

APPENDIX T: Metal Forming Glossary

A TYPICAL DRAW DIE ENGINEERING PROCESS

Clay models of a new vehicle are scanned and the outer shell surfaces are created in a design studio. Body-in-white engineers and designers are responsible to create all the inner parts and various structure and underbody parts. Flanges are created on outer surface parts to be joined with the inner panels. These parts are typically created in the car axis; with global X-axis runs from the front to the back along the car's center line, global Y-axis from the driver side to the passenger side and Z-axis going straight up.

During the clay design and shaping, simultaneous and multidisciplinary engineering may be practiced involving divisions/departments from design, engineering and manufacturing. Material suppliers may also be involved in this stage for consultation if advanced materials are to be applied. Multidisciplinary involvement in this early stage of a vehicle development allows manufacturing engineers to capture any part designs with "no make" conditions that would be costly if they were allowed to proceed to a later stage; while design envelopes can be pushed to their maximum potential within the state-of-art manufacturing capabilities.

During the advance feasibility phase, parts from the design studio are processed quickly to go through an engineering process involving mainly the process engineer and FEA simulation engineer. Addendum and binder are roughly built in order to conduct a reliable draw die simulation. The exact process eventually would be used to build the die may not yet be established, therefore similar processes from knowledge base are used as references. Rarely are secondary dies (all dies except draw die) simulated. The main task here is to provide some quick assessment of the part's manufacturability through fast design/engineering iterations.

During the hard die design and construction phase, stamping manufacturing processes (some in three dimensional) are established, by referring to existing knowledge base, with necessary modifications needed for the current part design, and with the limits of manufacturing equipment such as press type, shut height, maximum tonnage and automation, etc. The stamping process includes the number of dies (to make a complete part of the final shape), part tipping, draw height, trimming (direct or aerial), flanging, spring-back compensation requirements, etc. Not all areas of the part may be formed to its final shape in one draw die. Some involve redraw die if one area of the part is especially deep compared to the rest of the part, which may otherwise cause uncontrollable wrinkles, splits, or exceed the draw height limit without the redrawing. Some areas of the part (which may have "undercut" or "die locked" conditions) may be unfolded to the addendum, then trimmed and flanged in a flanging die later. A typical example of such can be found along the hood line of a fender outer. There may be multiple trimming and flanging dies, since not all areas of the drawn panel may be feasible for trimming or flanging all in one trim or flanging die.

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Referring to [Figure 70-1](#), a typical draw die development process flow for an outer part is illustrated. The part is tipped from the global car axis to a 'draw die' axis, which takes into account of balancing the internal draw angles over the entire part, and minimizing the overall draw height, etc. Hem flanges are unfolded off the part breakline ([Figure 70-1](#)) in one of the following ways:

- 1)Tangent extension of the part surface,
- 2)Horizontal surface,
- 3)Vertical down-standing surface,
- 4)Any angled surface between horizontal and vertical surface,
- 5)To the addendum surfaces to be designed; in this case, the unfolding will happen after the addendum design is complete.

Flange unfold must take into account the trimming condition later in the trim dies. Direct trim represents the trim steel going down in a draw direction (vertical); while aerial (cam) trim steel covers all other directions, driven by a 'cam driver' driven further by the vertical downward motion of the trim die. There are specific trim angle requirements for direct and aerial trim operations. Next, the part boundary is smoothed, filling up any gaps, holes and sharp features. The boundary will likely be modified later during the addendum build. Binder is created, based on the unfolded part boundary and overall part curvature. A developable binder surface, which consists of planes, cylindrical surfaces or a combination of both, is preferred; however, in some cases a doubly curved binder surface (undevelopable surface) must be designed for the purpose of reducing the draw depth at critical locations for material utilization, alleviating thinning, or both. Theoretical punch opening line (P.O. line, Detail #2 in [Figure 70-1](#)) can be offset from the smoothed part boundary in the plane normal to the draw axis, projected to the binder surface in the draw direction; some smoothing of the P.O. lines may be required. Generally, the finished P.O. lines should be consisted of mostly straight lines and radii, with generous transition among corners. P.O. lines do not follow tight corners, avoiding formation of wrinkles during the draw. In addition, design of P.O. lines must take into consideration the material utilization issue, especially in the blank sizing critical locations. Once P.O. lines design is complete, binder surfaces inside of the P.O. are trimmed and the remaining binder surface design is sent for binder closing simulation. Given a blank initial shape, simulation of the binder closing action can determine the quality of the binder design. Typically, for exterior outer panels, no buckles or wrinkles are allowed during the closing; for inner panels, some wrinkles are acceptable, or even desirable, depending on the part shape. Lower punch/post support may be introduced to reduce the draw height, alleviate thinning, or remove the initial blank drape into the binder cavity. Based on the binder closing simulation results, unacceptable binder design is sent back for rework, and the satisfactory binder design proceeds into the next step of addendum build, which is used to fill the space between the part boundary and binder surface. It is noted that the P.O. lines may need to be adjusted during the addendum design. The trimming condition may also be affected and modified during the addendum design. Next, draw simulation ensues, assessing the overall formability of the draw design. If quality targets are not achieved in the simulation, the process may go

all the way back to the tipping for redesign/reprocess; otherwise successful simulation will direct the draw surface design to the next stage of draw die structure design.

TYPES OF DRAW DIES

There are many different types of draw dies used to punch the part to their intended shape, as shown in [Figure 70-2](#). They basically can be divided into either single action or double action dies. Specifically (names may vary among different companies),

- 1) Air draw – Single action. It is a 3-piece die system with 1 piece upper (cavity) and 2-piece (binder and punch/post) lowers. The upper cavity (driven by press ram) moves down in one action to close with the lower binder, and then closes with the lower punch to draw the part to the home position. The lower binder is either sitting on an air cushion through pins that go through the press bed, or directly on nitrogen cylinders arranged uniformly between the bottom of the binder structure and the press bed; the punch is fixed onto the press bed. This is the most popular draw type, mainly because of its speed and efficiency. Its limitation includes a maximum draw height of 10”.
- 2) Toggle draw – Double action. It is a 3-piece die system with 2-piece upper (binder and punch) and 1 piece (cavity) lower. Upper binder, driven by the outer ram of the press, moves down to clamp the blank with the lower cavity; then the upper punch, driven down by the inner ram, closes with the lower cavity to complete the draw. Since this adds another action, it is slower than the air draw; however, this type of draw die is well suited to control the wrinkles created during the forming of difficult part, such as liftgate and door inner. Furthermore, this type of draw has a relatively large draw height, which is limited only by the press.
- 3) Air draw with pressure pad – Single action. This is very similar to 1), except an additional pressure pad, driven by nitrogen cylinders mounted on the upper die structure, closes first with the lower punch, then the entire upper comes down to finish the draw. This is similar to 1) in efficiency.
- 4) Stretch Draw (four piece) – Double action. It is a 4-piece die system with 2-piece uppers (upper binder and punch) and 2-piece lowers (lower binder and cavity). Upper binder moves down to close with lower binder, moving together for a certain distance (up to 2”), then upper punch comes down to completely close with lower cavity. Finally the binders move down together to their home position. This process is not used as often as 1), 2) and 3), however, it is very capable in forming difficult inner parts, especially those prone for wrinkles, such as liftgate inner, door inner and floor pan. Since there is a ‘pre-stretch’ action with the binders clamping the blank and moving down together, strain path change in the part during the forming is expected. This is the slowest draw type.
- 5) Crash Form Die – Single action. It is a 2-piece die system with no upper or binders. Upper and lower tool takes the same shape, with upper moving down to close with the lower tool. This is obviously a very simple die, which can handle simple

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parts, with not too much draw depth variation (near constant draw depth all around).

TYPES OF FLANGING DIES

There are three types of flanging dies, as shown in [Figure 70-3](#). All three types have a fixed lower (trim) post upon which the drawn (or partially trimmed part) is sitting, and a pressure pad (or multiple pads) which holds the part (which is loaded onto the post in a vertical direction) in place against the post. In a direct flanging process, the flanging steel ([Figure 70-3](#)) moves vertically down to 'wipe' or 'bend' the part to its flanged position. In an aerial flanging process, the flanging steel moves to form the flanges in an angle rather than the vertical direction. The steel is held by the cam slide, driven by a cam driver which in turn is driven by the trim die's downward movement. Since the finished flange forms a 'die lock' condition, meaning the flanged part will not be able to be lifted (retract) out of the trim die into the next die (or station), the filler cam ([Figure](#)) is moved horizontally out of the way so the part can be lifted up and out. Once the part is removed, the filler cam moves back into its home position ready for the next drawn panel to be loaded. In the rotary cam flanging process, the filler cam is called a 'rotor', which rotates out of the way for the flanged part to be lifted up and out. Some parts of the rotary cam flanging design are a patented process. In comparison to the conventional cam flanging, rotary flanging has the advantage of being very compact.

TYPES OF HEMMING DIES

There are two types of hemming dies, as shown in [Figure 70-4](#). Both processes have a fixed hemming bed, on which the flanged outer part is loaded; the inner panel is then loaded onto the outer panel; proper clamps are applied to hold tight the panels together and in place. In press (or table top) hemming, a pre-hemming tool is moved to form the flange into a halfway position, followed by the final hemming tool pressing down on the flange against the inner and outer panels to its final position. Many different shapes of hem tips can be achieved, as shown in the figure. In roller hemming, a pre-roller moves in a three dimensional curvilinear path following the hem tip, to form the flange partially. This is followed by a final roller, moving in another three dimensional path, to finish the hem shape. In the hemming of complex or high-end parts, many passes (rollers) are needed to achieve high quality hem surfaces. Similarly, with the design of different roller shapes, many shapes of hem tips can be achieved.

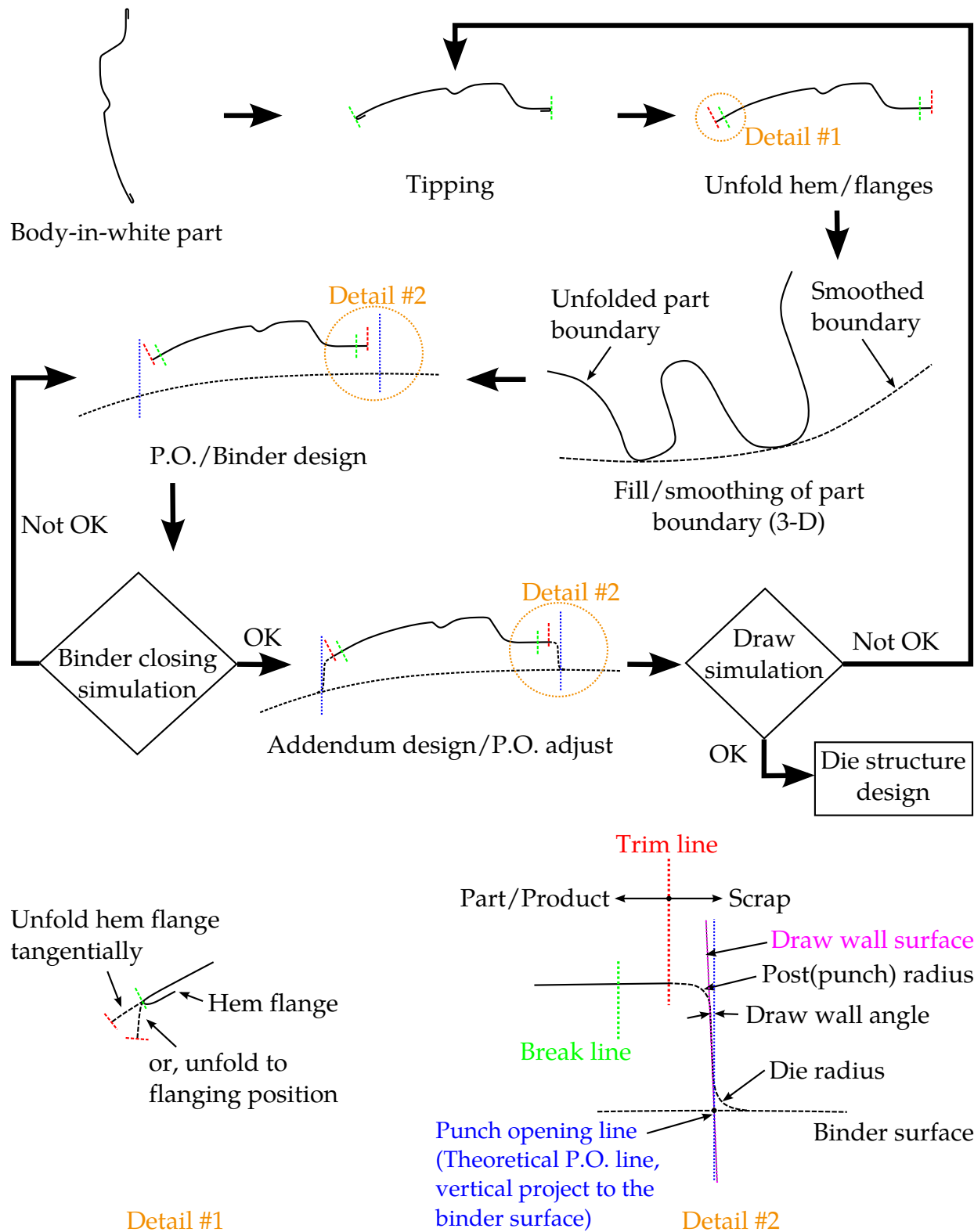
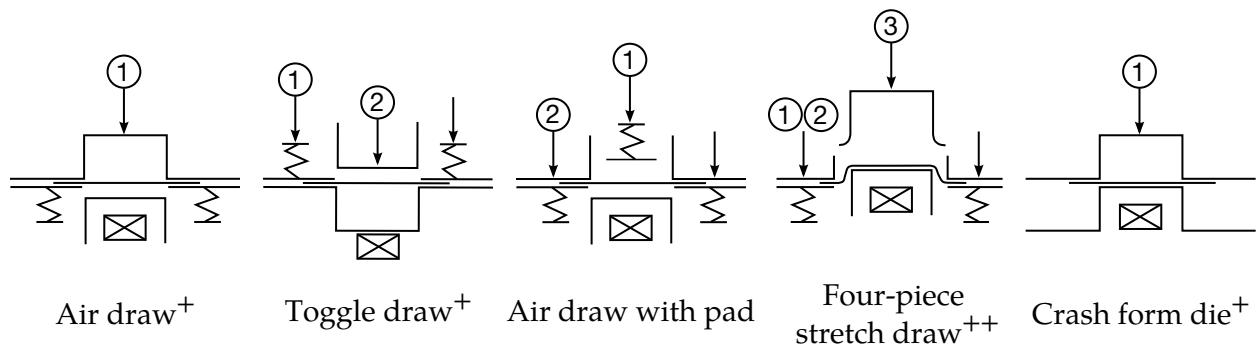


Figure 70-1. A typical draw die engineering process

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+ : single action

++ : double action

Figure 70-2. Types of draw dies

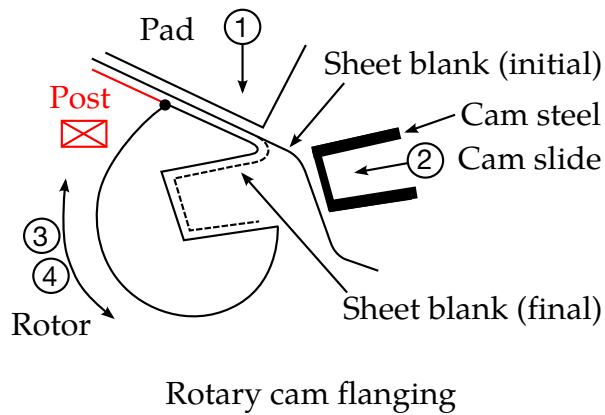
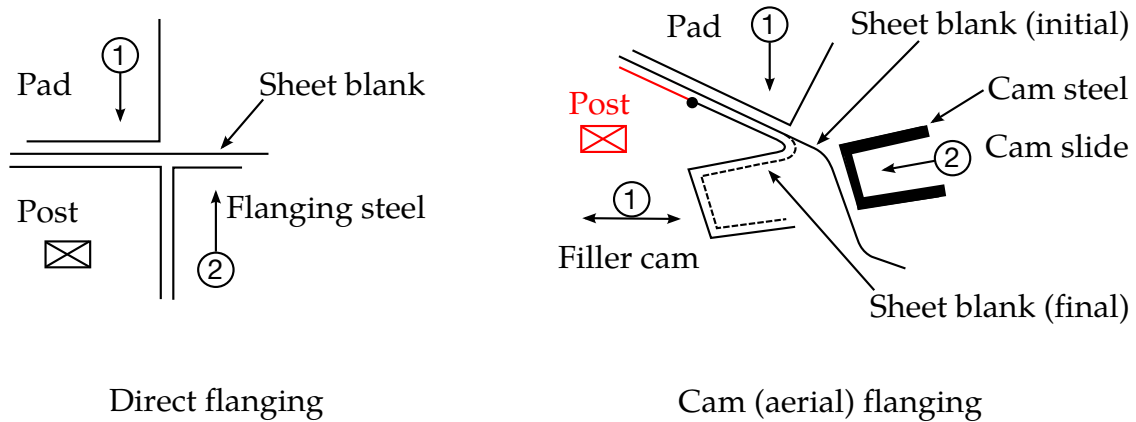


Figure 70-3. Types of flanging dies

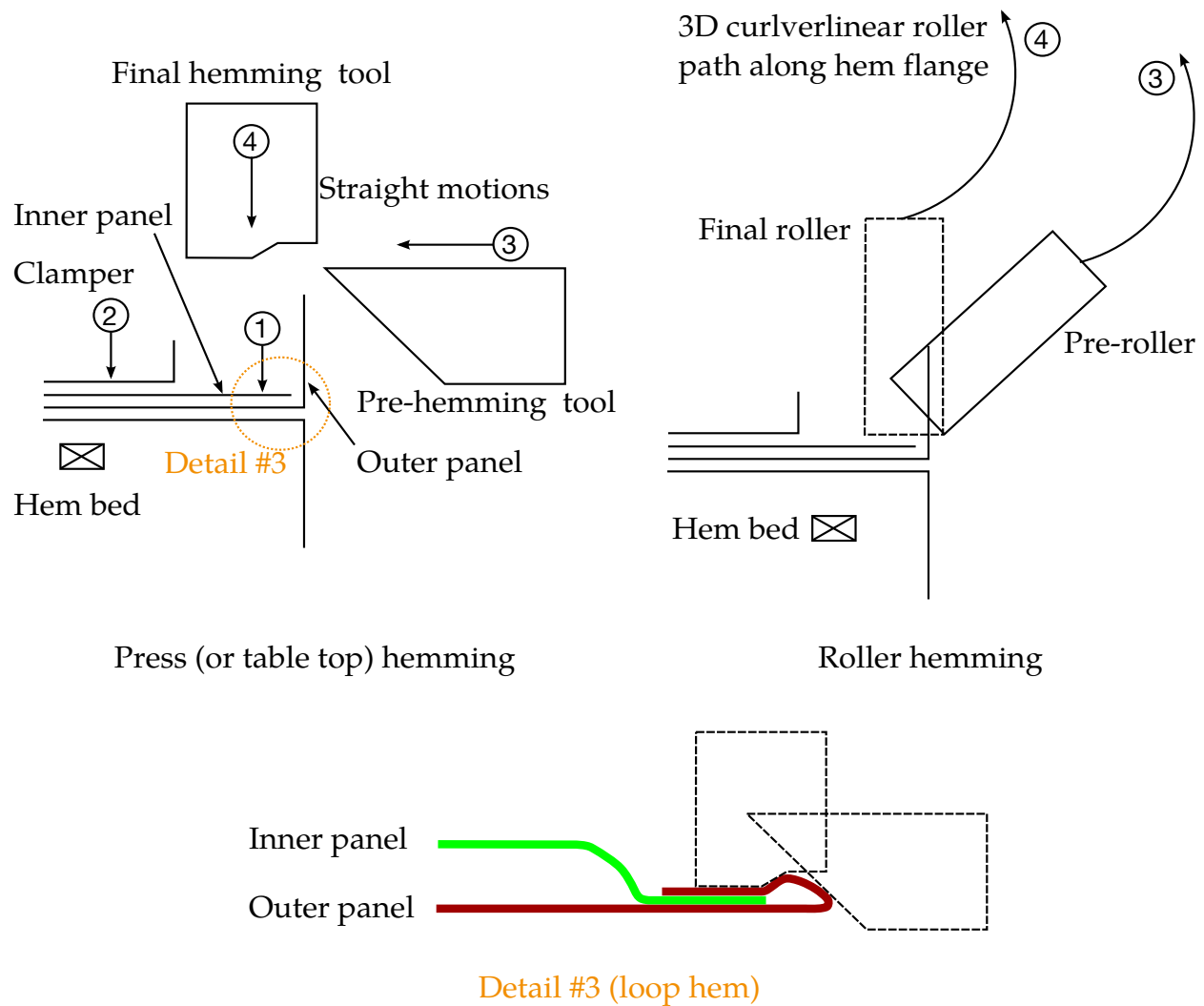


Figure 70-4. Types of hemming dies

