Abstract of the Thesis

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Title of the Thesis: **Parametric Investigation and Optimization of Single Point Incremental Forming (SPIF) Process for Hard-to-Form Material**

Abstract

Hard to form Ti6Al4V alloy sheet materials are widely used for different industrial products because of their superior mechanical properties. However, since Ti6Al4V is difficult to deform at room temperature due to poor formability, and deformed at elevated temperature. On other hand, the recent market needs have changed from mass production to small batch production such as rapid prototyping as well as customization in the sheet metal industry. Inconventional sheet metal forming, higher cost of tooling and larger lead time are major issues. In order to solve these problems, Single Point Incremental Forming (SPIF) sheet metal process technology can be used to form a variety of sheet metal parts in small batches and prototypes, without use of dedicated tooling at a lower cost. The main attractive features of this process are, reduced forming forces, simple tooling, enhanced formability and greater process flexibility as compared to conventional forming process. SPIF finds application in automobiles, aerospace, automotive, and customized biomedical components.

The present work, realizing the potential advantages of the SPIF process, focuses on determining suitable process parameters that are to be optimized when forming under localized friction heating, caused by high tool rotation. In accordance with planned experiments: preliminary, secondary and final experimentation have been investigated. The experiments were carried out on 0.6 mm and 1 mm thick Ti6Al4Valloy sheets, using an 8 and 10 mm diameter, hemispherical ended tool tip on a CNC milling machine (Jyoti Px- 10) with the tool dynamometer (Kistler-9272), Mitutoyo SJ-400A model of roughness tester, Vernier height gauge and infra- red gun to record the responses. Preliminary and secondaryexperiments are carried out to study the feasibility of Ti6Al4V sheet

forming at room temperature and evaluated the maximum safe forming angle of formed part with the critical input parameters in SPIF process. The effect of process parameters with varying speed, feed, step size and tool diameter on responses such as forming force, surface roughness, and formability has been studied using the Taguchi Method (TM).

Based on the experimental investigation results, the forming force is found to increase with the increase in step size, feed rate and tool diameter, whereas it is found to decrease with increase in spindle speed. The average roughness of formed parts is found increases with step size, feed and speed whereas decreases with tool diameter. The formability of the material (i.e. fracture depth) is found to decrease with, the increase in step size wherein increases with increasing in feed and tool diameter. Prediction regression models are also computed for forming force, surface roughness, and formability using MINITAB-17 software. Models are validated with experimental results with optimum set of parameters for each response under consideration. Further, model of forming force is also validated with the published result. Moreover, multi-optimization studies are also carried out using Taguchi- based Grey Relational Analysis (GRA).

This PhD Thesis would be useful in industrial applications; aerospace, automotive and non-automotive, transportation, biomedical, decorative products, customized and prototype sheet metal forming products made with Titanium alloy grade 5 (Ti6Al4V).

List of Publications:

1. V. D. Golakiya, M.K. Chudasama, Experimental formability study of Ti6Al4V sheet metal using friction stir heat assisted single point incremental forming process, International Journal of Engineering, Transactions C: Aspects Vol. 35, No. 03, (2022) 560-566. https://doi: 10.5829/ije.2022.35.03c.08 (SCOPUS).
2. V. D. Golakiya, M.K. Chudasama, H. K. Raval (2021) "Analyze and optimize thinning and forming force in single point incremental forming on AA6061-T6 using the finite element method" Book chapter: Recent Advances in Manufacturing Modelling and Optimization. https:// doi: 10.1007/978-981-16-9952-8. published in Springer (Scopus indexing).
3. V.D. Golakiya., K.K. Chauhan., T.P. Gundarneeya., "Optimization of single point incremental forming process through experimental investigation on SS 304 DDQ steel", Materials Today: Proceedings. https://doi.org/10.1016/j.matpr.2022. 02.283 (SCOPUS).