ABSTRACT

Single point incremental sheet forming (SPIF) is an agile sheet forming method with high potential to form intricate three-dimensional shapes. This process is mainly used for fast prototyping and low volume production of sheet metal parts. The benefits of SPIF process are highly flexible, short product lead time, low-cost die/tooling and high formability in comparison to conventional sheet forming techniques. Although many research work was carried out to the applicability of this process for industrial use, but unsatisfactory forming quality still hampers its use in industrial purposes. The research in this area is gaining momentum internationally to produce cold forming of polymers by incremental method. This is may be the very first attempt to do incremental forming of polymers in India.

The work in this thesis focuses on the development of SPIF process on polymers at room temperature. A set of polymer sheet materials having potential applications in the field of automobile, electrical and medical appliances are selected and formed to the desired geometry i.e. truncated cone with varying wall angle shape. The geometry was designed such a way that the forming angle varies with respect to depth. To evaluate the applicability of polymers on cold forming during the earlier stages, Erichsen cupping test was carried out. The Erichsen cupping test is a ductility test which is employed to evaluate the ability of sheets and strips to undergo plastic deformation in stretch forming. It was concluded that the polymers sheets can be cold formed same as metal sheets. Furthermore, Forming Limit Diagram (FLD) for polymers in SPIF is performed experimentally. In this thesis, forming angle, thickness distribution, surface roughness and forming

force are investigated by varying the process parameters such as sheet thickness, tool diameter, step depth, spindle speed and table feed. Design of Experiments (DoE) together with the Taguchi method was used to investigate the effects of process parameters and to plan the number of experiments. Three polymer sheets namely Polycarbonate (PC), Polyvinylchloride (PVC) and High Density polyethylene (HDPE) used for experimentation. Experimental results are tested by Analysis of Variance (ANOVA) technique and the regression equation was developed. The obtained result allows selecting suitable parameter to optimize the process. With optimized process parameter a confirmation experiment was conducted on polymers and the results are compared and the results are correlated. The following experimental results are studied with different process parameters and its influences are identified. **(i) Process formability:** The maximum forming angle as well as the successful forming depth were evaluated to clarify their influences on process formability during a cup-forming process. Sheet thickness was found to be the most influential forming variable followed by the step down. **(ii) Forming forces:** The trends in forming forces were analysed considering the influences of different draw angles, sheet thicknesses, step-down sizes and tool diameter during a cup forming process. **(iii) Geometric accuracy:** A study on the effect of process parameters on the accuracy of part produced was carried out. It is concluded that sheet thickness, tool diameter and step-down size on geometric accuracy was implemented. **(iv) Surface roughness:** The variation on surface roughness for the different process parameters are evaluated. Among all the three polymer materials, HDPE exhibits poor surface quality and PVC exhibits a good surface quality. Incremental step size has a significant influence on the surface quality in the sense that greater incremental depth can lead to a low surface quality. The more the step size used in forming, the worse will be the surface quality and vice versa. This can be attributed to the less overlapping of tool over the same path at higher step size.

A key problem encountered in SPIF is the non-uniform thickness distribution of formed parts and excessive thinning on severely sloped regions. This may lead to fracture and limit the process formability. To overcome this problem an innovative forming method was proposed, in which the sheet material is simultaneously heated during forming and parts are formed. The results have been evaluated in terms of the process formability and thickness distribution. The results showed that formability and dimensional accuracy were improved. In the final part of the thesis the formability comparison between metal and polymers are reported with optimum process parameter condition. It shows that Polycarbonate and Polyvinylchloride are formed as metals with limited forming depth in this process.

The work in this thesis explores various aspects of SPIF on polymers, although the most important contribution focuses on process parameter optimization and its validation, which greatly enhances the process formability and obtains more uniform thickness distributions of final products. This provides an insight into the future development and implementation of SPIF technology on forming of polymer parts.