Achievements in Mechanical and Materials Engineering

COMMENT Worldwide Congress on Materials and Manufacturing Engineering and Technology
16th - 19th May 2005 Gliwice-Wisla, Poland

COMMITTEE OF MATERIALS SCIENCE OF THE POLISH ACADEMY OF SCIENCES, KATOWICE, POLAND
INSTITUTE OF ENGINEERING MATERIALS AND BIOMATERIALS OF THE SILESIAN UNIVERSITY OF TECHNOLOGY, GLIWICE, POLAND
ASSOCIATION OF THE ALUMNI OF THE SILESIAN UNIVERSITY OF TECHNOLOGY, MATERIALS ENGINEERING CIRCLE, GLIWICE, POLAND

13th INTERNATIONAL SCIENTIFIC CONFERENCE ON ACHIEVEMENTS IN MECHANICAL AND MATERIALS ENGINEERING

Incremental sheet metal forming on CNC milling machine-tool

J. Kopac and Z. Kampus

Faculty of Mechanical Engineering, University of Ljubljana, Aškerčeva 6,
1000 Ljubljana, Slovenia, email: janez.kopac@fs.uni-lj.si ; zlatko.kampus@fs.uni-lj.si

Abstract: Incremental sheet metal forming is a promising process providing a short and inexpensive way of forming products having a relatively simple but interesting shape. The paper presents the process controlled by CNC milling machine-tool together with CAD/CAM Master Cam system and a smooth forming tool. With experimental testing and measurements the limits of forming without a full-size model were defined. By using a simple full-size model and the concept where the sheet metal can move vertically in the clamping device, better results and products were obtained.

Keywords: Incremental forming; Sheet metal forming; CNC machine; Limits of forming

1. INTRODUCTION

For sheet forming a number of different forming procedures have been used. In the past, sheet forming was performed on special rolls by means of which a certain shape was created. Today's fierce competition in the industrial world, there is a demand for more and more complex products. In order to meet the requirements, attempts have been made to stretch sheet metal on special models so that a desired final shape would be reached. However, a disadvantage of pressing was that for every product it was necessary to make a special tool, on which sheet metal was formed. Thus forming on presses can be appropriate only for high-volume production. Because industry keeps producing new products all the time, there is also a constant need to develop prototypes. So, different processes have been started where forming was performed without the tool or with a supporting tool that was cheaper than the real tools. This is how the development of the procedure of incremental sheet forming has been started. This process is performed on a CNC milling machine-tool with CAD/CAM computers support.

Instead of a mill tool we use a tool which has a small ball in the end and with this tool we can form the sheet metal that is rigidly fixed. In the contact between the ball and the sheet metal the forming process is going on. First our team tried to perform a simple forming operation without a supporting tool, but only simple forms could be produced. Then the process was improved by using a supporting tool with a simple form, and sheet metal was formed on it.

2. SOME CONCEPTS OF INCREMENTAL FORMING

By pushing process the sheet metal rotates together with the spindle. The tool which has a forming disc at its end forms the sheet metal from the centre outwards. The process is appropriate for round products only.

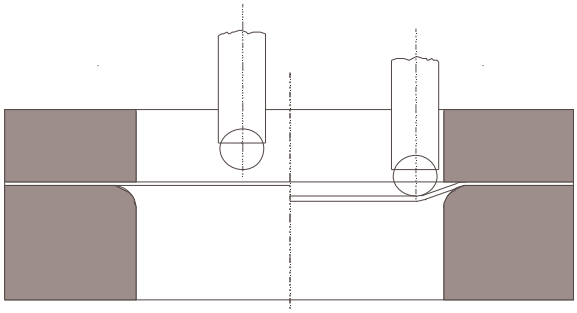

Figure 1. Forming with impression

Forming by impression is a process where the tool is stamped into the sheet metal which is clamped on its circumference [4]. The forming tool has a simple shape with a ball at its end. The tool travels over a definite distance forming the sheet metal to a final form (Figure 1).

3. EXPERIMENTAL SET UP

Forming is performed with a supporting tool [5] (Figure 2), where the sheet metal is chucked in a frame which can be moved vertically. Under the frame there is a model, which has to be made so that the tool moves along the model and in this way forms the sheet metal. The model (supporting tool) may have an intermediate or final shape.

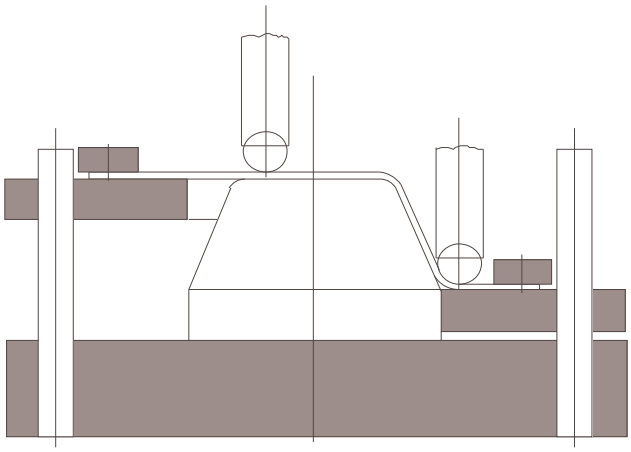

Figure 2. Process with a supporting tool (model)

In first tests, tools with a rounded end had been used [1÷5]. Soon afterwards these tools were added a small ball from hardened steel. For finding an optimum tool more testing will be needed, because the diameter of these small balls depends on the form of the product, kind of material, and the depth to which the small ball is impressed into the material in one movement.

The trajectory along which the tool moves is essential for successful production [1]. For this reason different processes have been developed of which two should be mentioned: a step-by step process moving outwards and a continuous process moving inwards.Because no central modification of the shape is involved, a smoother and finer shape is formed. The experimental testing has shown that in the second process the shape obtained by forming is finer and closer to the desired one.Tests were made on a CNC milling machine-tool Mori Seiki which has the following characteristics. From available literature it was evident that we need lubrication between forming. For this reason, tests were made with lubricated and non-lubricated type of forming.

For both tests, the same parameters were chosen:

- The sheet metal was square-chucked with inner sides of the clamping square 62 x 62 mm.
- The sheet-metal plate subjected to forming measured 60x60 mm.
- Depth of forming 5 mm.
- Diameter of the small ball 10 mm.
- Standard parameters on the machine-tool
- Method of forming: only along the outer edge.
- Lubricant: lithium grease.

The sheet metal in the form of a square was chucked, and a computer program for forming was made. In the first test no lubrication was applied and the forming was started on the inner edge of the chucked sheet metal. In the second test, lithium grease was put on the sheet metal before forming.

Result shows that the surface is smoother when the forming surface was lubricated with grease, whereas without grease it was rough and the aluminium plate did not form into a nice shape and the entire surface was picked. Some torn pieces have been indented into the base material so that damage occurred also on the bottom side. The forming zone on the bottom side is marked by unevenness because in this zone the material changed its own structure. If the depth of forming were increased, it would come to material failure.

4. RESULTS AND DISCUSSION

By testing of different kinds of sheet metal clamping for different final shapes we got result that with one type of clamping it is not possible to make different final shapes. They have also shown that it is not possible to make complex shapes without a model along which the forming is carried out

From tests is evident that we can easily form a square shape at square clamping, however the distance from the clamping edge should be minimal. From the second test it is evident that a round final shape cannot easily be formed with square clamping because the material is pulled on the edges where the distance from the edge of clamping is largest. In the third test the material got the final shape of a square which however, is far from the desirable shape [7]. This leads to the conclusion that if forming is performed without a model, the shape that is obtained, would is fine only if it is the same as that of the clamping. For example: if the clamping of sheet metal is square shaped, then we can make only a final shape in the form of a square. But even with this we have to be careful that the forming zone is as close to the

clamping edge as possible, otherwise, the sheet metal might deflect. From this we can see that for more complex shapes it is necessary to make a model for forming. However, there is still a danger of material failure on the edges.

5. CONCLUSION

Implementation of the technological process of incremental sheet metal forming is intended for rationalization of small batch production. Using it, the time necessary for prototype making can be shortened.

The forming tool that has proved successful has a small ball with a diameter of10mm, and grease should be used as lubricant to improve tribological characteristics. On Aluminium sheet metal with a thickness 1mm, tests have shown that the selection of the clamping mode on the machine-tool worktable is important. Forming closest to the clamping edge is important as well, and the shape of the clamping frame should be the same as that of the product (round, square, rectangular).

Another important strategy is the motion of the forming tool along sheet metal surface. The movement of the tool starting in the centre of sheet metal and then restarting from the initial depth from the interior into exterior has a priority. Optimal inclination of walls on the product are 45°, bigger angles may cause errors, cracks, and product failure, which has been shown in this paper.

To achieve higher product quality, a model can be put under the sheet metal as a supporting tool on the basis of which more demanding shapes can be reached. This means more work but it is not time-consuming and expensive because the model can be made on the same CNC milling machine tool with low surface roughness required. The forming conditions become much worse if, instead of aluminium sheet metal, steel sheet metal is used for the product. In the case when steel sheet metal has to be used it is recommendable that this is highly deformable and subjected at minimum hardening with respect to previous deformation.

REFERENCES

1. D.Leach, A.J.Green, A.N.Bramley: A new incremental forming process for small batch and prototype parts; 9th International Conference on Sheet Metal, Leuven, 2001
2. H.Iseki: An approximate deformation analysis and FEM analysis for the incremental bulging of sheet metal using a spherical roller; Journal of processing technology, 111 (2001) 150-154
3. Y.H.Kim, J.J.Park: Effects of process parameters on formability in incremental forming of sheet metal; Journal of materials processing technology, 130-131 (2002) 42-46
4. H.Iseki, T.Naganawa: Vertical wall surface of rectangular shell using multistage incremental forming with spherical and cylindrical rollers; Journal of materials processing technology, 130-131 (2002) 675-679
5. Boštjan Juriševic: Incremental sheet metal forming with high-speed water jet
6. Primož Erjavec: Incremental sheet forming, Diploma thesis S1019 FS-LJ 2004
7. Zlatko Kampuš, Janez Kopač: Gradual sheet forming, conference proceeding Orodjarstvo 2004, Slovenia