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FINITE ELEMENT ANALYSIS OF INCREMENTAL SHEET METAL FORMING WITH SUCCESSIVE TOOL PATHS FOR USE IN PROTOTYPE MANUFACTURING OF CAR BODY COMPONENTS

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The incremental sheet metal forming process can be described as deforming the sheet metal locally by a special forming tool into the desired final geometry by changing the location of the tool. This process, which is shown schematically in Figure 1, is a preferred forming process for prototype manufacturing, where the number of parts to be produced are low, since there is no (or partial) need for forming dies and the process is flexible since by simply changing the tool path, the geometry of the component can be modified easily. The tool path, generally, is implemented into a G-code script (obtained from a proper CAM package) and programmed into a CNC vertical milling machine which would perform the required motion of the forming tool.

In manufacturing of car body components for prototype, ISF, being a very efficient forming alternative yet, possesses some major drawbacks: Firstly, due to springback of the locally loaded sheet, obtaining desired geometrical tolerances are not easy. Secondly, some geometrical details, like walls with inclinations close to perpendicular direction to the sheet axis are hard to obtain in one tool pass due to the tearing of the sheet. With such drawbacks, it is not easy to design a tool path by just inspection and experience, especially when more than one tool path is to be implemented successively to obtain the desired geometry. Therefore, numerical simulations to justify the designed tool path are inevitable.

In this study, a selected car body component is manufactured by ISF. It has been shown

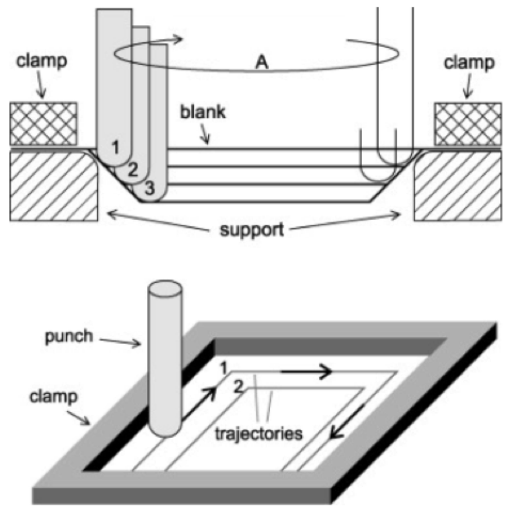

Figure 1: Schematic presentation of incremental sheet metal forming (ISF) process [1]

that, producing the part using a single-pass tool path is not possible due to the geometrical complexity of the part. As an alternative, a six-pass tool path is designed where each pass of the tool performs an updated geometry with the final pass to reveal the final geometry. The tool paths are obtained with the CAM package program Hypermill, all of which are then converted to tool tip coordinates using a separate MATLAB code. The tool tip coordinates are then inserted to a Finite element model created using ABAQUS. Previous studies show that, an explicit analysis results in good estimation of geometrical tolerances, yet it is not effective in evaluating the sheet thickness after deformation. Therefore, an implicit analysis is performed. Each tool path is simulated successively, revealing the final geometry of the part - which is sufficiently close to the desired shape.

To assess the numerical simulations, the designed tool paths are also programmed to a CNC vertical milling machine, where the production of the component is performed. After each tool path, optical measurements over the surface of the deformed sheet are taken to obtain the geometrical dimensions, strain and thickness reduction. The measured data is compared with the outcomes of the simulations and a very close match is obtained, which validates the effectiveness of FEM in simulating such deformation processes.

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