Simulation of Roller Hemming Process to Correlate the Design Parameters

Madhavi B. Raskar
Student of Mechanical Engineering Department
Sinhgad Academy of Engineering, Pune.

Prof. S. C. Shilwant
HOD of Mechanical Engineering Department
Sinhgad Academy of Engineering, Pune.

Abstract- **In hemming is process of, one panel is made to overlap the other and then both are joined by means of the extended edge which being folded back around the other, probably with the aid of some adhesive. The accuracy of the hemming operation affects significantly the appearance of the car's outer surfaces and has therefore a critical importance in the final perceived quality of assembled vehicles. It is used in auto car bodies such as doors, hoods, tailgates and trunk lids. The correlations between the hemming parameters such as flange length, roller radius, pre-strain, rolling direction, pre-hemming robot path on hem surface, are studied with the help of Pamstamp2G software. With the help of Pamstamp software the simulations of hemming parameters show the effective way of optimizing the correlation of hemming parameters.**

Keyword- Roller hemming, hemming parameter, simulation, wrinkle formation, correlation.

INTRODUCTION

Roller hemming technology has been introduced as a new production technique which has several advantages in terms of cost and time saving for trial and error. Hemming is the final forming process in stamping; which determines the aesthetics of automobile. A hem is a bent edge of a metal sheet and hemming is a process by which that edge is bent. Hemming is the last or one of the latest stage operations used in the automotive industry to join inner and outer closure panels together such as hoods, doors, tailgates, etc. The bending or folding process moves the flange of the outer panel over the inner one. Different hemming processes are introduced such as press-and-die, table-top, and roller hemming to enhance the capacities and capabilities of assembly processes in automotive industry.

The die hemming is probably an oldest way of automation. The hemming with the help of presses is called die hemming. In die hemming, it includes hemming die which is product specific, and all other components are universal. For flange opening angles of 90, ° the process is performed in two hemming steps: one pre-hemming and one final hemming step. Two presses are needed for a conventional die hemming process where each press performs a hemming steps (one pre-hemming and one final hemming step).The movement pattern of this process is vertical. Both the pre and final hemming steps are performed vertically. Die hemming is performed fast. The die hemming installations are therefore very suited for high volume production. New products can be hemmed with the same installation when the hemming die is replaced.

A tabletop hemming installation is completely product specific. There are a lot of different tabletop systems available with their own specific features. More complex product geometries can be hemmed with tabletop systems. The tabletop hemming process is suited for high volume production. A cycle time is similar to die hemming. It is easy to integrate a tabletop installation on an assembly line. A disadvantage of the installation is the high investment level. The table top hemming is the more sophisticated hemming installations. The pre-hemming tools hem the product from the side horizontally. The final hemming is performed vertically. The movement pattern of the pre-hemming step can also be horizontal, vertical or a combination of both. There are several drawbacks associated with die and table top hemming operation. So that the new method introduced in market is a roller hemming process. In roller hemming, as the name suggests a robot runs a roller around the edge of the sheet so that hemming takes place as a continuous, sequential and in localized operation.

(a)

(b)

(c)

Fig No-1 Types of Hemming-(a) Die (b) Tabletop (c) Roller hemming

HEMMING PROCESS

Hemming is an assembly process by plastic strain, which consists in bending the edge of one sheet, called the outer part, over the edge of another, called the inner part. It gives neat and compact joint. However, it is less strong than a welded joint. It is on the other hand possible to combine hemming with other additional joining methods, for instance gluing, in order to increase the strength of the joint. This assembly method is widely used in the automotive industry for thin sheets involved in the opening parts of vehicles, such as doors, hoods, or even trunks. Being the last step in the production of closure panels, Flanging is followed by Pre-hemming. In this, a pre-hemmer forces further deformation of the outer panel by certain degrees (e.g. 30°, 45°, 60°).

2. Pre-hemming

The outer part rests on a die. The inner part rests on the outer part and is held in place by a down holder .With this constraining method the inner part can deform during the analysis.

3. Final Hemming:

Final hemming is the last step. This is completed with a final hemmer that is designed to produce a finished bend angle of approximately 180°. Depending upon the number of pre-hemming steps involved, hemming is divided into two stages: a) Three-stage hemming b) Two-stage hemming. In three-stage hemming process, there are two pre-hemming and one final hemming step whereas one of the pre-hemming steps is eliminated in two-stage hemming process as seen in fig.2.

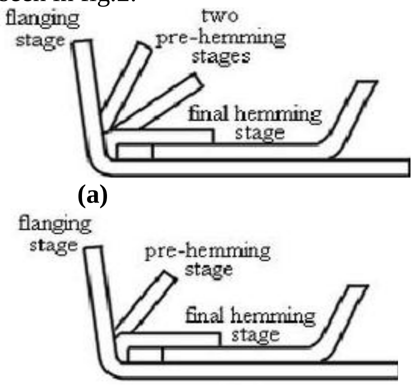


Fig No.-2 :(a) Three-stage (b) Two-stage hemming

SIMULATION OF HEMMING PROCESS

The simulation tool has to perform complex trajectories and accommodate various roll profiles in order to render accurate material shaping. This would ultimately allow precise design of doors, hoods, back-lid, trunks and other component early in the development phase of future vehicles. The initial bending of the flange happens before the actual pre-hemming. The roller is moved in the z-direction. The first pre-hemming step starts by moving the roller along the flange (Fig.3.). The opening angle of the flange is reduced from 110°to 45°. And in the final hemming step the same procedure is followed. First the roller is moved in the z-direction of the local coordinate hemming has a critical influence on the final part and assembly quality.

Stages in Hemming:

Hemming involves the bending of the edge of a sheet on to itself or another sheet, i.e. the nominal bend angle is 180°.The hemming operation is usually a three step process: Flanging, Pre-hemming, and Hemming.

1. Flanging

Flanging takes place during the drawing operation and consists in bending the sheet edge up to 90°to 110°.

Outer Part of assembly is design in CATIA V5 software. Then it import in Pamstamp2G software for analysis. axis of the roller. The actual hemming is started by moving the roller along the flange in the x-direction. With the help of Pamstamp software the simulations of hemming parameters shows the effective way of optimizing the correlation of hemming parameters. The force is other thing dependent on the hemming material, the outer and inner part geometry and the process settings of the robot roller hemming process. This simulation served as basic input to set up the process, without ever requiring a physical tool. The simulation model will be explained below divided into the following parts:

Geometry, Material, Contact, Robot and path Meshing Process steps and Results.

1. Geometry

An outer part material BH220 is studied.

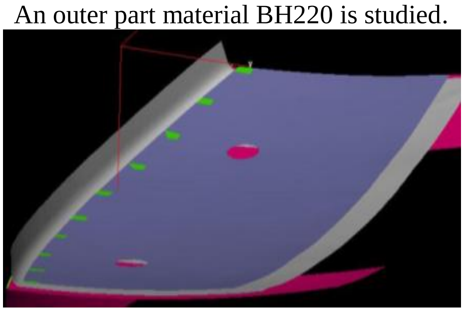


Fig No.-3: Outer and inner part on die.

2. Material

Material	BH220
Yield Strength (MPa)	220 -270
Ultimate Tensile Strength (MPa)	340 -400
Lankford's Coefficient	r -≥ 1, 5
Work Hardening Coefficient n	≥ 0,16Bake Hardening
BH2 (MPa)	≥ 35

Table No. – 1 Material Specification

3. Contact

There are a lot of parts in contact during the hemming process:

• The outer part rests on a hemming die.

• Inner part/Outer part. The inner part rests on the outer part. At the end of the hemming process the outer part toughes the inner part to create a hem.

• Inner part/Down holder. The inner part is constrained by a down holder.
• Outer part/Pre-hem tool. The pre-hem tool bends the flange during pre-hemming.
• Outer part/Final hem tool. The final hem tool completes the hemming by bending the outer part to a hem.

4. Robot and path

In the real process, the robot is composed of several parts, which have a fixed geometry, and all together have a certain behaviour. A robot is composed by a roll, a base and a robot frame. The base, created along the Z-axis of the robot frame, is used to define the robot trajectory.

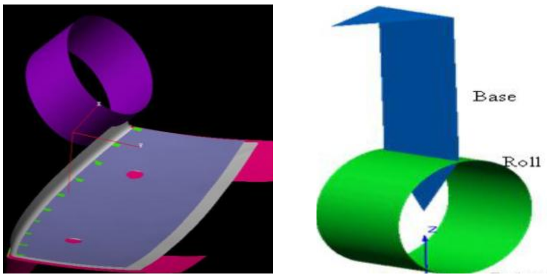


Fig No. - 4: Robot components and path for hemming

5. Meshing

The complete integration of Delta MESH Stamping into PAM-STAMP 2G it is functionality of automatic meshing within the software. With Delta MESH meshing it is certain to obtain a high quality mesh allowing to rapidly starting the design process. As a good simulation result requires a good mesh, Delta MESH will do just based on the initial CAD file; the program will automatically generate a connected mesh.

6. Process steps

In this case, the same robot will pre-hem and hem the flange border in 45° pre-hemming and 0° final hemming. It will go first in one way and then it will go in the opposite way to return to its initial position.

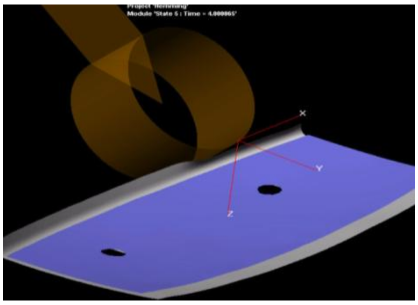


Fig No.-5: Hemming process

For the first way, the arm of the robot will be rotated of 45° in order to pre-hem the flange border. And during the second way, the rotation will be removed in order to hem the flange border. This process will be represented by a mono-stage project in which the robot will have a rotation angle for the first way and no rotation for the return. The change of angle will be done when the robot will be at the end point of its trajectory.

SIMULATION RESULT

During final hemming, this wave pattern can be fully flattened out. But in some cases these wave patterns appear in the end product's quality after final hemming (depicted in Fig No.-6). On the outer surface of the product the wave pattern can be seen, decreasing the dimensional and surface quality. The diameter of the roller has an effect on the deformation area along the flange. It may therefore have an effect on the forming of wrinkles along the flange. By varying the diameter of the roller its effect on roll-in and wrinkling after pre-hemming is investigated.

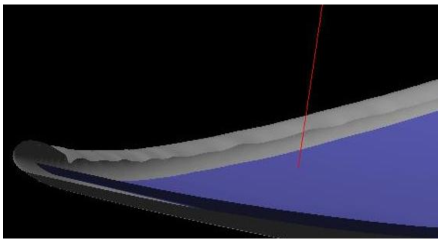


Fig No.-6: Wrinkle formation on the surface

PARAMETER STUDY BASED ON 'DESIGN OF EXPERIMENTS

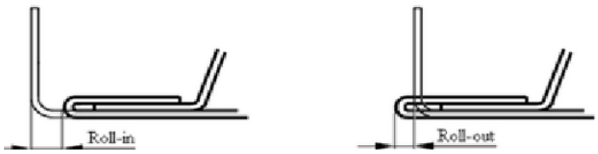


Fig. No -7: Displacement in Hemming Line (a) Roll-in (b) Roll-out

Before discussing some of the important parameters from these mentioned parameters let us study the concept of roll-in and roll-out. The displacement of the contour is called" roll-in" if the outer part edge moves inward and "roll-out" if the outer part edge moves outward as seen in fig. Roll-in and roll-out values affect the visual quality of the parts so that, it should be controlled accurately. These values are preferred to be uniform and small along hemming line. Roll-in tends to be seen on convex contours whereas roll-out tends to be seen on concave edges.

1. TCP-RTP Distance:

The TCP – RTP distance is defined as the perpendicular distance from the roller tool centre point (TCP) to the robot target point (RTP) located at the edge of the hemming bed.

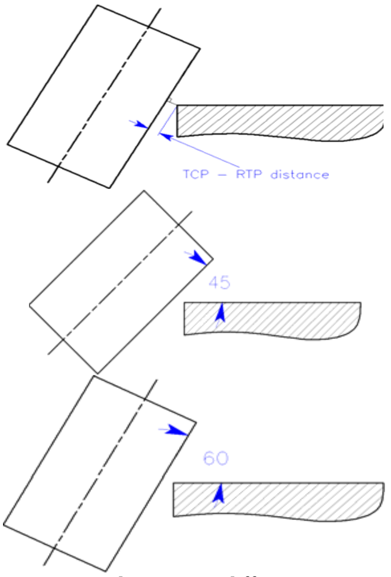


Fig. No-8: The TCP – RTP distance two different orientations of the roller

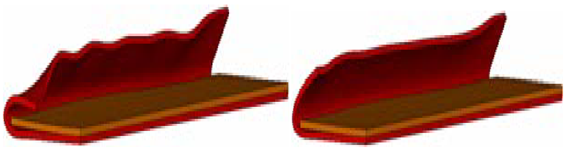
When the TCP – RTP distance is 0.5 mm the theoretical roll-in value is 0.3 mm. This value is taken as the low value of the parameter. The high value of this parameter is 1.5 mm. Very little plastic deformation occurs if this distance is increased more (in combination with a roller orientation of 60°) resulting in zero result values.

2 .Orientation of the roller:

The orientation of the roller is the angle of the roller with the horizontal. The orientation angle of the roller defines in how many steps the product is hemmed. In a standard three step hemming process the orientations are: 60° -> 30° -> 0°.In a two step hemming process they are: 45° -> 0°. Some of the angles are product specific.

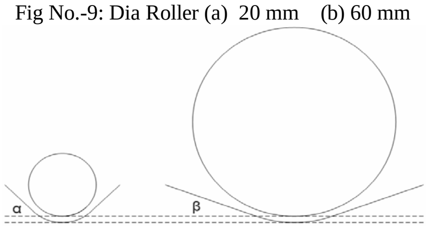
3. Diameter of roller:

The diameter of the roller has an effect on the deformation area along the flange. By varying the diameter of the roller its effect on roll-in and wrinkling after pre-hemming is investigated. The smaller roller shows a wave pattern in the flange after



(a) **(b)**

Fig No.-9: Dia Roller (a) 20 mm (b) 60 mm



(a) **(b)**

Fig No.-10 (a) Line Contact (b) Point contact

The process, whereas the larger roller does not (fig. 10(a) and (b)). The diameter of the roller also determines the size of the stress and strain distribution; the larger diameter shows only a local stress and strain concentration at the top of the flange (point contact). The smaller roller shows a stress and strain concentration over the full height of the flange (line contact). The flange (dotted line) is bent extremer around a smaller roller. The tangent line of the roller at the flange has a larger angle with the smaller roller.

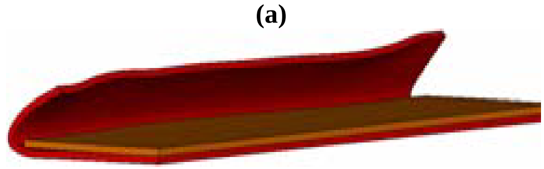
4. Flanging Length:

The flange length (L) is the distance from the bend to the edge of the panel which is shown in fig.. For reducing the defects and compact joint the flange length generally considered is 9 to 9.5 mm. The flange angle is taken from 90° to 110°.The radius (R) of this flange is generally 3mm.The above discussed are some of the important parameters. There are many more parameters like pre-hemming angle, pre-strain, flanging die radius, pre-hammer path, clearance, material of the panel, rolling direction, path of roller, etc.

SIMULATION RESULTS

The simulations of a 20 mm and 60 mm roller are compared with each other with the same process settings. The position and orientation of the forming line depicted in Figure is the same for both simulations and based on: TCP – RTP distance = 1.5 mm and the orientation of the roller θ = 45°.

(a)

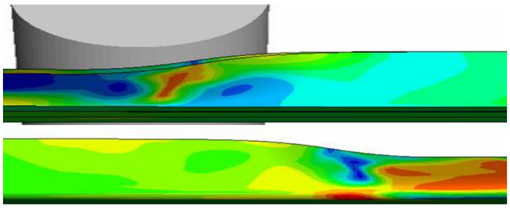


(b)

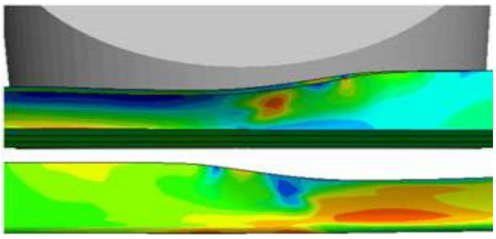
Fig No.-11 Diameter Roller: (a) 20mm (b) 60 mm

More peak stresses are seen in the top of the flange for the bigger roller. These stresses in the material change during the process. Different stress areas are plotted in Figure for the smaller roller. The area in front of the roller is depicted right; in the middle figure the area at the roller is depicted both side. The area behind the roller is depicted left. As can be seen in the figures, the stresses differ from the inside and outside area of the flange. At all areas their states are opposite (tensile – compression).And during the process the stress state alternates between tensile and compression.

The smaller roller shows a wave pattern in the flange after the process, whereas the larger roller does not• When the roller passes the flange, each point in the flange undergoes subsequently a forth and back bending deformation. The diameter of the roller determines the peak value of the occurring bending stress; the smaller the diameter, the higher the peak stress value. The diameter of the roller also determines the size of the stress and strain distribution; the larger diameter shows only a local stress and strain concentration at the top of the flange (point contact). The smaller roller shows a stress and strain concentration over the full height of the flange (line contact). Because the smaller roller shows a resulting wave pattern in the flange after the process.



(a)



(b)

CONCLUSIONS

1. The diameter of the roller determines the deformed shape locally during the pre-hemming and has therefore an influence on the forming of wave patterns along the flange.
2. Simulation show that number of Wave, which is one of the wrinkling characteristic, decreases in the pre hemming stage by using a roller with larger diameter.
3. In all flange heights the smaller roller will bent the flange more. The stress peaks are higher for the smaller roller.

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