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A Novel Modification to the Incremental Forming Process, Part 2: Validation of the Multi-Directional Tooling Method

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Abstract

Incremental forming (IF), a novel sheet material forming technique which has the ability to eliminate the need for die sets, forms sheet material through the use of a non-cutting tool that gradually deforms the sheet material into the desired shape. Generally, the shape of the tool tip is a hemisphere.

In the following works, the authors validate a novel tool shape, presented in Part 1 of this research, that allows forming of the sheet material in multiple directions at a rapid rate. The works described herein demonstrate that a more complex tool tip can result in greater formability, improved surface finish, and reduced springback. The tested tool tip shape described herein is that of two hemispherical tips, revolved about a common radius from a single axis, vertically offset to half of the tool path's step size.

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Keywords: incremental forming; springback; formability; tool geometry; surface finish

1. Introduction

Incremental forming (IF) is a sheet material forming method with great potential in the manufacturing industry. IF is a process which uses a computer numerical control (CNC) mill or dedicated IF machine to control a hemisphere shaped tool that forms the material. The most common toolpath used is a helix, which begins at the outermost perimeter of the desired shape and gradually travels downward, moving along the part's contours. Two variations of the IF process are single point incremental forming (SPIF) and double point incremental forming (DPIF). The

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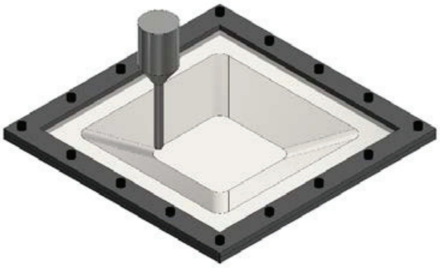

Figure 1. Representation of a typical single point incremental forming setup

primary difference between these processes is that SPIF utilizes only one forming tool, while DPIF utilizes two (one on either side of the sheet material). Figure 1 shows an example of a common SPIF setup.

IF has the advantage of being a dieless forming process, which makes it desirable for manufacturing companies. While IF requires greater deformation energy than stamping due to the significantly larger displacement of the tool, the process greatly saves material [1]. IF is an excellent forming method when prototyping parts since it does not require the use of dedicated dies. Therefore, parts can be changed quickly by changing the tool path of forming.

In addition to being a material-saving process, IF also has an advantage over traditional stamp and die forming in that it enables the sheet material to deform above the conventional strain-based forming limit. This was discovered to occur because the top, middle, and bottom surfaces of the material do not exceed the forming limit curve simultaneously [2]. Others have proposed additional contributing factors that increase the forming limit, such as through the thickness shear [3].

While IF, in general, is a widely-researched topic, variations in the type and geometry of the tooling have been largely neglected. The most common tool shape is a hardened steel hemisphere. This shape allows for simple and quick machining and provides relatively effective results. It was found that, in order to obtain the greatest levels of formability using this method, the largest possible diameter tool tip should be used [4]. Choosing a slow feed rate for use with this type of tool can also increase formability [5].

A roller-ball type tool has been investigated for use in IF. This tool uses a free-spinning sphere mounted to the end of the tool in order to contact the material, and can be used with or without lubricant. Using this tool reduces friction and improves formability, as well as surface finish [4-6]. Another forming tool geometry employs a flat-end tool; shown to improve profile accuracy, formability, and reduce forming forces [7]. Also, the effects of vibrating and ultrasonic tools have been shown to decrease forming force, decrease springback, increase formability, and improve surface finish [8,9].

Covered in Part 1 of the present works are novel variations of IF tooling. These modifications can be seen as the use of asymmetrical tooling, which features structures offset from the axis of the tool. By creating a tool in this manner, it was proposed that the surface finish, formability, and springback can all be improved, without the need for complex vibrating machinery [10].

2. Tooling

In traditional IF, the material is formed in one general direction and is formed at the desired feed rate. It was discussed in Part 1 that many improvements can be seen when using tooling which featured an offset structure [10]. This would increase formability by spreading the forming region across more material. Additionally, surface finish would improve from the “smearing” effect of the tools’ movements. This research aims to validate the performance of this forming method.

While the effects discussed in Part 1 can be achieved using many different tool configurations, the tool shown in Figures 2 and 3 was used for the validation testing that is described herein. The tool features two, 9.5 mm (0.375”) diameter hemispherically shaped tips constructed from 50-55 HRC hardened steel. These tools revolved about a