Comparing Two Robot Assisted Incremental Forming Methods: Incremental Forming by Pressing and Incremental Hammering

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ABSTRACT: This paper explains and compares two different robot assisted incremental forming processes: robot assisted incremental forming by pressing and robot assisted incremental hammering. Both processes are based on robot assisted forming, but forming of the material is different. In this study, these two processes have been used to form the same test geometries. The deformed geometries have been compared and analysed. The measurements include material elongations, sheet thinning and sheet surface hardening.

Key words: Incremental Forming, Industrial Robot, Incremental Hammering

1 INTRODUCTION

In recent years new sheet metal forming processes have been developed and introduced to industry in order to increase the flexibility and meet the present-day challenge of manufacturing prototypes with flexible forming technologies, [1][2]. The trend in sheet metal forming industry is to manufacture more complex parts a and faster introduction of new and individual products in small lot series [3]. Incremental forming (ISF) is suitable for this kind of manufacturing and has great potential in flexible production.

ISF is performed in several variations all over the world. The forming machinery varies from special incremental forming machines to milling machines and robot assisted forming.

Typically the forming methods have been classified according to the number of contact points in the forming. There are two variations, that are presented in Figure 1, two point incremental forming (TPIF) and single point incremental forming (SPIF). Variations A and B describe the TPIF process, and variation C shows the SPIF process principle. In TPIF there are two contact points with the sheet: the tool and the supporting tool. In SPIF no support tools are needed.

Most of the forming machinery can be used both for TPIF and SPIF processes, which creates a number of process variations. In literature all incremental sheet forming processes are considered as one, even if the conditions of the processes can be very different from each other.

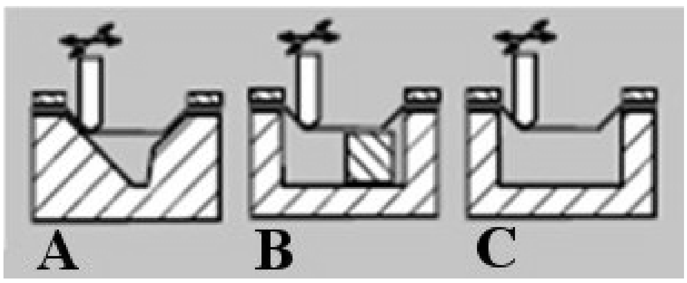

Figure 1. Incremental forming variations

This paper concentrates on robot assisted incremental forming. It describes and compares the two different robot assisted incremental forming processes: robot assisted incremental sheet forming by pressing (RAIFP) and robot assisted incremental sheet forming by hammering (RAIFH). Both processes are based on robot assisted forming, but the way of deforming the material is different.

2 ROBOT ASSISTED INCREMENTAL FORMING PROCESSES

2.1 Robot assisted incremental forming by pressing

RAIFP is patented by Tuominen [4] and further developed by Vihtonen et al [4] . In this method the material is deformed by pressing and sliding a forming tool on the surface of the blank, similarly to most of the incremental forming process variations. The forming equipment is shown in Figure 2. The forming method is based on a strong industrial robot, that is used to perform a TPIF process, i.e. to press the forming tool against the sheet metal along the predetermined forming path and thus forming the sheet metal into desired form. The parts are formed on the convex surface, while the blank holder descends as the forming proceeds. Also SPIF process is possible with this setup, by fixing the vertical movement of the table and changing the path generation mode.

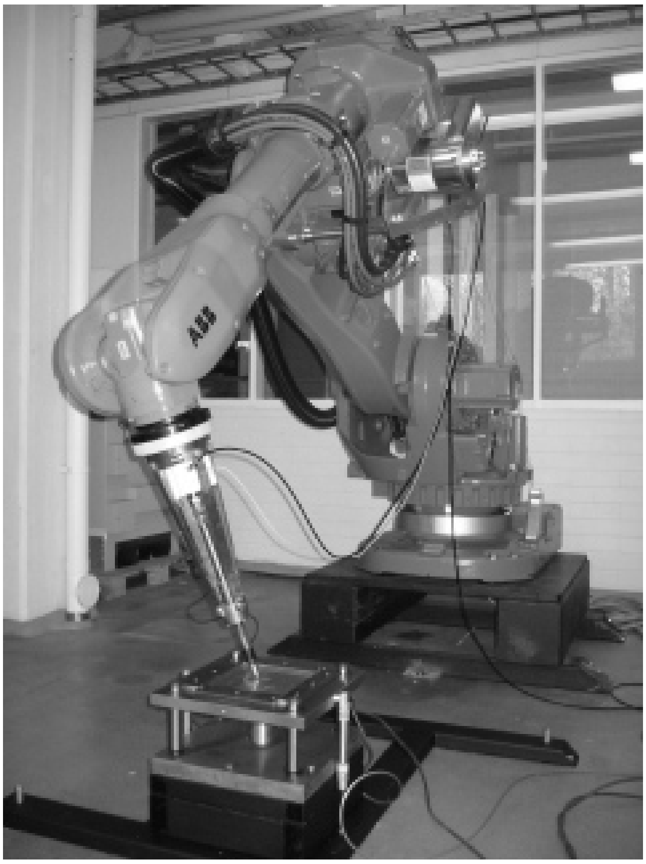

Figure 2 Setup of RAIFP

Tools used in forming are cylindrical poles with a polished spherical end with a diameter varying between 6 and 25 mm. In the pressing application the parts are formed from the convex surface, which makes the support tool necessary. There are also applications of concave forming, where support tools are not needed, or their need is smaller. In these applications the material tends to move to the bottom of the part and create a bump in the bottom.

A support tool below the sheet blank is always required when forming on convex surface, regardless of the incremental forming method. Simple geometries can be formed using a simple support tool, such as a square bar, at the highest point of the part. With complicated geometries the support tools are met with higher demands, in some cases even a complete support. A support is always needed under the highest point of the part and under the edge of planar surfaces. If the edge is not supported, the metal bends unwantedly as the forming proceeds.

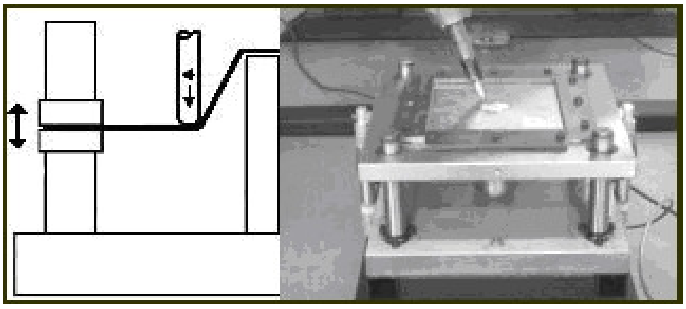

Figure 3 Forming principle and a small forming table in RAIFP

2.2 Robot assisted incremental hammering

In RAIFH the deformation of sheet metal is caused by a hammer tool. The high-frequency oscillating hammer punches creates the deformation of the sheet metal. Similarly to RAIFP a strong robot is executing the movement with the interacting hammering tool above the clamped sheet metal (Figure 4). Contrary to RAIFP, RAIFH is working absolutely dieless. The sheet is clamped horizontally, with a fixed clamping fixture, and not supported beneath. By high-frequency hammering along the predetermined path the sheet metal deforms concavely to the designated shape. Additional convex details can be formed by turning the part and forming it from the reverse side. Thus combined concave and convex geometries depend on different forming strategies. If the geometry makes it necessary parts have to the rotated and formed in different forming steps.

The hammering tool itself consists of an eccentric connecting rod which excites the vertical movement of the tool. In order to reach a high frequency and a stabilized system the eccentric punch of the hammer is balanced by two mass rings, [5]. Since the forming tool executes hammer punches most of the deformation remains below the hammering tool because of the inertia of the sheet metal. The forces in direction of the moving path can also be reduced to a minimum.

TPIF can also be used in RAIFH. In order to be able to form the largest variety of geometries and to meet the requirements to reduce tooling, and thus costs, research on SPIF is preferred.TPIF was also tried out with RAIFH, but in order to be able to form the most possible combinations and varieties of geometries and to meet the requirements of the industry to reduce tooling supports and thus costs most research on SPIF was done.

Table 1 shows the comparison of RAIFP and RAIFH in terms of the most important geometrical and process parameters related to this technology.

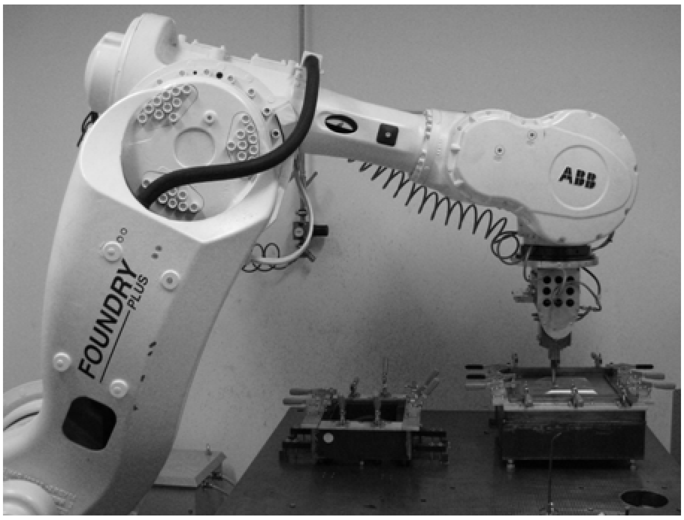

Figure 4 Operating setup of RAIFH

Table 1 Comparison of RAIFP and RAIFH processes

Parameter	**RAIFP**	**RAIFH**
Wall angle	n. 70°	60°-70° depending on material
Radii	Depending on material and total geometry, appr. r~2mm	
Working area	Machine dependent, not process limited	
Materials (forces)	Al 5mm Mild steel 3mm Stainless steel ~2mm	Al 3mm Mild steel 2mm Stainless steel ~1mm Also other materials
Programming	Commercial CAD/CAM, Machine dependent control software	Commercial CAD/CAM, translator between CAM and the robot developed by IPA

3 STRAIN TESTS

Two test geometries were formed with both forming methods, a circular cone with a upper diameter of 32mm (A) and a square cone with a upper side length of 40mm (D). They are shown in Figure 5. The geometries were formed with both methods, but on different side. RAIFP formed the convex surface of the parts and RAIFH formed the concave surface of the parts. The height of both geometries was 100mm, but the forming was stopped when the material fractured. A 0,75 mm thick deep drawing quality steel DC04 was used as a test material. All the sheets were marked with 2mm square grid for measuring the strains after the forming. The measurement was taken from the first sound square next to the fracture.

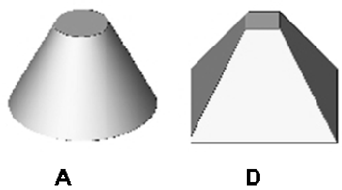

Figure 5 The test geometries

4 RESULTS

The true strains measured from test parts are presented in Figure 6 and Figure 7, each forming method in one chart. They show the known fact, that strains in ISF are significantly higher than in conventional forming. In addition to that, these results show that the robot assisted methods produce similar strains in direction of major strain, but on the minor strain the RAIFH produces wider range of strain states.

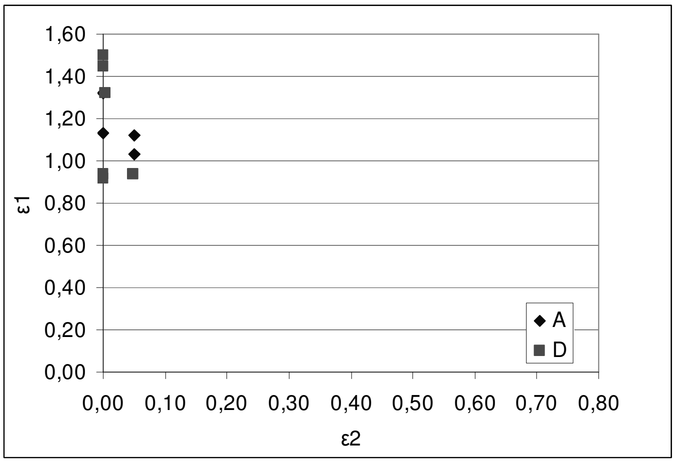

Figure 6 True strains with RAIFP for geometries A and D

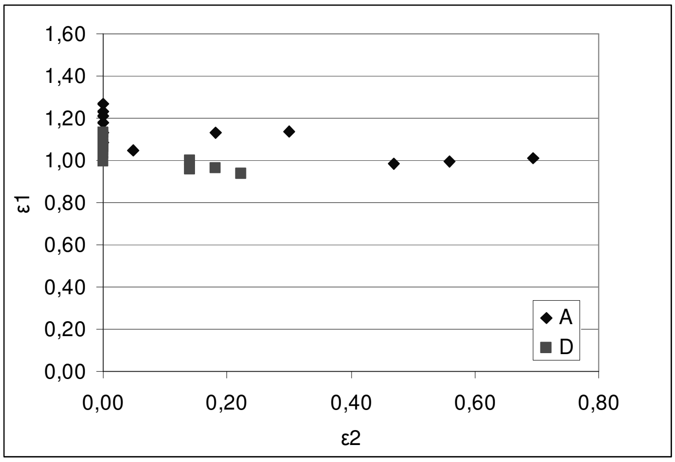

Figure 7 True strains with RAIFH for geometries A and D

The sheet thinning was also measured. With the same material and the same test geometry, the thinnest part of RAIFP-formed part was 45% of the original thickness, and the part formed with RAIFH was 30% of the original thickness.

5 CONCLUSIONS

The results of this research show, that the two forming methods are very close to each other. The both methods are able to form same features, and neither one of them is more capable in terms of geometrical features. However, hammering forming can be used to form perforated steel, which is not possible with the pressing forming.

The results of the strain measurements show that the strains achieved with robot assisted incremental forming methods are very close to each other in the direction of main (major) strain. The strains are also significantly higher than what is achieved with conventional forming methods, which is a commonly known fact. Interestingly the strain in the direction of minor strain differs between RAIFP and RAIFH. One explanation for this is that in RAIFH the deformation is caused by a single punch, and not by pressing or drawing.

The material formability appears to be slightly larger in hammering, when simple geometries are formed. Yet the experiments on industrial cases show that in larger geometries the sheet tears a earlier than the forming limit studies suggest. Material thinning is strong in both of the forming methods, but appears to be stronger in hammering, the final thickness being only about 30% of the original thickness. This, and the vibration of the sheet during forming can cause the earlier fracture.

Future work should cover more materials and more test geometries to be able to define the limits of the process thoroughly. Forming limit diagram as itself is very likely not the correct tool for determining the limits of ISF processes.

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