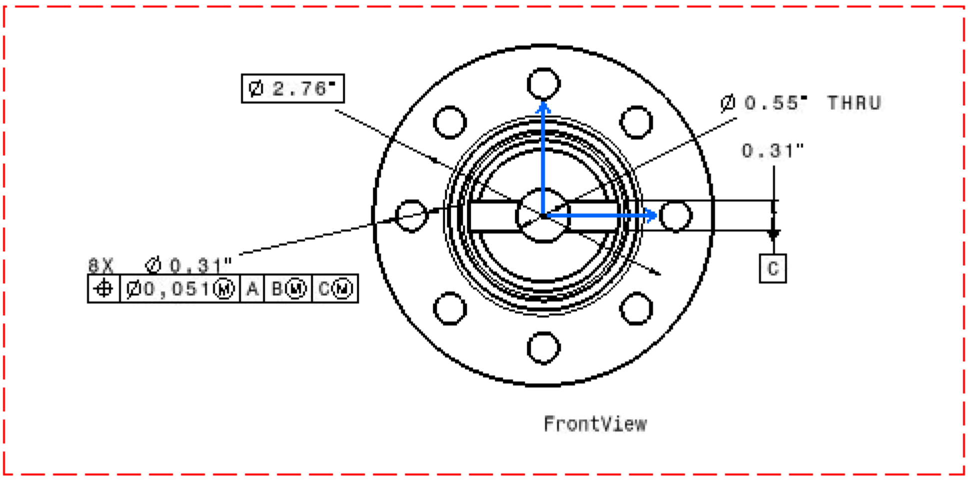
In the 2D drawing, click View from 3D in the Projections toolbar.



Swap back to the 3D model, then pick a View from the tree.



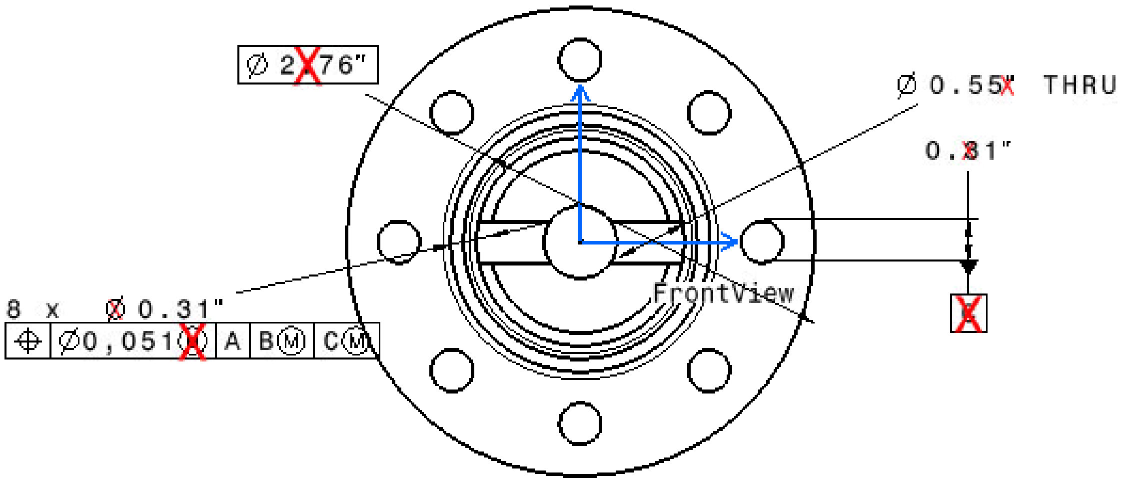
Click anywhere in the background of the drawing and enjoy your new view!



Repeat the process as needed for any additional views.

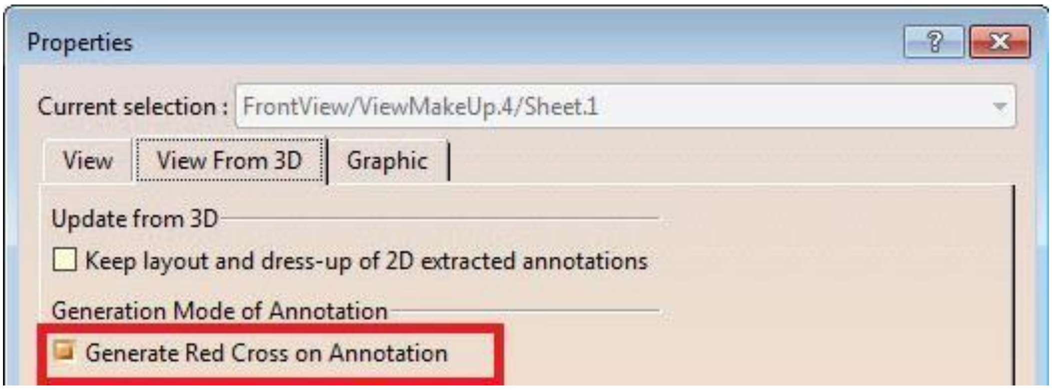
Tidying Up

On occasion, when create 2D drawings from 3D parts, red Xs will appear on the dimensions. This typically indicates that the drawing dimensions point to an item that's hidden in the 3D model.

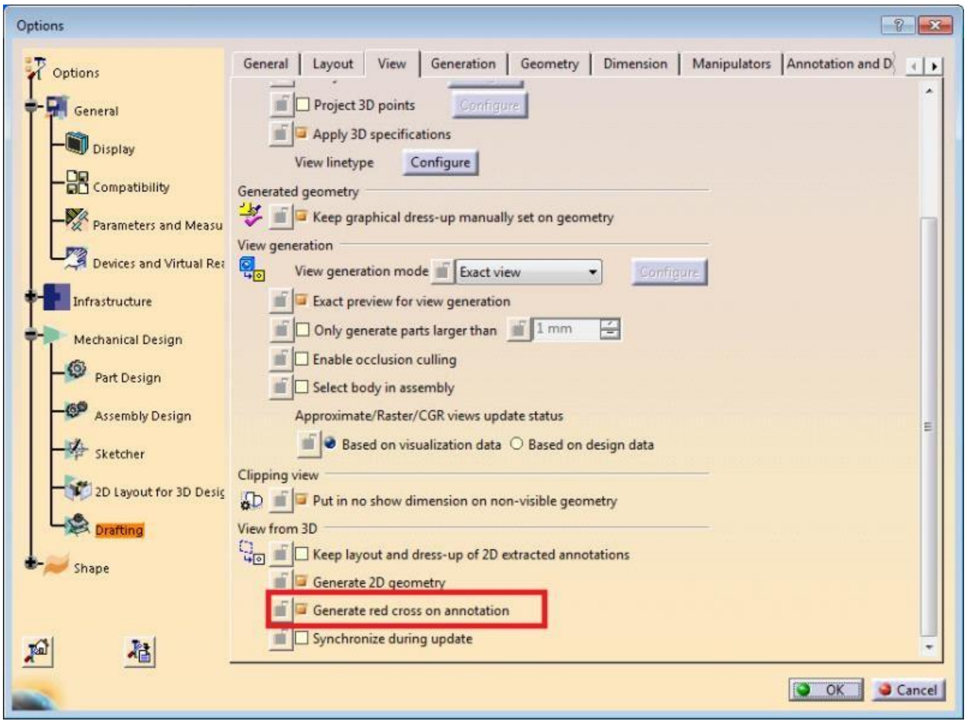


There are two main ways to remove these Xs:

Right-click the offending view (or views) and choose Properties. In the View from 3D tab, turn off Generate Red Cross on Annotation.



2. To disable the red Xs entirely, go to Tools > Options > Mechanical Design > Drafting > View and turn off the Generate red cross on annotation option from here.



If any additional drawing views are needed, they can be added to the drawing as usual in the Drafting workbench. (Information on creating other drawing views is available in the CATIA V5: Generative Drafting class.)

Building views in this manner can be useful to bridge the gap between the 3D and 2D world. Rather than rebuilding the same information twice, build it once in 3D and then reuse that info for the 2D drawing.

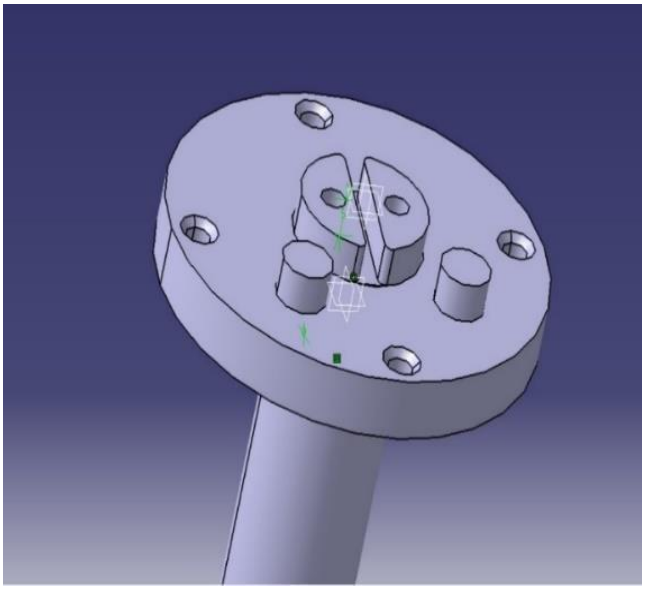


Fig. 4.10 Final CAD model of bending mechanism

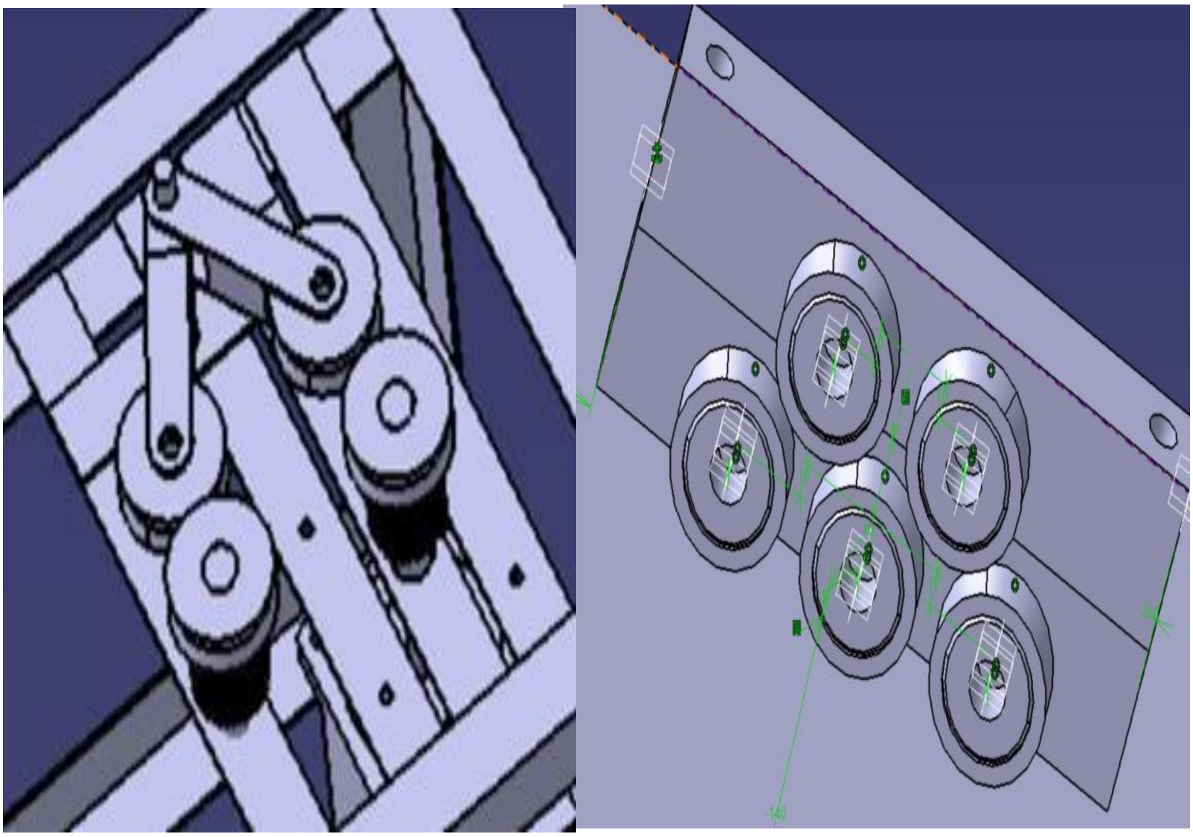


Fig 4.11 Prototype CAD model of feeding mechanism

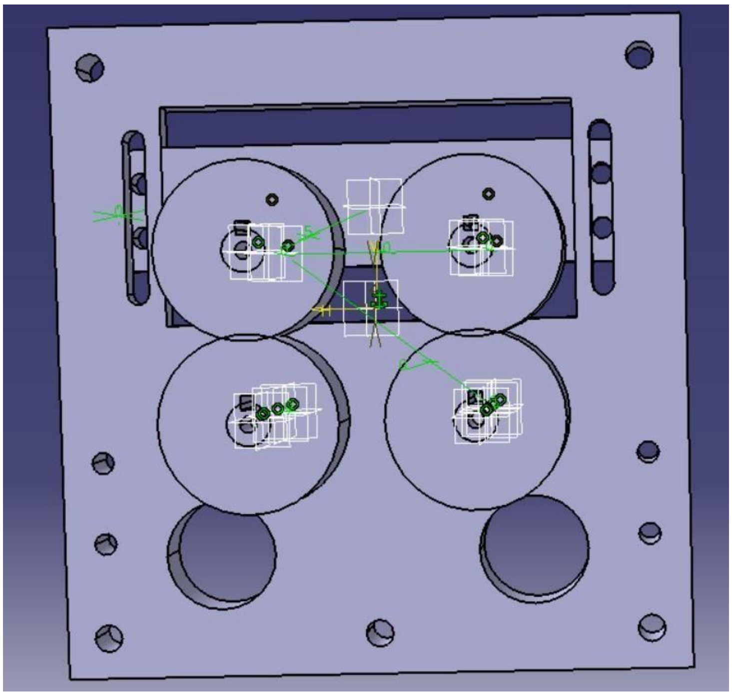


Fig 4.12 Final CAD model of feeding mechanism

Assembly Procedure:

When building a CATIA assembly with joints and/or constraints, there are a few key rules to keep in mind.
Rules for Building an Assembly

1. Know which assembly or sub-assembly to build in.

a. Parts that need specific measurement control.

b. Parts that make up a sub-assembly need

to be controlled/constrained within that sub-assembly

2. Know which constraints or joints to use.
a. Constraints are basic restrictions for 3D geometry.

b. Joints apply the same restrictions for 3D geometry, but also add kinematic parameters to show the motion of the part.

3. When building an assembly, first apply the constraint to the moving part and then to the fixed or non-moving part.

4. Turn off automatic update; this will stop the constraints, measures, and parts from automatically updating.

a. This also allows manual updates to the assembly, which will allow more control while building the assembly.

When no sub-assemblies are present:

If the assembly structure has multiple parts but no sub-assemblies, apply a Fixed Constraint to the part that is not intended to move. Then apply other constraints from the moving part(s) to the fixed part. The fixed constraint is just to ensure the primary part remains stationary.

When Multiple Sub-Assemblies are Present:

If the assembly has multiple sub-assemblies, first apply constraints to the parts under the sub-assembly.

Note that a Fixed Constraint can be used in the sub-assembly to ensure the parts won't move in different or multiple directions. TheFixed Constraint will not affect the

upper-level assemblies. Make sure to activate the sub-assembly to apply constraints, as CATIA will not automatically apply the constraints to the sub-assembly.

Updating the Assembly

Whenever constraints are being applied, the user can "build" the assembly by using Update All. This will verify that the direction is correct, or if the constraint is correct for the scenario. Then use the Undo button to undo the constraint on the part(s).

Rigid Assembly (default):

A rigid product (CATIA default) is an assembly of parts that, in terms of building the assembly with constraints, will use the assembly as a whole. If the sub-assembly has constraints, those constraints will act as normal but the upper-level constraints will apply to the entire sub-assembly.

Flexible Assembly:

A flexible product is an assembly of parts that, in terms of building the assembly with constraints, will use the individual parts under the sub-assembly. Parts under a flexible assembly still require constraints to be built under the required sub-assembly.

If the sub-assembly has constraints, those constraints will act as normal but the upper level constraints will apply to the individual parts and build accordingly with Degrees of Freedom. To switch the product from a rigid assembly to a flexible assembly, right-click on the assembly and highlight the Product1 object and select .Additionally, in Assembly Design, the same icon is on the Constraints toolbar.

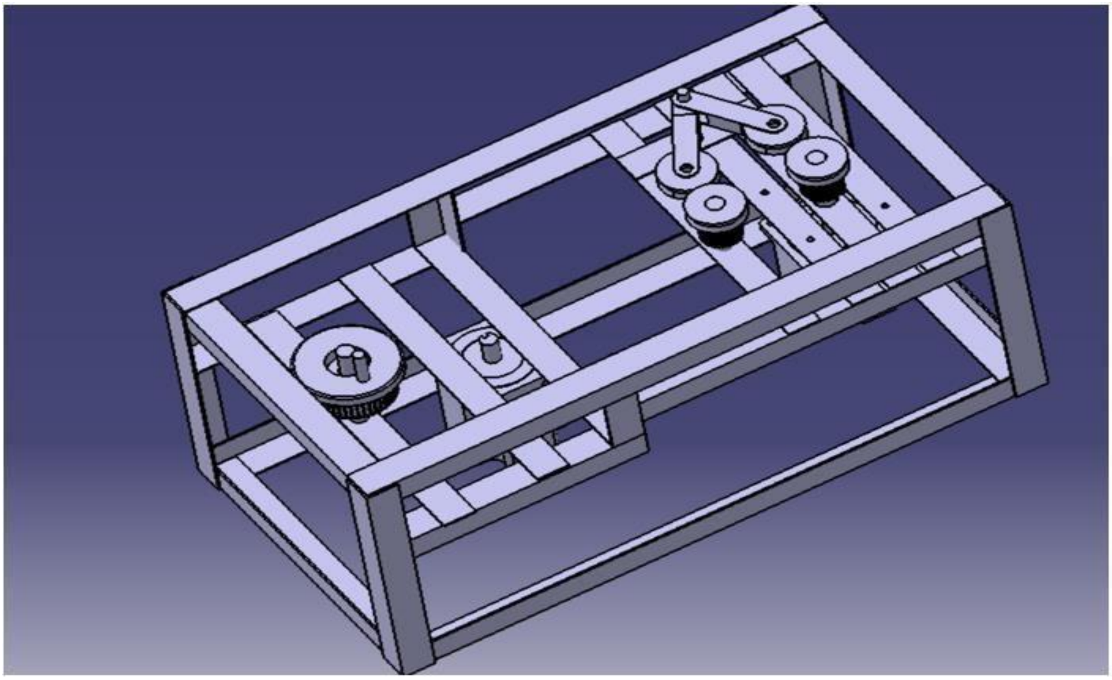


Fig 4.13 Final CAD model of Prototype mechanism

MANUFACTURING OF THE MACHINE

5.1. Guiding channel

The wire guiding channel is a slotted cylinder with a specification of 4 mm. The primary purpose of this channel is connecting the feeding and bending mechanisms together and ensures a straight entrance between the die and the pin of the bending head. After the ending of the overall operation of the product forming (Feeding, Bending), the process of produced shaping is repeated sequentially.

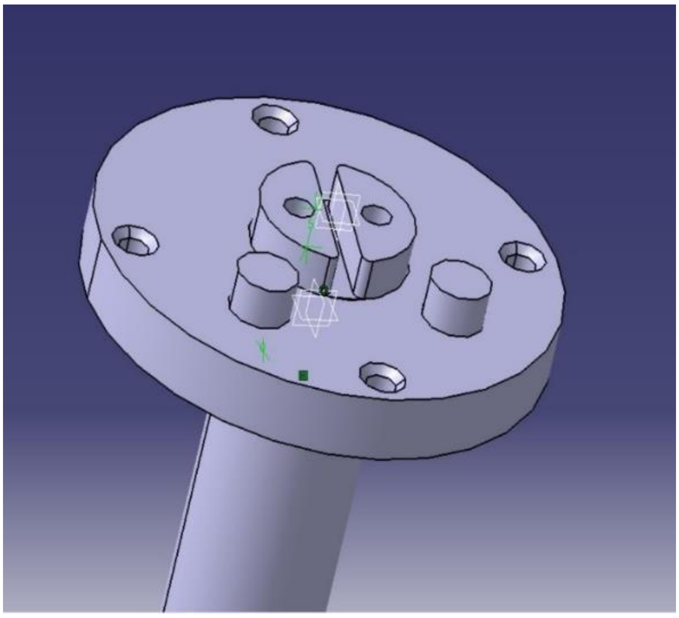


Fig 5.1 Guiding channel

5.2 Machine frame

A structural frame, which supports the mechanical and electronic parts, other components and physical construction is combined for the bending machine figuration. The specification of the machine frame used in this prototype is a rectangular frame.

The Material used is mild steel. Dimension of the framework bar are 35*5*5 mm. We have used the arc welding process

Arc welding is a fusion_welding process used to join metals. An electric arc from an AC or DC power supply creates an intense heat of around 6500°F which melts the metal at the join between two work pieces.

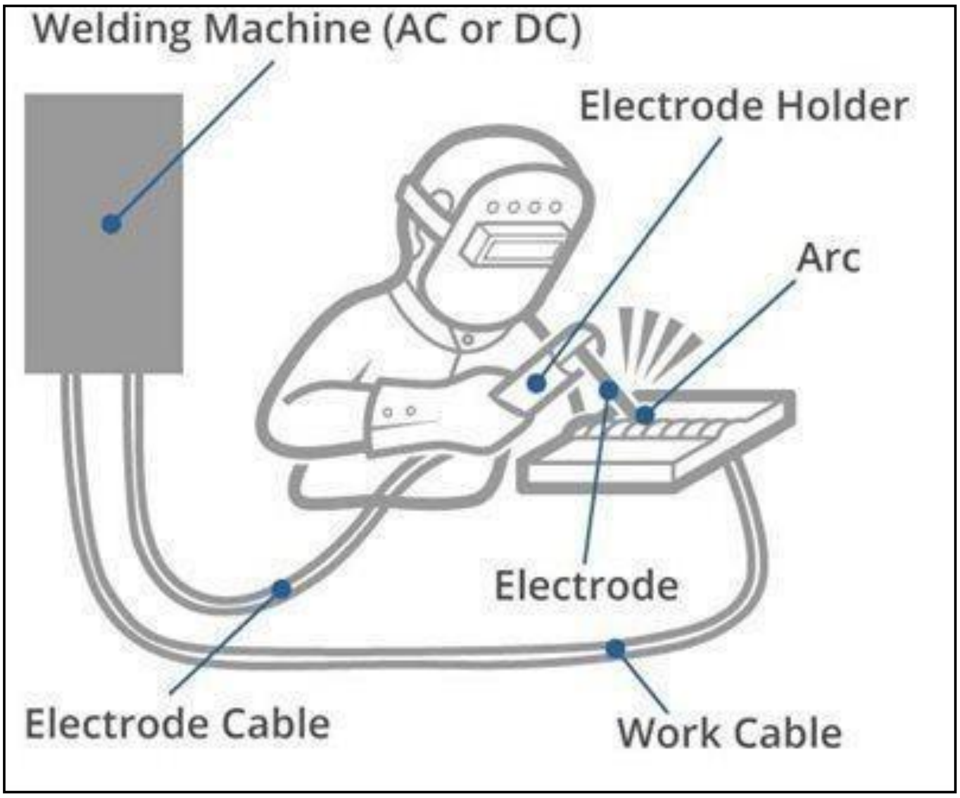


Fig.5.2 Principle of Arc Welding

The arc can be either manually or mechanically guided along the line of the join, while the electrode either simply carries the current or conducts the current and melts into the weld pool at the same time to supply filler metal to the join.

Because the metals react chemically to oxygen and nitrogen in the air when heated to high temperatures by the arc, a protective shielding gas or slag is used to minimize the contact of the molten metal with the air. Once cooled, the molten metals solidify to form a metallurgical bond.

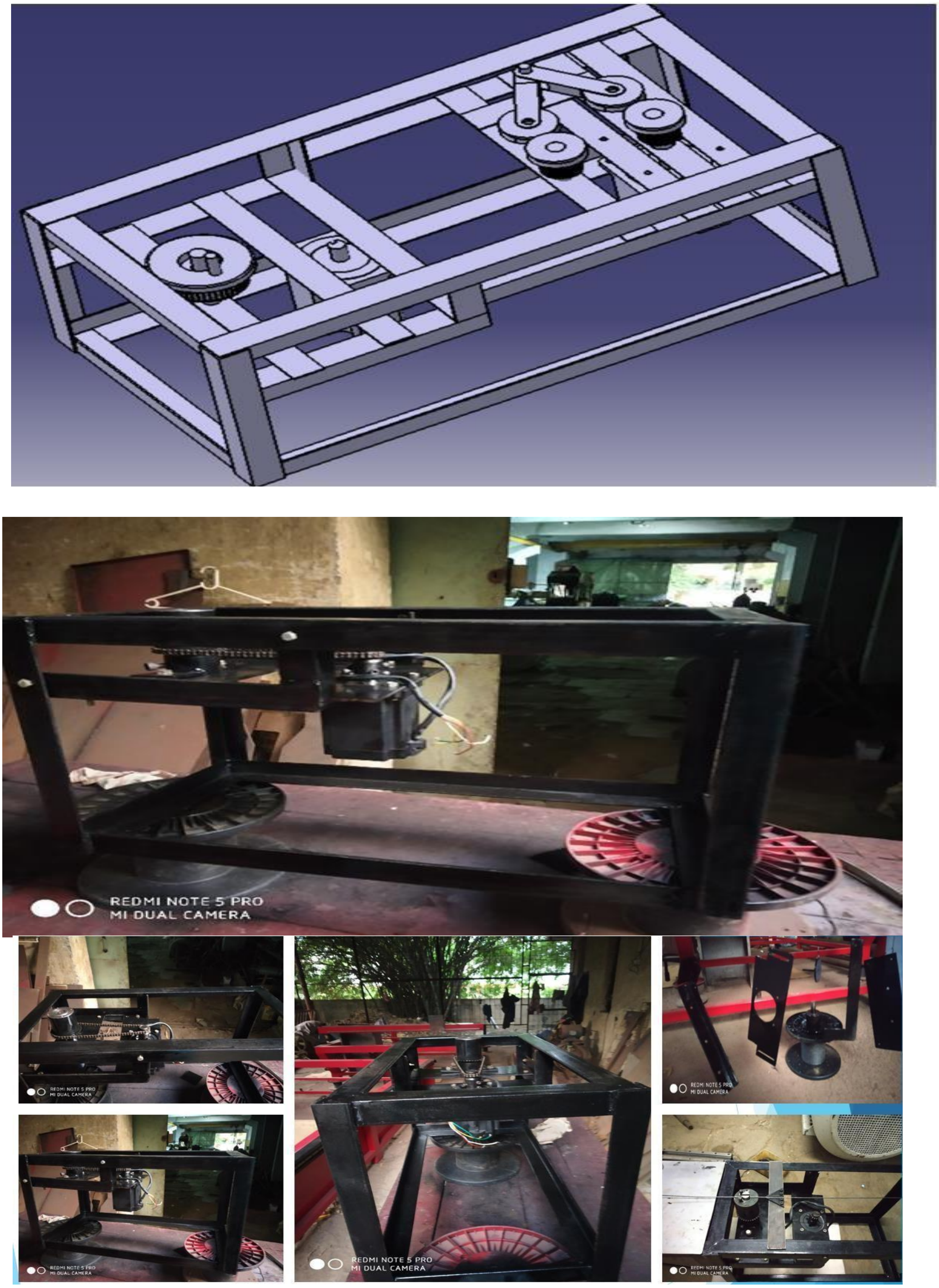


Fig 5.3 Machine frame

5.3 Feeder Components

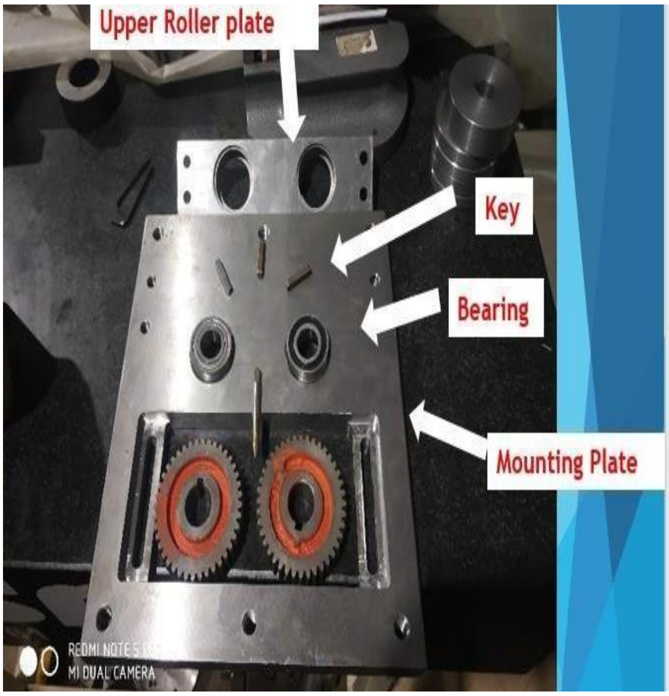


Fig 5.4 Feeding Mechanism components

Table 5.1 Feeding Components

Components	**Material**	**Manufacturing Processes/Method**
Shaft	20MNCR5 STEEL GRADE	Lathe Machining ,DRO , Cylindrical Surface Grinding ,Tapping, Key Slotting
Mounting Plate	Mild Steel	Gas Cutting , Dro , Lathe machining , Surface grinding
Bearing	SS	Ball bearing (id17/od35)
Roller	EN8D ROLLER	Lathe machining
Key	Mild Steel	----

5.4 Bender Components

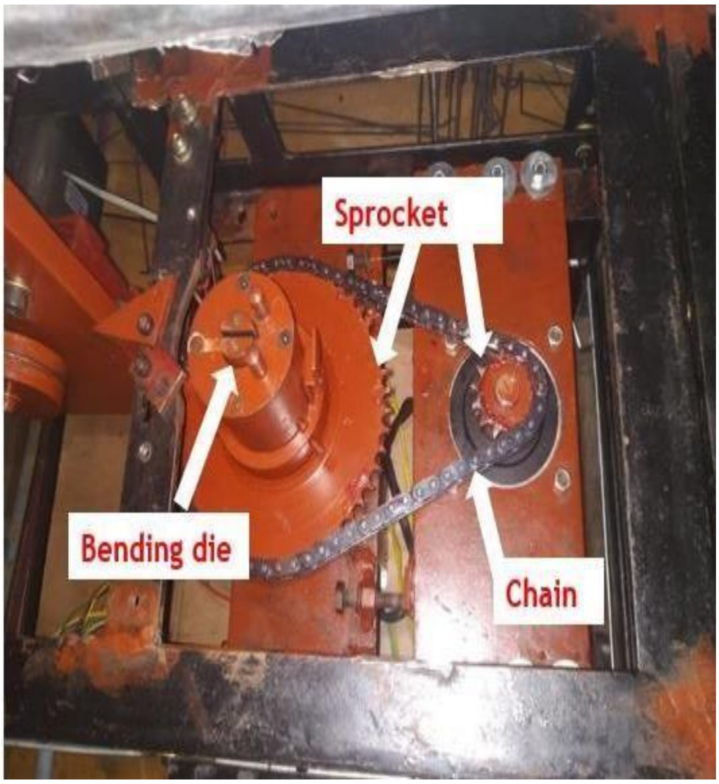


Fig. 5.5 Bending mechanism Components

Table 5.2 Bending Components

Components	**Material**	**Manufacturing Processes/Method**
Shaft	20MNCR5 STEEL GRADE	Lathe Machining, DRO, Cylindrical Surface Grinding
Chain and Sprocket	Mild Steel	Standard
Bearing	SS	Ball bearing 6007
Key	Mild Steel	----

Fig 5.6 Final Wire Bending Machine

AUTOMATION

The controller part is considered the main part assembled for the reason of controlling the other parts. It consists of a central controller (Arduino NANO), one DC motor drivers. The central controller is an Arduino NANO board, which interfaces the machine with the user's PC via USB cable, the communication between the PC and the NANO is accomplished through the serial monitor using the Arduino IDE. The central controller reads the input (angle/wire length) from the user via a serial monitor, saves and converts it into Byte length number (transition protocol sends one byte at a time). The transmitted values (bending angle/flange length) represent the set point of any finished product.

Fig 6.1 Controller

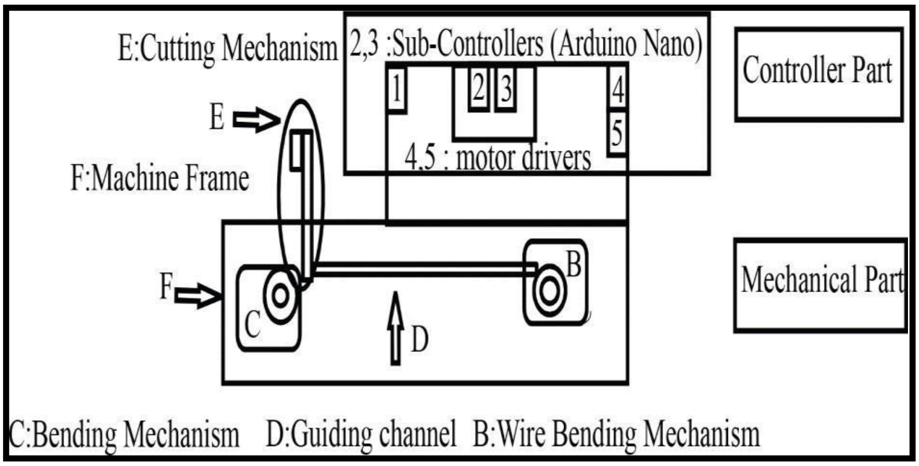


Fig 6.2 electronic system layout

Another essential task for the central controller is controlling the feeding and cutting mechanisms by sending a drive signal to the servomotor. An Arduino Nano board is programmed with micro close loop control algorithm for the purpose of bending and feeding. The set point (bending angle/flange length) is received from the central controller. The feedback signal is obtained based on the optical encoders coupled with the motor and according to the feedback and set points, the output signal of the micro controller is calculated then sent to the motor driver to drive it to the required set point. The modules of the motor drivers used in this prototype are a high-power chip, which is a fully integrated chip with high-current half-bridge motor drive.

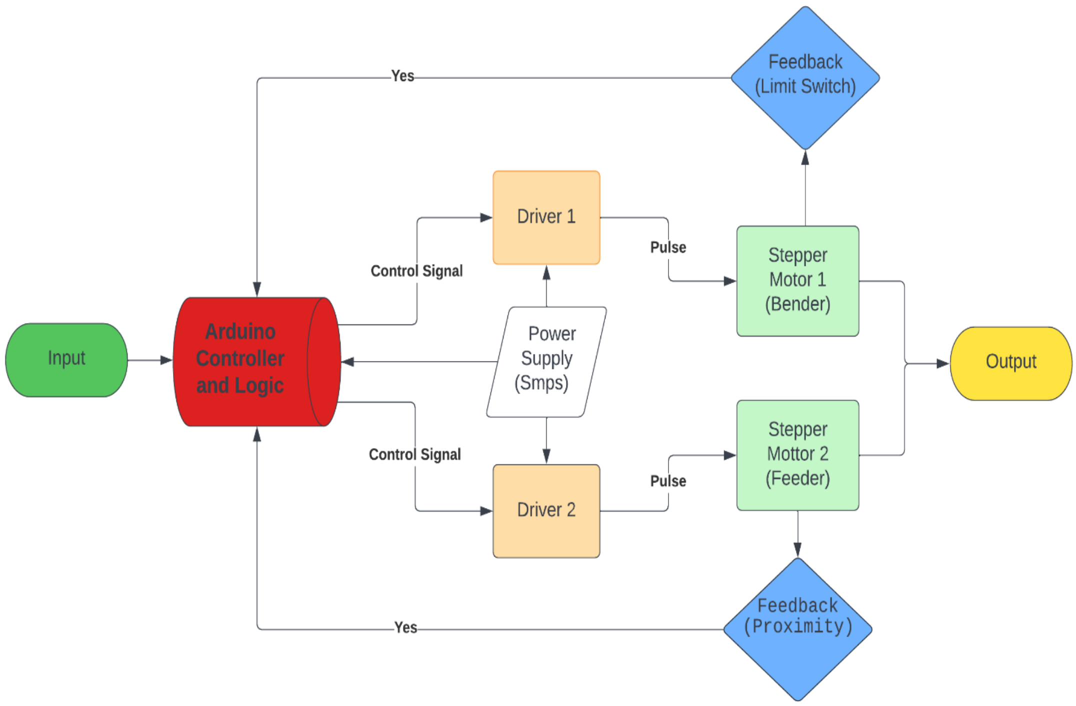


Fig 6.3 Block Diagram of Automation System

Fig 6.4 Technology Used

6.2 Algorithm development for bending machine

The main goal of this work is to implement and develop a more accurate wire bending machine, in which the needs of this accurate machine have been highlighted. The main point depends on the proposed algorithm, which has been developed based on separating the controller of the process. The central controller is responsible mainly for controlling the sub-controller, where the sub-controllers are programmed using microcontroller to manage the entire mechanisms of feeding and bending separately. To ensure that the outcomes of these mechanisms are compatible with the input data from the central controller. The overall processes of the proposed accurate bending machine are summarized as follows:

– Using GUI, the degree of bending angles and number of sides;

– Data of the targeted shape has been loaded in the central controller;

– The controller has been activated based on the data gathered from the central controller for the feeding purposes.

– Feeding processes have been carried out and evaluated through the central controller, based on standard data. Microcontroller has examined the feeding parameters to obtain the optimum value.

– Bending processes have been accomplished based on the data gathered from the central controller and with the standard bending data;

–the overall shape has been examined to match the standard value of the targeted form. The wire bending machine has been designed, developed and tested in the premises of mechanical department.

6.3 PCB Designing For Controller

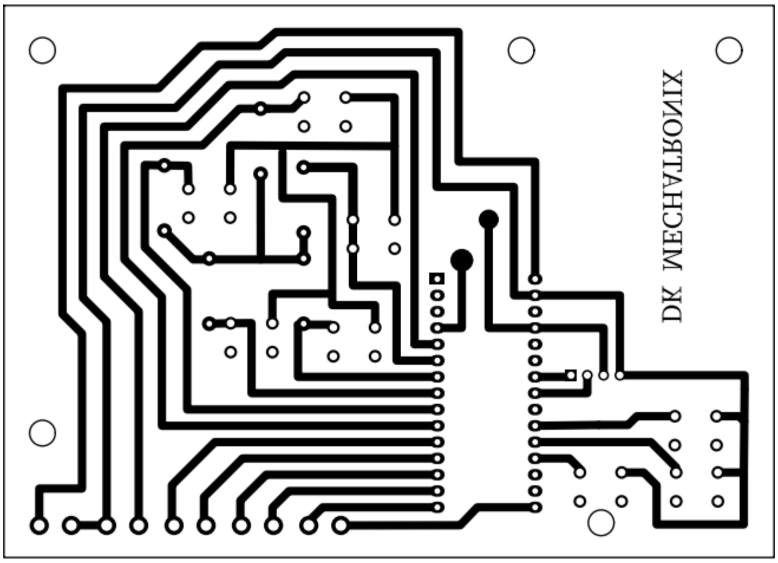


Fig. 6.5 Printed Circuit Board

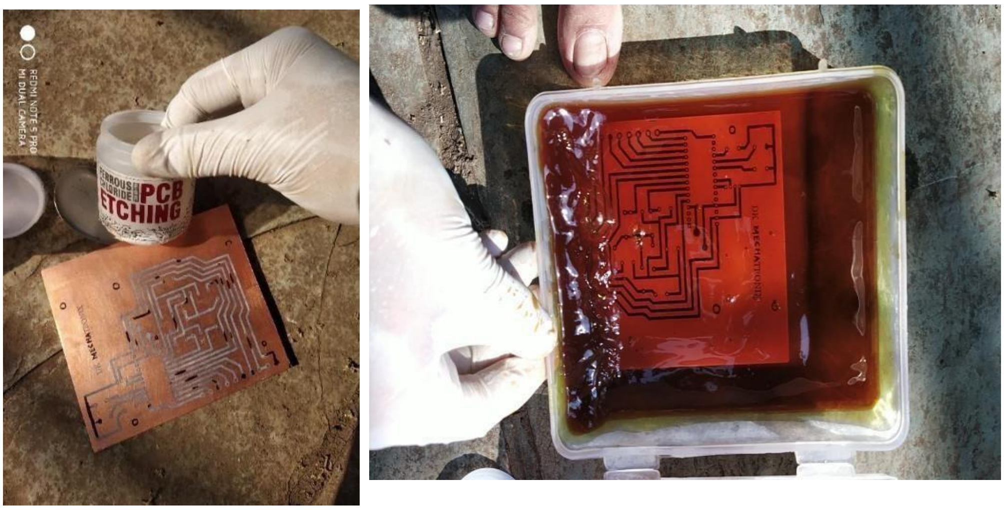


Fig. 6.6 Etching

A printed circuit board, or PCB, is used to mechanically support and electrically connect electronic components using conductive pathways, tracks or signal traces etched from copper sheets laminated onto a non-conductive substrate.

6.4 Interfacing Electronic Components with Arduino through Algorithm

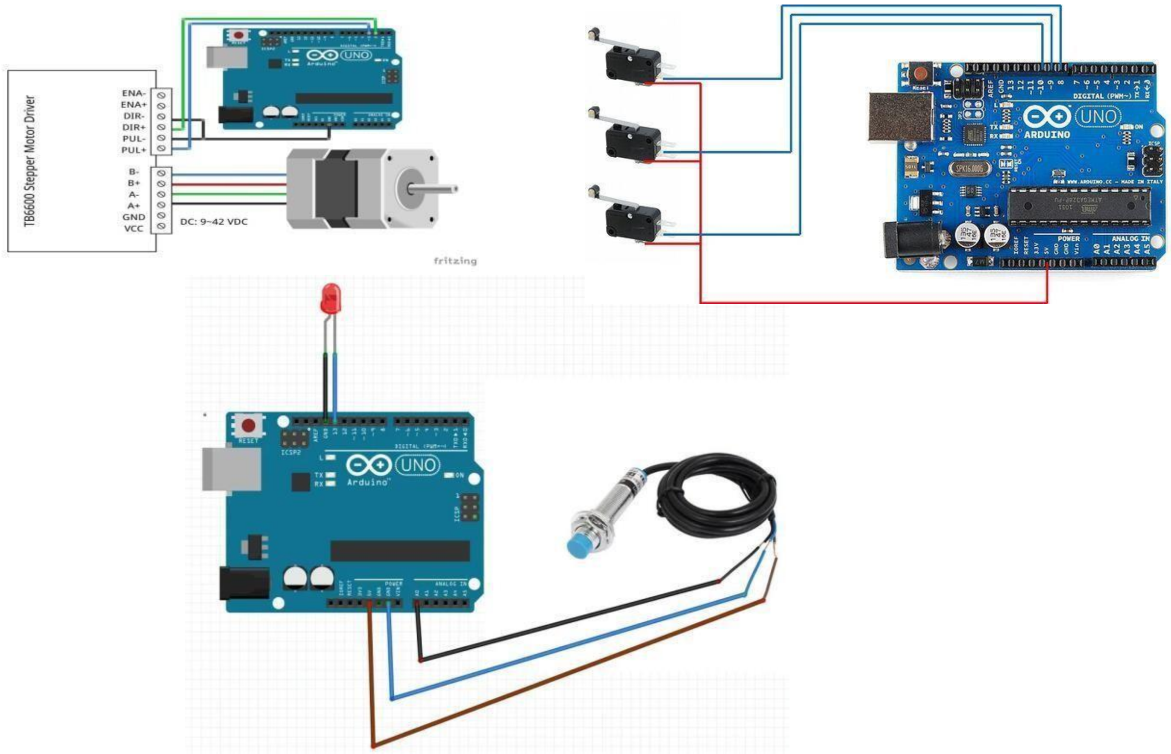


Fig 6.7 Interfacing of Arduino with Limit switch, Proximity Sensor and Motor

Fig 6.8 Sample Algorithm run in Arduino IDE

6.5 List of electronic components.

Table 6.1.Electronic components

No.	Components	Specification	Qty	Purpose
1	Stepper Motor	1. Nema 87 Kgcm 2. Nema 45 Kgcm	2	To get precise motion of bender and feeder
2	Motor Driver	YAKO ORIGINAL YKD2608MH 6A 18-80V DC	2	To Drive stepper motor using pulse
3	Controller	1. Arduino Nano 2. LCD Display 3. Pushbutton 4. PCB	1	To Control Stepper motor motion
4	Sensors	1.Limit Switch 2.Proximity Sensor	2	To get feedback of stepper motor's shaft position
5	SMPS	1. 48 volt DC	1	To give power supply

Basic elements of the machine:

1. Stepper Motor

A stepper motor is an electromechanical device converting electrical energy into mechanical power. At the same time, a stepper motor is a brushless, synchronous motor that can divide a full rotation into a huge number of steps. When a stepper motor is applied with electrical command pulses in the proper sequence, the shaft or spindle of the stepper motor rotates in discrete steps, allowing precise control of the motor's position without any feedback mechanism, as long as the motor is sized for the application.

Motor Specification:-

Table No.6.2 Specification of motor

SPECIFICATION	BH 86SH 118 - 6004 AK		
	MODEL		Bipolar
1	Rated Voltage	V	2.52
2	Current / Phase	A	6
3	Resistance / Phase	±10% Ω	0.42
4	Inductance / Phase	±20% mH	4.25
5	Holding Torque	Nm	8.70
6	Rotor Inertia	G-CM^2	2700
7	Weight	KG.	4
8	No of Lead	N^0	4
9	Operating Voltage	VDC	48 - 170
10	Operating Voltage	VAC	34 - 120

CHARACTERISTICS
Step Angle - 1.8^0
Step Angle Accuracy - ± 3 Arc Minute
Insulation Class - H
Ambient Temperature - -20^{0}C + 50^{0}C
Temperature Rise - 80^{0}C Max (Rated Current Phase 2 ON)
Insulation Resistance 100 M Ohms Min.500 VDC
Dielectric Strength 820 VAC For One Minute
Shaft Radial Play 0.02 Max. Play (450 G Load)
Shaft Axial Play 0.08 Max. Play (450 G Load)
Max.Radial Force 220 N (20MM From Front Flange)
Max.Axial Force 60 N

Fig. 6.9 Steeper Motor

2. Motor Driver

Motor drivers act as an interface between the motors and the control circuits. The motor requires a high amount of current whereas the controller circuit works on low current signals. So the function of motor drivers is to take a low-current control signal and then turn it into a higher-current signal that can drive a motor. Stepper motor with driver is the driver circuit that controls how the stepper motor operates. Stepper drives work by sending current through various phases in pulses to the stepper motor

Fig 6.10 Motor driver YKD2608MH

3. Proximity sensor

It often emits an electromagnetic field or a beam of electromagnetic radiation (infrared, for instance), and looks for changes in the field or return signal. The object being sensed is often referred to as the proximity sensor's target. Different proximity sensor targets demand different sensors. For example, a capacitive proximity sensor or photoelectric sensor

Fig 6.11 Proximity Sensor

4. SMPS

SMPS stands for Switched Mode Power Supply. It is an electronic gadget or module that comprises a combination of inductors, capacitors and semiconductor gadgets like diodes and MOSFETs. It is utilized to change over a specific DC voltage to another DC voltage level. It is utilized rather than straight or ohm converters since of higher efficiency. It could be a key portion an in almost all domestic electronic equipment's (like portable chargers, PC control supplies, etc.). It works by employing a semiconductor switch like MOSFET to switch on-off the supply voltage at a specific exchanging recurrence to control the yield voltage

Input = 240 Volt AC – 50Hz

Output = 48 Volt DC – 10Amp

Fig 6.12 SMPS 1011

5. Limit Switch

A limit switch is a type of sensor that works to detect the presence and absence of an object. It can be mechanically activated by interacting with other substances. As the object contacts the actuator of the switch, it eventually moves to the limit of the actuator where the position of the contact changes.

Fig 6.13 Limit Switch

5. Arduino NANO

It is one kind of microcontroller board which is designed by the Arduino team. This microcontroller is based on Atmega168 or Atmega328p. It is fairly similar to Arduino Uno board but when it comes to pin-configuration and features, this Nano board has replaced Arduino Uno due to small in size. As we know that while designing an embedded system small size components are preferred. Arduino boards are mainly used to build electronic projects. Embedded systems, robotics, etc. But the Nano boards are mainly introduced for the beginners who are not from the technical background.

Fig. 6.14 Arduino Nano

TESTING AND VERIFICATION

7.1 Accuracy and precision verification

A wire with a specification of 1.5-4 mm diameter made from mild steel has been used experimental purposes in which data have been gathered and recorded regarding the bending angle, as well as bending.

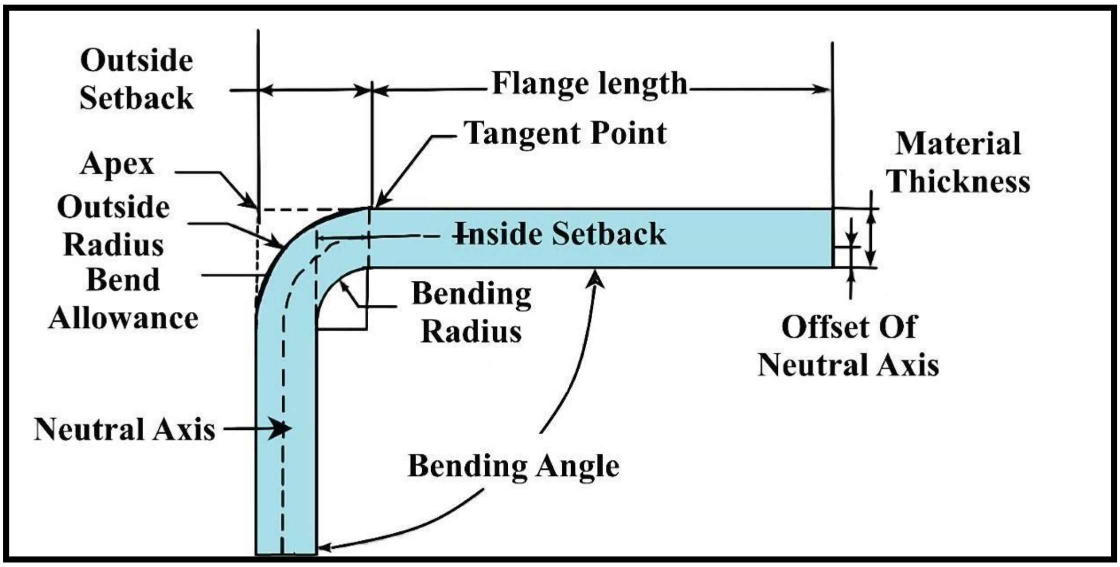


Fig 7.1 Bending Diagram Parameters.

Ten different dimensions of an equilateral triangle design sample with ten tries for each dimension (variable flange length, fixed bending angle equals to 60 degrees and bending radius equals to 3 mm) have been selected being produced

using the bending machine, and the products have been formed two times. Firstly, using the proposed bending machine, in which the proposed algorithm is applied. Secondly, using a bending machine implemented without applying the proposed algorithm. Calculations of bending angle and bending radius have been made for each product industrialized and the results have been compared in terms of error rates with respect to the standard design of the product designed using CAD/CAM application. Also, the accuracy of bending angle and bending radius measurements for the equilateral triangle product are verified respectively. Bending angle and bending radius measurements of the products manufactured using the proposed bending machine for different dimensions and trails of products show up highly accurate measurements if compared with the measurement of the products manufactured using a bending machine designed without the proposed algorithm. Overall (bending angle and bending radius measurements) witnessed a high accuracy. In addition, accuracy, as well as precision of products, has been amended for the parameters of bending angle, as well as bending radius. Despite the above improvement of machine output, a limitation has been recorded in terms of wire material and thickness. Due to the simplicity of the pilot product, it is difficult to utilize the machine for the manufacturing of products with big dimensions and we intended to develop the prototype to be more applicable for any industrial application be it small, medium, large scale.

7.2 Discussion of experimental results

Utilization of the wire bending machine has testified high importance, in which the need of using the bending machine has raised with the growth of industries. The current project has proven that the development of a bending machine is necessary in the field of forming industries and this project proved that this machine is able to produce a product of any design. An enhancement is necessary to include in this machine by increasing the ability of this machine for the bending process for any material to reach the optimum stage of the utilization of bending machine in the industrial sectors. The current project also has shown that the utilization of the proposed algorithm has tremendously helped the production of accurate products, since the separation of process controller has raised the accuracy and precision measurements of the products.

The current project is also considered useful for industries that require a product with high-precision measurements. As compared with previous studies, the proposed machine gained a high level of accuracy of measurements for the fabricated products, as well as the precision of measurement for the products. A reason beyond this enhancement belongs to the handiness of the proposed algorithm, which helped the reduction of error rate between the produced products and standard products.

Fig. 7.2 Triangle

Fig. 7.3 Hook

Fig 7.4 Spring, zig zag, ring

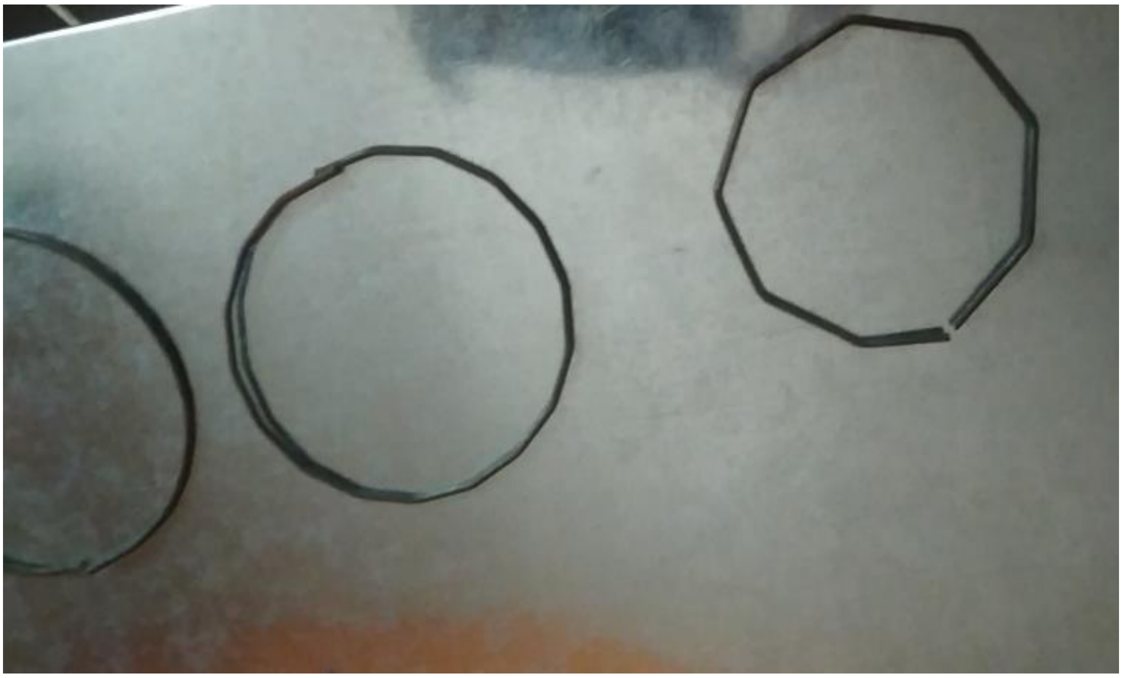


Fig 7.5 Polyg

ADVANTAGES

The advantage of 2D wire forming processes is that the machines work in conjunction with traditional wire forming machines. Adaption of 2D programming allows these machines to perform automated operations more effectively. Once a wire forming machine has been 2D programmed it is capable of fabricating wire parts and components continuously. Depending on the tooling and complexity of the design, it can even produce complete wire forms. 2D compatibility with other wire forming machines increases productivity and ensures greater precision than manually operated machines simply cannot equal.

Here are few more advantages of automated Wire Bending Machine:-

- Its versatile technology, wire forming offers two-dimensional or three-dimensional bending
- Products can be produced in greater rate with higher accuracy and thus, less waste.
- The machines work in conjunction with traditional wire forming machines.
- Adaption of Arduino programming allows these machines to perform automated operations more effectively with the feedback sensors.
- Arduino based Wire bending machine compatibly worked with other wire forming machines leading increase in productivity.
- It ensures greater efficiency and accuracy than manually operated machines.

FUTURE SCOPE

2D Wire Bending Machine require further research to develop 3D Wire Bending Machine. There are lot of opportunity to capture markets in wire bending products and forming technology manufacturing. Future technologies in Wire bending machine will makes it more accurate with higher efficiencies as there can be no accurate product hence, we tend to improve constantly. There is wide scope to include mechanisms which involves in manufacturing processes of wire products these processes are wire straightening and wire cutting in one go. Also, the stack operationalizing the processes can save time, money, labor cost. This is going to be the trending sector under Industry 4.0.

Coming to automation in wire bending machine there are lot of scope to automate wire bending machine by using AI and ML and repeated iterations. Although manufacturing of wire product through automatic wire bending machine is more efficient than conventional processes, it is still not popular as other manufacturing processes like CNC machining processes therefore this technology is still in developing phase. Besides using automatic wire bending machine its higher machine cost is that main problem can be overcome by using. We can hope better Industrial policy in coming days as Industrialization is imperative for national growth in terms of Socio-economic factors.

CONCLUSION

1. Design and development of 2D wire bending machine have been achieved successfully according to the business standards, in which the machine is able to create any frame shapes such as triangular, rectangular, polygonal, curvature, and so forth with higher precision, efficiency and production rate at minimal manufacturing cost.

2. 2D Wire bending machine can bend wire having 1mm to 5mm diameter of material spring steel, High bounce MS wire, Copper, Aluminum, Brass and so forth after further optimizations and enhancement of dimensions we can even bend wire of diameter up to 10mm.

3. 2D Wire bending machine can perform bending operations at maximum torque of 30 Nm, maximum wire feeding rate 100 mm/sec, maximum bending angle 0 to 270 degrees, minimum bending radius 3mm.

4. With significant human intervention we can produce the 3D design products from our 2D Wire Bending Machine

5. Development of the algorithm programmed within this automated machine has proven that this algorithm is necessary for obtaining accurate products. The product accuracy has improved, the parameters of bending angle and bending radius witnessed an increase in its accuracy.

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