RESEARCHES REGARDING AN INCREMENTAL FORMING PROCESS BY MEANS OF AN INDUSTRIAL ROBOT

BY

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Abstract. The purpose of this research is to present the results obtained from a sheet metal forming process performed by means of a KUKA industrial robot. The experimental work was carried out on a custom layout in order to measure the sheet metal deformations during the forming process by means of an optical measuring system.

Key words: incremental sheet metal forming, industrial robot, metal deformations, optical measuring system.

1. Introduction

Nowadays the competition on the production level is characterized by flexibility and innovation. Traditional sheet metal forming processes, best used for large volume production lack the flexibility and require a substantial investment cost. In order to produce prototypes and pre-series components at a reasonable cost and in a reasonable time, a new kind of process needed to be developed to meet the requirements described above. Single point incremental forming process is an emerging process for manufacturing sheet metal parts that is well suited for small batch production and prototyping (Jeswiet et al, 2005). This process displays great flexibility, does not require expensive tools and can be performed on a diverse set of machines. Unlike traditional metal forming 

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processes, performing fast production changes are possible due to the simplistic machine configuration. Although the time required to manufacture a product is longer than on a traditional forming press, the time spent on tool design and prototype production is significantly shorter.

Incremental forming of sheet metal parts can be performed on specially constructed incremental forming machines, CNC milling machines and more recently by means of industrial robots (Sasso et al, 2008).

Incremental sheet metal forming caught the interest of scientific research groups very early on because of its great potential and applicability in various fields. Promising results were reported in manufacturing medical implants by means of single point incremental forming (Ambrogio et al, 2005).

2. Incremental forming

A brief description of the SPIF process principle is presented in (Fig. 1). The blank (2) is fixed by means of the blank holder (3). In order to shape the sheet metal part, 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.

Even though incremental forming displays great advantages, this process has two major drawbacks: low shape and dimensional accuracy of the sheet metal parts. Some solutions have been identified in order to eliminate these drawbacks. One of the most promising is the optimization of the process tool paths (Cofaru et al, 2008). A large number of research results about incremental forming have been published in recent years, aiming to find out what machine is best suited for this process and of course what are the most important process parameters both in running experiments and for production (Oleksik et al, 2010). Although in the first articles regarding this process experiments were done with the help of special machines or CNC milling machines, in recent years a large number of articles were published in which the authors have conducted experiments using industrial robots (Meier et al, 2009).
3. Experimental layout

The experimental layout used for the incremental forming consists of a six degrees of freedom anthropomorphic robot KUKA KR 6 (Fig. 2), a custom blank holder, a custom tool holding unit and the forming tool. The KUKA KR6 robot has great flexibility and is suitable for both point-to-point and continuous-path controlled tasks. The position and the orientation of the blank holder were chosen in this manner so that the optical measurement system ARAMIS could be used in order to measure the strains during the actual incremental forming process.

![Experimental layout used for incremental forming](image)

ARAMIS optical measurement system is used as an extensometer in order to measure the strains. ARAMIS consists of two high resolution cameras and the computation system. ARAMIS uses a diffuse network of points applied on the surface of the metal sheet and is able to measure the displacements between these points during the deformation process and thus it can determine the principle strains.

4. The methodology of the experiment

The first step in order to incremental form sheet metal parts by means of an industrial robot is to program the trajectory of the robot. The program code needed for the robot to manufacture a truncated pyramid shaped part was designed in DELMIA software. The next step is to calibrate the ARAMIS measurement system. ARAMIS uses a caliber in order to define the area (96mm x 96mm) on which the measurements can be done without errors.

After the calibration of the measurement system is done, the steel sheets need to be cleaned and spray painted with white mate paint in order to avoid reflections. In order to preserve some of the elastic properties of the white paint,
the sheets are left to dry for approximately 20 minutes. After that, a fine network of black points is applied on the steel sheets, using a black spray paint so that ARAMIS can measure the strain during the forming process.

Next step is to clamp the steel sheet inside the custom stand and lubricate the surface of the steel sheet that will come in contact with the forming tool. Because the sheet is in a vertical position, additional lubrication is required during the forming process.

5. Experimental study

For the experiment, a steel sheet with the thickness of 0.4 mm was chosen. The material properties of the sheet metal part were identified and published in (Chera et al, 2013) paper. The material is very similar to DC04/St14 and has very good deformability properties.

The dimension of the steel sheet is 250 mm x 250 mm. A hemispherical head punch with a diameter of 10 mm was chosen for this experiment.

The shape of the incremental formed part is a truncated pyramid and the dimensions are presented in (Fig. 3a). The trajectory of the forming tool attached to the KUKA KR 6 robot was designed and simulated in DELMIA software (Fig. 3b).

The incremental step for this experiment is 0.5 mm and the duration of the forming process is approximately 5 minutes.

ARAMIS measurement system is set to take photographs of the painted side of the steel sheet once every 4 seconds. At the end of the experiment, the photographs are analyzed and the part is recreated in a tridimensional environment.

ARAMIS provides the tools in order to visualize the principle and secondary strains, the thickness reduction and the displacements in the steel part at different stages during the forming process.

As the results from ARAMIS are analyzed, it can be concluded that the maximum values of the major strain (Fig. 4) and those of the minor strain (Fig. 5) are in within acceptable limits.
The maximum value of 0.402 for the major strains was attained on the faces of the truncated pyramid shaped part.

![Fig. 4 The major strain variation](image)

The maximum value of 0.112 for the minor strains was attained on the corners of the truncated pyramid shaped part.

![Fig. 5 The minor strain variation](image)

The results regarding the thinning variation (30.3%) that was obtained from the measurement are presented in (Fig. 6).

![Fig. 6 The thinning variation resulted from the measurement](image)

6. Conclusions

The experimental and simulation results had shown that the sheet metal forming process by means of an industrial robot has a great potential for use in the production of prototypes and small batch sheet metal parts. Future work will cover a comparison between the experimental results and the values obtained from the finite elements analysis done by means of ANSYS/LS-Dyna software.
REFERENCES


CERCETĂRI PRIVIND PROCESUL DE DEFORMARE INCREMENTALĂ REALIZAT CU AJUTORUL UNUI ROBOT INDUSTRIAL

(Rezumat)

Lucrarea de faţă prezintă rezultatele obţinute în urma studiului experimental al procesului de deformare incrementală la care s-a utilizat un robot industrial serial cu şase grade de libertate KUKA KR 6 ca echipament de lucru. Obiectivul principal al acestui studiu constă în masurarea „on-line” a deformărilor şi a subțierii relative a materialului de pe suprafața pieselor deformate incremental cu ajutorul sistemului optic de masurare Aramis. Pentru a putea măsura deformării în timpul procesului de deformare incrementală este necesară expunerea spre camerele foto ale sistemului optic Aramis a feței semifabricatului ce nu vine în contact cu poansonul de deformare. Din acest motiv s-a proiectat și executat un stand experimental care să permită fixarea semifabricatului în poziție verticală, astfel semifabricatul este expus pe direcția camerelor de achiziție ale sistemului optic de masurare. Acest sistem dispune de un soft propriu de prelucrare a imaginilor capturate. Aramis folosește o rețea difuză de puncte aplicată pe suprafața pieselor deformate și este capabil să măsoare deplasările dintre aceste puncte. Astfel se pot obține valorile si harta de distribuție a deformărilor principale respectiv secundare și a subțierii relative a materialului de pe suprafața pieselor deformate incremental.