Analysis of local thickening by beading and compression using FEM

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Abstract. This paper analysed the local thickening of tailored blanks using Finite Element Method. In this process, local thickening was produced at the centre of the sheet by beading and compression. In the beading process, the sheet is beaded freely and no change in thickness occurs. The beaded area was then compressed with no change in width to form a thicker portion at the centre of the sheet. The amount of thickening formed increases with the increase of the beading height. However for beading height 8 mm folding occurred. These processes do not involve joining and hence stress concentration by the change of thickness can be prevented.

1. Introduction
The demand of lightweight vehicle is increasing to reduce fuel consumption and global emission. Tailored blanks having thickness distribution are attractive in automotive industry for the purpose of weight reduction. Generally, sheets having different thicknesses and strength are joined together by laser welding and it is called tailor-welded blanks. Tailored blanks control the thickness distribution of sheet metals, and thus material utilization is improved, strength is increased and weight is reduced. For example, area requiring high strength is made thicker, while low strength area is made thinner. Although tailor blanks are advantages, the stress concentration from the change in thickness at the weld area affects the formability of the parts [1]. As the thickness ratio increases, the formability of the tailor welded blanks decreases. Rojek et al. [2] investigated the mechanical properties of the weld zone of tailor-welded blanks. Satya Suresh et al. [3] investigated the formability of tailor-welded blanks joined by TIG and laser welding. During forming, thinner area deforms more as compared to the thicker area and hence failure occurs at the thinner one. Tailored blanks without joining are also produced by rolling process [4]. The gap between rolls is controlled to produce blanks having thickness distribution. The stress concentration is reduced from the gradual change in thickness between thick and thin areas. Han et al. [5] investigated the production of tailor rolled blanks with thickness change in both longitudinal and transverse directions. For cold stamping, the thin area produced by rolling possesses higher strength as compared to the thicker part due to work hardening. Sun et al. [6] reported that tailor rolled blanks for automotive parts improves the energy absorption and crashworthiness. Wernicke et al. [7] produced local thickening of sheets by in-plane swaging. A roller is used to form an accumulation of material and hence thickness is increased.

During stamping of sheet metal, the corners of the stamped part undergo excessive thickness reduction causing the part to fracture. Tan et al. [8] reported that thickness reduction occurred at the inner corner of a wheel disk after stamping for a uniform thickness sheet. Increasing the whole thickness of the part to prevent thinning at a small area will add extra weight and cost. Therefore an optimum thickness distribution is needed to improve the formability of the stamped part without...
adding extra weight and hence the material usage can be improved. Sheets having local thickening are attractive for this purpose as the thickness and strength of the part can be controlled. This study analysed the local thickening of tailored blanks by beading and compression using Finite Element Method (FEM).

2. Approach of local thickening by beading and compression

Figure 1 shows the stages in producing sheet having local thickening by beading and compression. In the 1st stage, the sheet is beaded freely and the beading portion is produced at the centre of the sheet. The width of the sheet reduces while no change in thickness occurs during this stage. Then in the 2nd stage (compression), the beaded portion is compressed to produce local thickening. During compression, force is applied on the flange of the sheet using springs and blank holders to prevent wrinkling. Both ends of the sheet are constrained to prevent change in the width direction. Floating die aids in removing the sheet after the compression process.

![Figure 1: Local thickening of sheet by beading and compression](image)

The analysis of the two-stage forming process is conducted by Finite Element Method using Ansys Workbench software based on explicit-dynamic formulation. The width of the sheet is between 101 mm to 106.5 mm and the thickness is 1.0 mm. The width is varied according to the beading die height, \( h = 3, 5, \) and 8 mm. The dimension of the tools is given in Figure 2. Since the groove of the beading punch and the width of the compression punch is 20 mm, the width of the local thickening will be limited within 20 mm. The beading die is made flat with varying beading heights. The compression die is designed with flanges on both ends to constraint the width of the sheet. Figure 3 shows the finite element model of local thickening by beading and compression. The processes were conducted under one stroke. The material is Aluminium and the properties are as listed in Table 1. The tools are made rigid while the sheet is flexible. The meshing element of the sheet is quadrilateral /triangle.
Figure 2: Dimension of tools

Figure 3: Finite element model of local thickening by beading and compression

Table 1: Material properties

| Properties               | Value |
|--------------------------|-------|
| Density (kg/m³)          | 2710  |
| Young’s modulus (GPa)    | 71    |
| Yield Strength (MPa)     | 290   |
| Poisson’s ratio          | 0.3   |

3. Result & Discussion

Figure 4 shows the resulted sheet having thickness distribution after the beading and compression processes. The sheet follows the shape of the beading die of 180° and forms a beaded portion at the centre. No change in thickness occurs during beading. The compression die limits the change in the width direction to allow for thickening to form. Thickening are formed for beading height 3 mm and 5 mm while folding occurred for beading height 8 mm.
Figure 4: Sheets after beading and compression

The maximum change in thickness for beading height 3 mm and 5 mm are 5% and 70%, respectively (see Figure 5). As the beading height increases the maximum change in the thickness increases. A large beading height will produce large beaded area and hence more thickening are observed. However folding was observed for beading height, $h = 8$ mm. The shape of the beaded area affects the formation of thickening and folding. Figure 6 shows the cross-sectional view of sheets after beading and compression. The beaded area for beading height 3 and 5 mm is triangular while for beading height 8 mm the side walls are almost vertical. The vertical sidewall causes folding.

![Figure 5: Maximum change in thickness after beading and compression](image-url)
4. Conclusion
Local thickening by beading and compression has been analysed by using Finite Element Method. The sheets having thickness distribution were produced without joining. The amount of thickening formed can be controlled by varying the beading height. Beading height of 8 mm produced folding due to the vertical side walls formation after beading process. A formability test is to be conducted in the future to understand the effect of local thickening on the drawing depth and thinning compensation.

References
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