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ScienceDirect

Procedia Manufacturing 10 (2017) 510 – 519

Procedia MANUFACTURING

45th SME North American Manufacturing Research Conference, NAMRC 45, LA, USA

A Novel Modification to the Incremental Forming Process, Part 1: Multi-Directional Tooling

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Abstract

Incremental forming (IF) is a novel sheet material forming technique, which has the ability to eliminate the need for die sets. The IF method forms sheet material by use of a non-cutting tool, which gradually deforms the sheet material into the desired shape. In the following works, this research proposes a range of novel tool geometries that allows forming of the sheet material in multiple directions at a rapid rate, allowing for greater formability, improved surface finish, and reduced springback. Additionally, several tool features are proposed which achieve this forming motion. Part 1 of this research describes the design of the tooling, as well as variations that are possible with the tool's geometry. In part 2 of this research, the proposed forming method is validated.

Peer-review under responsibility of the organizing committee of the 45th SME North American Manufacturing Research Conference

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

1. Introduction

Incremental forming (IF) is a sheet material forming method, which has proven to have great potential in the manufacturing industry. IF uses a machine, such as a computer numerical control (CNC) mill or a dedicated IF machine, to control a hemispherically shaped tool that forms the material. IF has the advantage of being a dieless forming process, which makes it desirable for industry. Relative to other aspects of incremental forming (e.g.

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Peer-review under responsibility of the organizing committee of the 45th SME North American Manufacturing Research Conference
doi:10.1016/j.promfg.2017.07.035

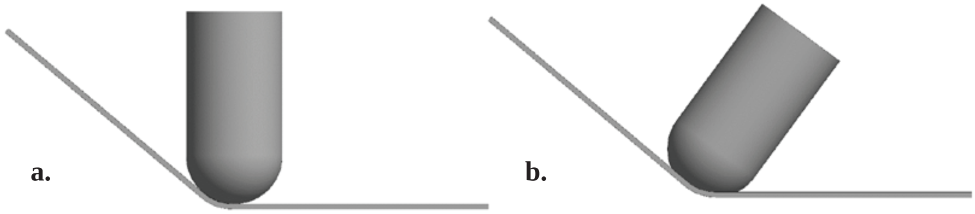

Figure 1. Comparison view of (a) conventional single point incremental forming and (b) a common robot incremental forming configuration

forming conditions and process parameters, etc.) the tooling used in incremental forming has been a largely neglected area of development. However, limited research does exist on variations of tooling/tool geometry.

The most common tool shape is a polished hemisphere constructed out of hardened steel. These parameters allow for simple and quick machining and provide relatively effective results. When utilizing this shaped tool, to achieve the greatest part accuracy, it is best to choose as large of a radius as possible while not exceeding the smallest radius of the desired geometry, as a larger tool tip results in part inaccuracies in corners of the formed geometry [1]. When aiming to increase formability, an optimum ratio of tool size to sheet thickness must be found [2,3]. Choosing a slow feed rate for use with this type of tool also can increase formability [3].

In addition to the rigid hemisphere tool tip, a roller-ball type tool was investigated for use in IF. This type of tool incorporates a free-spinning sphere mounted to the end of the tool, and can be used with or without lubricant. Using this tool reduces friction significantly and improves part formability and surface finish [1,3,4].

Flat end tools have also been used in IF [5]. The tools used were cylinders of various diameters, with different sized edge radii. It was found that the flat end tools result in better profile accuracy compared to conventional, hemisphere, tipped tools. It was observed that the hemispherically tipped tools left the unformed region at the interior of the formed part curved. The flat end tools are able to spread the tools deformation such that a portion of the interior section of the part is formed in addition to the wall of the part resulting in a flat region in the center of the part. Additionally, under optimal parameters, the formability of the forming process can be improved. Utilizing the flat end tool also results in lower forming forces.

An expedient variation of the incremental forming process was created by Kwiatkowski and Tekkaya [6,7], in which two forming tools are positioned on one side of the sheet material. The tools then form the material simultaneously. By using this method, the forming time can be reduced significantly. Several mechanisms capable of performing this action were proposed.

The use of a 5-axis machine to control the forming tool can also be seen as a variation of the tooling process, as it enables the material to be contacted in ways not achievable by conventional means. Figure 1 shows a comparative view of conventional SPIF and this modification. This process, also known as Robot Incremental Forming, is a moderately researched process and several advances have been achieved. A hammering tool has been developed which applies a hammering motion to the workpiece. It was concluded that this modification only changes the minor strain value and slightly increases the formability of the process when forming simple geometries [8-10]. Additionally, various methods have been employed which aim to increase the geometrical accuracy of formed parts [11,12]

The hammering tool used in robot incremental forming is similar to the ultrasonic vibration tool used in conventional SPIF. This tool vibrated at 20 ± 0.5 kHz with an amplitude of 7.5 µm. The addition of ultrasonic axial motion to the tool resulted in decreased forming force, decreased springback, increased formability, and improved surface finish. However, only one frequency and amplitude was investigated, and no correlation can be given to frequency/amplitude and the various effects on these results [13,14]. Other investigations of vibrating tools show similar results [15].

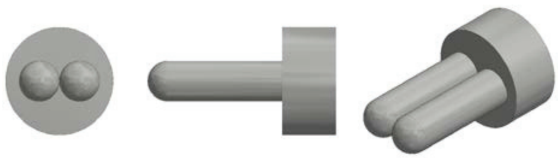

Figure 2. Example model of an asymmetric tool