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# Effect of feed and step depth in hole flanging using single point incremental forming

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**Abstract.** Single Point Incremental Forming can be used to form hole flanges in automobile and aerospace applications. In hole flanging using single point incremental forming, a study on effect of feed and step depth on formability has been carried out. Hole flange thickness is taken as formability criterion. Moreover, effect of those parameters on surface roughness has also been studied to understand effect of Single Point Incremental Forming. The results obtained by experimental work were analyzed and are presented here.

## 1. Introduction

Hole flanging operation is used to form flange on a sheet metal with pre-cut hole. In Automobile and Aerospace applications flanging is required to increase strength of edge and for providing support to join other part or for aesthetics. Single Point Incremental Forming (SPIF) is a method of Incremental Sheetmetal Forming (ISF) technique in which a tool with hemispherical head is used to form required shape without the use of die. This technique is cheaper and offers high formability as compared to conventional forming process due to necking suppression [1], [2]. Many researchers have been explored ISF and SPIF process and worked towards establishing it as a standard forming process. [3–10]. The use of SPIF technique for hole flanging operation has been explored by many researchers. Hole flanging using SPIF (HSPIF) process can be performed with multistage approach as proposed by Z.Cui and L.Gao [11]. In their work, three strategies of multistage hole flanging were investigated to achieve better formability and it was noted that increasing flange diameter in small step size gives optimum geometry with high formability. The limitation with multistage approach is high operation time. To reduce the time of operation, single stage approach can be used; it has been explored in detail by M.Borrego et al [12]. Thickness distribution on the formed flange is an important criteria to decide quality of flange. Tingting Cao et al [13] developed a new tool to get uniform thickness distribution, better thickness distribution was obtained as compared to the hole flanging SPIF process using conventional tool.

Effect of operational parameters in any process requires attention as the quality of the part depends on them. Tool rotation speed, feed and step depth are process parameters for SPIF process. Tool rotation speed affects the friction between tool and sheet metal during ISF operation, forming forces, surface roughness and thickness distribution along flange height. Durante et al [14] experimentally investigated the effects of tool rotation in ISF to form a frustum of pyramid on AA7075-O material using Steel tool with hemispherical head. The authors observed that the direction of tool rotation (CW-CCW) does not affect forming forces, but the increase in tool rotation speed decreases the force required for forming. It was also observed that as the tool rotation speed increases, friction between tool and sheet metal decreases. Surface roughness varies but not considerably with variation in tool



rotation speed. In HSPIF, as the tool rotation speed increases more uniform thickness profile is obtained which is similar to SPIF [15]. Increasing the tool rotation speed reduces friction force in HSPIF (same as SPIF) which decreases thickness reduction and surface roughness. Study of process parameters in SPIF by straight groove tests shows that formability increases as feed rate decreases [5].

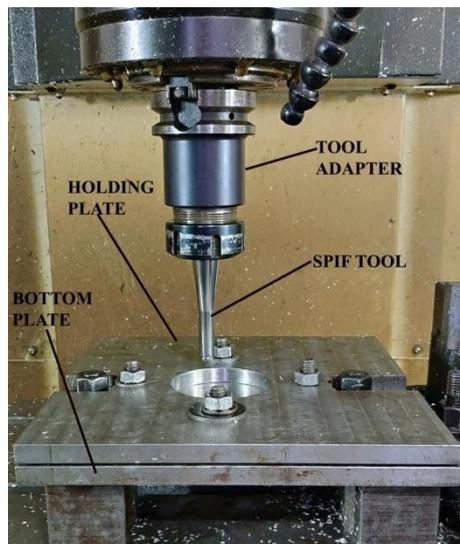
It is observed from the literature review that the parametric study had been carried out for SPIF. However, the effect of feed and step depth is yet to be studied in single stage HSPIF. In this work, experiments were performed to obtain hole flange on Aluminium 1050 sheet metal using single stage SPIF to study effect of step depth and feed on Thickness distribution and surface roughness. The obtained results are analyzed and presented in this paper.

## 2. Experiments

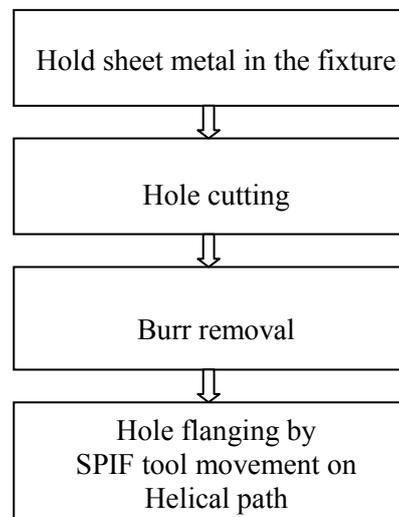
### 2.1 Experimental set up

Aluminium 1050 sheet metal of 1.5 mm thickness was used in this work. The sheet metal was cut into the small sheets of size 100 mm x 100 mm. The sheets were held in a fixture, between holding plate and base plate. The base plate was rested on the table of Vertical Milling Centre with enough gap at bottom to accommodate formed flange. Holding plate and base plate were aligned and held together by bolts, top plate can be slide out to put the sheet metal at required place and then using nuts it was fixed on the bottom plate with sheet metal in between.

SPIF tool of 10 mm diameter with hemispherical head was used to form flanges. The tool was machined on a CNC lathe from a round bar of EN31 material and after machining it was hardened and tempered. The tool was traversed along the contour to form a hole flange. CNC programs were used for traversing the tool. The experimental set up is shown in fig.1 (a).



(a)

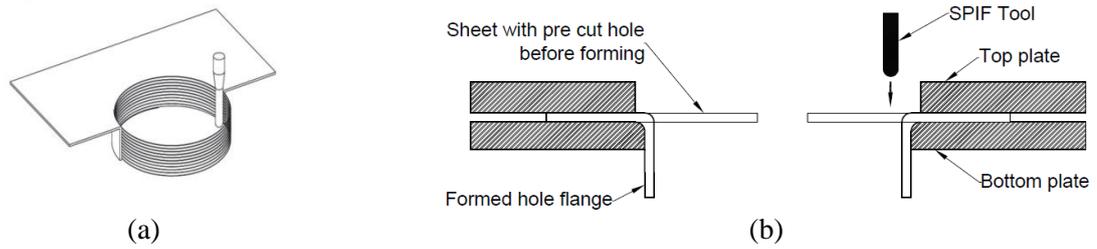


(b)

**Figure 1** (a) Experimental Set up, (b) HSPIF process steps

### 2.2 Methodology

The HSPIF process steps are shown in fig.1 (b). The sheet metal was held in the fixture and hole cutting (not drilling) was done using end mill cutter. It was required to remove burrs from the hole edge manually. Then lubricant was applied on the top surface of the sheet. Hole flanging was then carried out by moving the SPIF tool on a helical path as shown in fig.2 (a), the pitch of the helical path is equal to the step depth. Single stage approach as shown in fig.2 (b) was used for the process.



**Figure 2** (a) Tool path of HSPIF , (b) Single stage approach of HSPIF

To analyze effect of feed on thickness and surface roughness, experiments were performed by varying the feed value from 600 mm/min to 2100 mm/min in the steps of 300; constant step depth value of 0.5 mm was used for all experiments. To analyze effect of step depth on thickness and surface roughness, experiments were performed by varying step depth value from 0.5 mm to 1.75 mm in the steps of 0.25; constant feed value of 300 mm/min was used for all experiments. The experimental data used for the experiments are shown in table 1. Thickness was measured by pointed anvil micrometer and surface roughness was measured by portable surface roughness tester.

**Table 1** Experimental data

| Tool diameter | Sheet size      | Sheet thickness | Pre cut hole diameter | Final flange diameter | Tool Rotation speed |
|---------------|-----------------|-----------------|-----------------------|-----------------------|---------------------|
| 10 mm         | 100 mm x 100 mm | 1.5 mm          | 34 mm                 | 58 mm                 | 0 rpm (no rotation) |

**3. Results and Discussion**

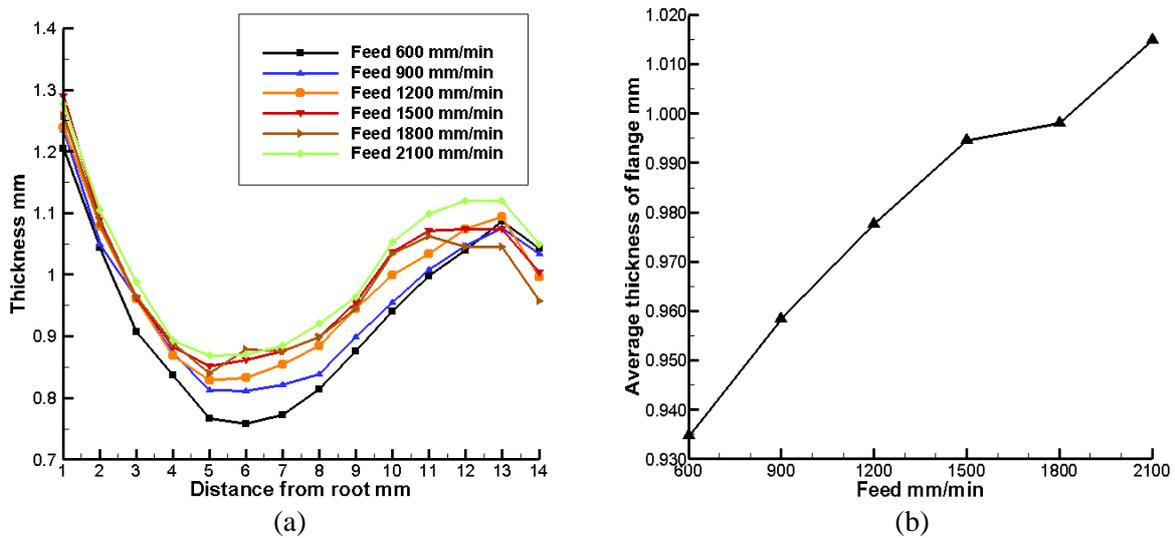
*3.1 Effect of feed*

Experiments were performed to study effect of feed on thickness distribution, average thickness and surface roughness. The formed hole flanges are shown in fig.3.



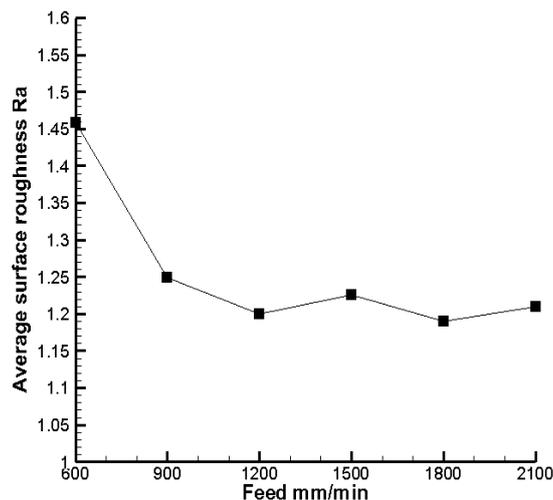
**Figure 3** Hole flanges formed using SPIF to study effect of feed

The thickness was measured on the flange at four places at interval of 90° circumferentially and at interval of 1mm along the flange height. Then, average of circumferential values was calculated which gives average thickness distribution on the flange.



**Figure 4** (a) Effect of feed on thickness distribution on flange, (b) Effect of feed on average thickness of flange

The thickness distributions on flanges obtained from experiments with varying feed rate are shown in fig.4 (a). It is observed from the plot that as the feed rate increases the thickness at most of the measured point increases and the overall thickness distribution comparatively becomes more uniform. Moreover, the average thickness values along the flange height were calculated and have been presented in fig. 4 (b). It is observed from the plot that as feed rate increases, the average thickness increases. The reason behind this change in thickness distribution and average thickness may be the change in dynamic friction between the tool and sheet metal with change in feed rate. As the feed rate increases, dynamic friction decreases because the tool and particular spot on sheet metal remains in contact for lesser time. This results into less wear of sheet metal, so the thin layer chipping during the process decreases and thicker flange is obtained. The difference in thickness value is found to be 17 % when the feed was increased from 600 mm/min to 2100 mm/min. This will help to form the components at faster pace with better formability.



**Figure 5** Effect of feed on surface roughness

The surface roughness was measured along the flange height on all the flanges, results are shown on plot in fig.5. It is observed from the plot that increasing the feed from 600 mm/min to 900 mm/min reduces the surface roughness Ra value from 1.459 to 1.229. However, the experiments with feed 900 mm/min to 2100 mm/min do not show much change in the surface roughness.

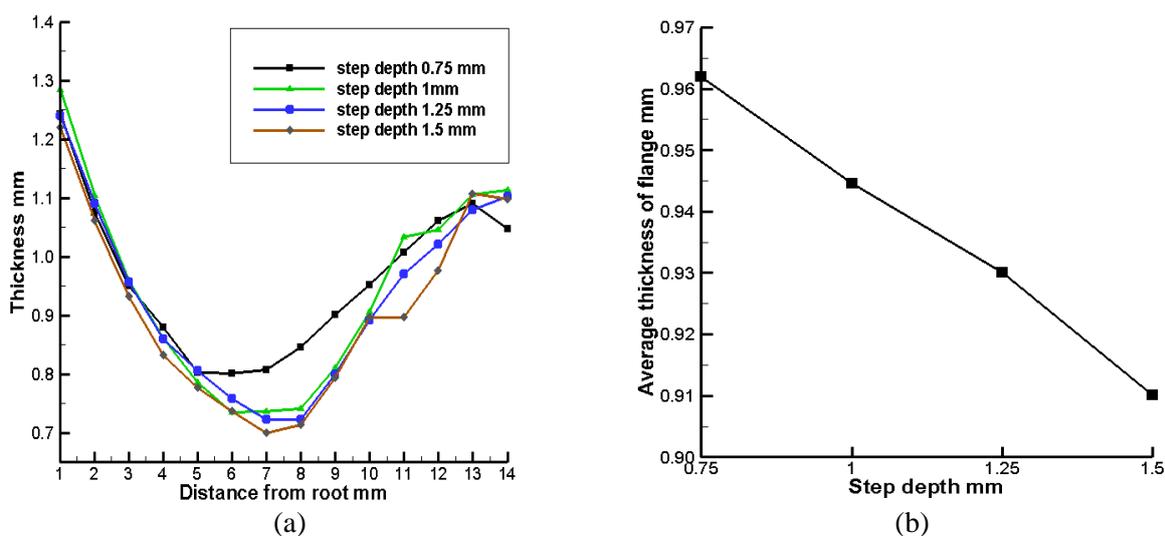
### 3.2 Effect of step depth

Experiments were also performed to study effect of step depth on thickness distribution, average thickness and surface roughness. Hole flanges were formed by varying the step depth value while the feed was kept constant as 300 mm/min. The measurement of thickness was carried out in the similar way as mentioned above. The formed hole flanges are shown in fig.6.



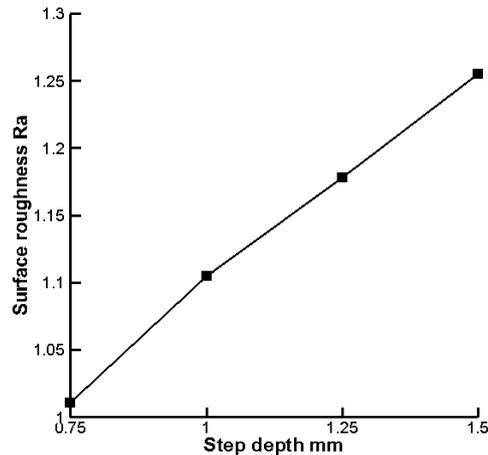
**Figure 6** Hole flanges formed using SPIF to study effect of step depth

The thickness distributions on the flanges are shown in fig.7 (a). It is observed from the plot that as the step depth increases thickness at most of the places along the flange height decreases. The overall thickness distribution is better with smaller step depth value. Moreover, the average thicknesses of flanges were calculated and are shown in fig.7 (b). It is observed that with increase in step depth the average thickness of the flange decreases. As the step depth is equal to the pitch of the helical path of tool, it is the distance tool moves vertically per radial movement. In case of increased value of step depth, tool stretches more amount of material in downward direction. So, in comparison with low step depth value, higher step depth results in more stretching of sheet; which reduces the thickness of sheet as observed from the plot of thickness distribution and the plot of average thickness of flanges in fig.7. The difference in the thickness value is found to be 5 % when the step depth changed from 0.75 mm to 1.5 mm.



**Figure 7** (a) Effect of step depth on thickness distribution on flange, (b) Effect of step depth on average thickness of flange

The surface roughness (Ra) values were measured along the flange height on inner surface of the formed flange. The change in surface roughness with change in step depth values can be observed from fig.8.



**Figure 8** Effect of step depth on surface roughness in HSPIF

It is observed that as the step depth increases the surface roughness increases. The higher value of step depth increases the distance of tool travel in vertical direction which results into bigger circumferential marks on the inner surface of the flange and increased surface roughness.

### Conclusions

The increase in feed rate enhances the formability (17% in average thickness). The increase in step depth results in reduction in formability (5% decrease in average thickness). However, both parameters do not have substantial effect on surface roughness. Higher feed rate and moderate step depth may result in faster production with optimum formability.

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