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Automated Driving by Standardizing and Scaling the Manufacturing Strategy

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Abstract

Driving, an incremental forming method, can be carried out on driving machines. In a past project, this traditionally manual manufacturing method was automated through performing manual manipulations and manufacturing identical parts by robot handling. An advancement of this automation scheme is to define a set of standard sheet metal parts and derive a manufacturing strategy by combining tracked strategies for these standard parts. In this paper, we present a method to derive manufacturing strategies for geometric variations of standard sheet metal parts. In addition, a model describing the relation between geometric and process parameters is built to improve transformed manufacturing strategies.

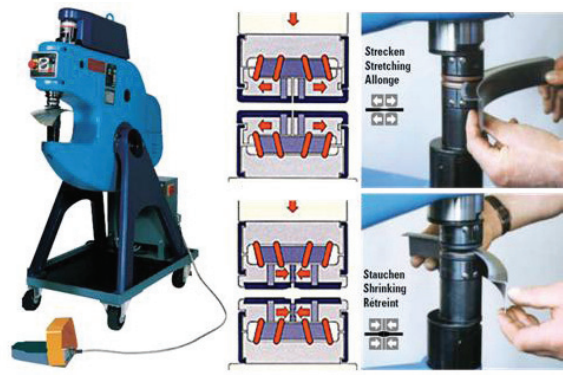
Keywords: Incremental Forming; Driving; Automation; Standardization; Transformation; Manufacturing Strategy

1. Introduction

In the field of sheet metal forming, there is a tendency towards reducing time cycles of production and at the same time achieving a high degree of customization as well as to an increasing number of prototypes. This requires a flexible and economic manufacturing method for individual part and small batch production.

One option to achieve these objectives arises from the so called Amino-Method. Since the early 1980s many investigations have been made to modify and optimize this process and to identify limits and constraints on it [1], [2]. Even though much effort has been spent in order to decrease these limitations, still there are strong bounds on the process [3], [4].

Within the framework of this paper we will focus on a more promising alternative to meet the requirements stated at the beginning: The driving process, an incremental forming method, which is carried out by a driving machine, the so called Kraftformer (Fig. 1 (a)). The machine employs universal tool sets that can be used to create almost any geometry for the sheet metal parts.



(a) (b)

Fig. 1. (a) Driving machine; (b) Driving tools for stretching and shrinking [5]

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The main tools used on the driving machine can perform stretching and shrinking in local forming areas of the metal part (Fig. 1 (b)). The final geometry is produced by this incremental forming method in a large number of steps. Even though this process is one of the oldest known incremental forming methods, systematic research investigations in this area have not started before 2001.

Research effort has been put into studying and analyzing the driving process and clarifying the scope and spectrum of applications [6], [7], [8], [9].

Driving is traditionally a manual manufacturing method. It needs to be automated to reduce the labour costs and to achieve cost-effective production. In [10], the automation scheme copied driving was introduced, in which an industrial robot was used to replace the manual manipulations. This automated driving process has two steps: The first step is to synchronously record the process parameters (stroke positions and forces) as a manufacturing strategy in the manual forming process by an optical tracking system; the second step is then to translate the manufacturing strategy for the interaction between the robot and the driving machine.

Because of the manual tracking step, the method developed above is suitable for a small batch size but not for individual parts. In order to further increase the automation level or rather to reduce the manual work in that automation process, it is proposed to derive the manufacturing strategy for a new metal part from a database of standard manufacturing strategies.

2. Problem Formulation

Driving is a very complex forming process, in which the material properties are changing by work hardening and the contact conditions are varying with every stroke. This makes it very difficult to directly model this driving process, thus a model-free idea will be presented here. It uses knowledge developed within the copied driving project, see [10]. The process is depicted in Fig. 2.

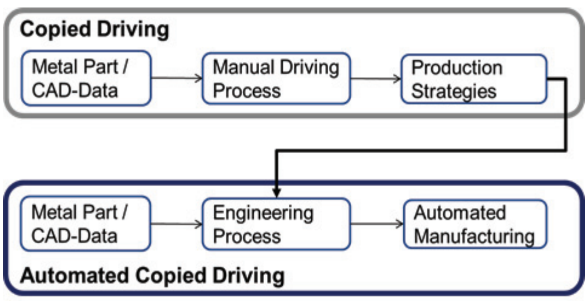

Fig. 2. Automation scheme: Automated copied driving

To further automate the manufacturing process, we now aim at completely replacing the manual driving step by deriving a manufacturing strategy for a new metal part from the strategies already recorded. The first step is to define a number of standard metal parts, from which, after a suitable fragmentation, the new metal part will be constructed. To keep the required number of standard metal parts as small as possible, it is essential to derive manufacturing strategies for transformed variants of these standard metal parts from the recorded manufacturing strategies. This transformation process will be the main focus of this paper.

3. Problem Formulation

With a manufacturing strategy, a metal sheet can be formed into some desired end geometry. On the one hand, while the number of manufacturable end geometries is infinite, the geometry features are mathematically describable by a limited number of geometric parameters. On the other hand, there is an infinite number of manufacturing strategies, even for a single corresponding geometry. Hence, it is essential to define a sheet metal part with a standard geometry and a corresponding manufacturing strategy.

3.1. Extraction of geometry features

Fig. 3 shows a motorbike tank that was produced by copied driving. It consists of a total of 10 metal parts welded together. These parts have different but similar geometries. The geometric features of one of them can be extracted and idealized into a combination of four simple geometrical components: one flat square surface, two quarter cylinders and one eighth of a sphere. Of course, the other combinations of the geometrical components could also be defined as required.

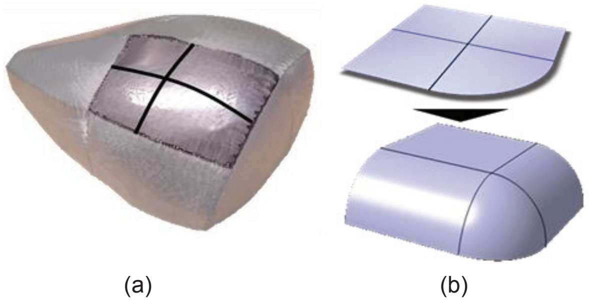

Fig. 3. (a) Motorbike tank, produced by the copied driving; (b) Exaction and idealization of the metal part

3.2. Standard manufacturing strategy

To obtain the geometry defined in the last section, the metal part must be formed with the driving machine using some manufacturing strategy. Such a strategy contains the forces of the strokes together with the six-