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Evaluation of forming forces in ultrasonic incremental sheet metal forming

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Abstract: In this paper, a new type of sheet metal forming technology using ultrasonic vibration applied to SPIF (single point incremental forming) process is presented. Forming force during forming process can induce fracture and affect accuracy of the sheet metal. Design of ultrasonic sheet metal forming equipment can be based on this study, which takes into account magnitude and changing law of the forming force. ABAQUS finite element software was used to simulate and analyze influence of different frequencies and amplitudes of ultrasonic vibration on the forming force in single point incremental forming process. Results show that ultrasonic vibration can reduce forming force and improve surface quality of the forming process. In addition, an experimental system using ultrasonic single point incremental forming was designed. Effect of the amplitude on ultrasonic vibration was studied experimentally. Experimental results were consistent with the result from finite element simulation.

Keywords: ultrasonic vibration; single point incremental forming; forming force;

1 Introduction

Currently, Small batch production or prototyping of sheet metal is formed primarily employing conventional forming processes with conventional tool and die sets. For example, in the aerospace industry, about 200 stamping dies are used each year for a typical batch size of about 5000 components [1]. However, financial and energy costs are very expensive to manufacture special tools and die sets. In addition, these tools and die sets need to be stored in free time, resulting in inventories that occupy large amounts of space and are very expensive to maintain. Therefore, using traditional forming processes of sheet metal to manufacture small batch production is not very desirable.

In early 1990s, Matsubara first proposed the use of SPIF (single point incremental forming) in manufacturing, and this process is based on the "layered manufacturing" concept used in rapid prototype manufacturing technology [2]. In this process, a complex 3D shape is discretized into a series of two-dimensional contour layers, and processing is implemented the tool on the two-dimensional surface based on a predefined contour layer by layer. Thus, such a process allows digital manufacturing of sheet metal. An advantage associated with using SPIF is the quick turnaround time for development of prototypes. Thus, development and production of multi-variety products in small batches can be achieved at low cost. Application of SPIF technology prevents disadvantages (e.g. lots of die sets, high costs) in products, often associated with traditional sheet metal forming. However, SPIF method has drawbacks such as high forming force, poor quality, and difficulty in forming shape complex parts.

Durante and et al.[3] proposed based on results using finite element simulation and experiments that rotation speed of the tool would affect the friction coefficient, which in turn would result in a change in the required forming force, forming temperature and forming precision. Henrard and et al. [4] used finite element