CAM APPROACHES FOR THE INCREMENTAL FORMING PROCESS

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Abstract: Incremental forming technologies, particularly asymmetric single point incremental forming (ASPIF) have a great potential in manufacturing. This work present the implementation of computer aided manufacturing technologies (CAM) in incremental forming. CAM software packages are mainly designed for cutting profiling processes and their use in incremental forming processes need some particular approaches which are described in the paper.

Key words: CAM, CNC machine-tools, incremental forming, robots, toolpaths.

1. INTRODUCTION

Asymmetric single point incremental forming (ASPIF) has been recognized as a solution with great potential in manufacturing small batches or even single sheet metal parts (Ambrogio et al., 2005), (Jeswiet et al., 2005). A description of the ASPIF process principle is presented in figure 1.

The blank (2) is fixed by mean of the blank holder (3). In order to realize the shape of the sheet metal part, one of the active elements, usually the punch (1) has an axial feed movement on vertical direction, continuous or in steps s (incremental), while the other element, the active plate (4) carries out a plane horizontal movement.

However, in spite of its potential, the industry is still reluctant to apply the ASPIF process on a large scale, due to two major drawbacks: low shape and dimensional accuracy of the parts and sheet metal integrity (Micari et al, 2007).

Another major drawback, which was not formally recognized, but still has a great influence upon the development of the ASPIF process is the lack of a set of dedicated computer assisted tools and approaches.

2. COMPUTER ASSISTED TECHNIQUES

A flowchart of the computer assisted techniques which may be involved in the ASPIF process is presented in figure 2.

The following acronyms were used in figure 2: CAD – computer aided design, CAE – computer aided engineering, CAM – computer aided manufacturing.

Fig. 2. Flowchart of the computer assisted techniques for the ASPIF process.

Fig. 1. The ASPIF process.
2.1 CAM stages
While the CAD stages of the process (building the 3D model, exporting/importing the CAD neutral file) and the CAE stages (FEA analysis and simulation) may be carried out using well known CAD/CAE tools, the situation with the CAM stages (generating the processing trajectories and the NC code and processing the part) is somehow different (Oleksik et al. 2009). Using general purposes CAM programs, designed for cutting processes, leads to some particularities:

- the coordinates of the points lying on the processing trajectories may be calculated by the software, due to the fact that the programmed point is the center of the tool, both for the milling tool and for the punch
- the process simulation and the visual representation of the processed part cannot be used, being practically useless, because CAM programs take into consideration the cutting edges of the tool and the way in which the material is removed between the geometry of the workpiece and the geometry of the final part.

Consequently, the user may use CAM programs designed for cutting processes for incremental forming, but in a specific way. Thus, instead of generating the processing trajectories (toolpaths) by extracting them automatically from the geometric 3D model of the part, the user has to define manually these trajectories, leaving the CAM software to calculate the coordinates of the points lying on the toolpaths. These coordinates will be used for generating the NC program. Of course, the above mentioned trajectories may be calculated based on the surfaces of curves of the 3D model of the parts, but are not identical with them, as in the cutting processes. Moreover, the user cannot use the simulation result for estimating the shape and dimensional accuracy of the part.

Figure 3 shows a comparison between the CAM stages for a cutting process (a) and for an incremental forming process (b).

The process simulation stage may be also used for incremental forming, but its utility is very low, allowing the user to have a vague idea about the final shape of the part, while in a cutting process it provides accurate information about the dimensional shape and accuracy of the final part.

The generation of the NC program may look similar for both processes, but one has to keep in mind the fact that usually CAM programs optimize the program generation for cutting.

2.2 Toolpaths
Normally, a CAM program automatically generates the toolpaths by means of the final shape of the 3D model of the part, taking into consideration the cutting tools and the cutting process. Because the ASPIF process and tools (punches) are not implemented in the any existing CAM program, the above mentioned automated toolpath generation cannot be performed. Instead of automatic generation of the toolpaths, based upon the analysis of the process and tools, the toolpaths were defined as singular curves and each curve was build or imported within the CAM program.

Figure 4 shows the process of generating the toolpaths for a manufacturing a sheetmetal part by ASPIF, using a manual process of generating the toolpaths. The 3D model of the part is presented in figure 4a. Contour curves, which are obtained by cross-sectioning the 3D model of the part with horizontal planes, equally spaced on Z axis are presented in figure 4b. Contour curves are reported in the literature as the most used toolpaths for processing parts by ASPIF (Rauch, 2009). The CAM package used for this application has the ability to generate the curves by sectioning the 3D model in any defined plane. Thus, even the user has to define the section parameters manually, the process of obtaining the contour curves is facilitated by the software.

In order to obtain better shape and dimensional accuracies (Breaz et al., 2012), more complex toolpaths (Archimedes spirals – fig 4c) were used in conjunction with contour curves.
Generating the Archimedes spirals is also a facility of the CAM software package. As in the other case, the user has to introduce the parameters of the spiral manually.

In conclusion, it can be stated that even the generation of the toolpaths is a manual process, it also includes elements of automation and interactivity.

3. TECHNOLOGICAL EQUIPMENT

The ASPIF process requires an accurate multi-axes control of technological movements, together with the control of process parameters such as the feed of the punch. Consequently, the most used technological equipment for incremental forming processes are CNC machining centers (CNC milling machines) and industrial robots, which are able to fulfill the above-mentioned requirements.

Two main aspects have to be taken into consideration when using CNC machines and robots for this process:

- the technological forces are higher as the ones in the cutting processes and may damage the equipment, so a preliminary estimation of these forces has to be performed;
- in order to avoid collisions between the mobile elements (for CNC milling machines) and singularity points (for industrial robots), a simulation process is needed.

As mentioned in the previous paragraph, simulation has no relevance by the point of view of the relative movements between tool and workpiece, which are used to visualize the removal of the material and to assess the final shape of the part. However, the simulation becomes very important when, due to the complexity of the processing toolpaths, involving complex movements of the machine-tools and robots, the user has to check for machine elements collision and for singularity points. Thus, the user has to create the 3D model and the kinematic of the technological equipment, either machine-tool or robot. Models and kinematic for some technological equipment may be found as standard in the libraries of the CAM software packages, but in most of the cases the user has to build them, using specific software.

Figure 5 shows the model of a CNC milling machine-tool which was used by the authors for manufacturing parts by means of ASPIF process, while in figure 6 a model of an industrial robot used for the same task is presented.

**Fig. 4.** a – 3D model of the sheetmetal part; b – contour curves; c - Archimedes spirals; d. processing toolpaths obtained by combining the contour curves with Archimedes spirals
Fig. 5: 3D model and kinematics of the CNC machine tools used for processing parts by means of ASPIF process

Fig. 6: 3D model and kinematics of the industrial robot used for processing parts by means of ASPIF process

4. CONCLUSION

The Asymmetric single point incremental forming (ASPIF) technology is still regarded as a new one, not yet implemented on an industrial scale. One of the reasons for that is the lack of tools and methods specifically designed to apply computer assisted techniques within the process. This paper has presented some approaches for applying CAM techniques, using general purpose CAM solutions. A comparison between the stages of processing a part by means of cutting and ASPIF, using a CAM software package, designed for metal cutting, was presented and the differences were highlighted. Toolpaths generation during ASPIF, by means of a CAM program was identified as a manual process, compared with the automated one used in cutting. However, with a proper choice of the software package and of the driving curves used as processing toolpaths, elements of automation and interactivity may be introduced. A combination of contour curves and Archimedes spirals was proposed as processing toolpaths for processing a complex shape by means of ASPIF. Finally, the need of using 3D models and kinematic for the technological equipment for running a simulation process, in order to check the collisions between the moving elements of the machines and to check the occurrence of singularity points of the robots was introduced and two models, for a CNC machine-tool and for an industrial robot were presented.

5. REFERENCES