Modular fastening system and tool-holder working unit for incremental forming

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Abstract. Incremental forming can be usually unfolded either on CNC milling machine-tools or serial industrial robots. The approach proposed in this paper tackles the problem of designing a modular fastening system, which can be adapted for both above mentioned technological equipment. The fastening system of the sheet-metal workpiece is composed of a fixing plate and a retaining plate. The fixing and retaining plates will be made up of different individual elements, which can be easily repositioned to obtain different sizes of the part. Moreover, the fastening system has to be able to be positioned either horizontally (to be fitted on CNC milling machines) or vertically (to be fitted on industrial robots). The paper also presents the design of a tool-holder working unit which will be fitted on KUKA KR 210 industrial robot. The working unit will be mounted as end-effector of the robot and will bear the punch, driving it on the processing toolpaths.

1 Introduction

Sheet metal forming is a manufacturing process widely spread in industry because almost all body parts of automobiles are made of sheet metal. But not only this field requires sheet metal parts, so other fields of applications include aeronautics industry, food industry and medicine [1-3].

Most of the sheet metal parts are obtained by cold plastic forming, and one of the most well-known processes is deep-drawing. The major drawback of this forming process is that it requires very complicated forming tools. Therefore, with it are involved very high costs and times for producing a part. Consequently, this process is recommended only for large batches of parts.

A possible alternative is to use single point incremental forming process (SPIF). The principle of this forming manufacturing process is presented in figure 1, where the blank 3 is fixed between a blank holder 2 and an active plate 4. 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 (I) on vertical direction, continuous or in steps (incremental) and also an horizontal movement (II).

However, an important drawback of the use of this type of tool is the fact that only parts belonging to a single size range of the sheet metal blank can be processed [4-8].

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Fig. 1. The tool used for incremental forming.

For this purpose, there is real a demand of designing different solutions that allow the user to change the dimension of the blank in a flexible manner. The work presented in this paper proposes a flexible, modular fastening system incremental forming.

2 Modular fastening system and tool-holder working unit for incremental forming

2.1 The support structure of the forming tools

The support structure of the forming tools is presented in figure 2 and it can be observed here that it very simple profiles were used, which were cut to different sizes, noted with 1. The structure was fastened with socket countersunk head screws M8, 3. The reinforcing elements 2 were fitted with the same type of screws.

The entire assembly was positioned on a support plate 4. The software package used for designing the system was SOLIDWORKS.

Fig. 2. The support structure.

2.2 Active plates

One of the most important element of an forming tool is active plate (figure 3). The active plate is designed to allow the use of 5 intermediate positions in which as many additional active elements can be placed for each of the two X or Y axes. Similarly, on the second direction 5 intermediate positions can be used.

These intermediate positions of the active plates allow the user to adjust the size of the blank. This is the reason why figure 4 a presents the additional active plates for the X axis noted with 2, while with 1 is the same active plate. In figure 4.b the additional active plate for the Y axis (noted with 3) is presented.

Fig. 3. Active plate.

Fig. 4. Supplementary active elements a) on X axis a) both on X and Y axes.

2.3 Retaining plates

To fasten the sheet metal blank, retaining plates are also required. These are composed of elements that have been called "retaining plates in I-letter shape" which can be positioned in parallel with the X axis and can be moved to any of the 6 points of the active plate 1. They were marked with 2 in figure 5 and figure 6. These retaining plates in I-letter shape also have threaded holes for fastening purposes.

Besides these, intermediate retaining elements marked with 3 are required, as shown below in figures 5 and 6. These elements have a straight-forward construction, being made of plates with the same width and height, the only difference being the length. These plates are equipped with threaded holes for easy fastening in the active plate.

Fig. 5. Retaining elements.

The active plate allows the use of various supplementary active elements to obtain the desired dimension on the sheet metal blank, which can be fitted in different positions (figure 6).

Fig. 6. Retaining elements.

From figures 5 and 6 it can be noticed that the socket countersunk head screws are used both for fastening the retaining plates and the active plates on the support structure.

To adjust the shape of the sheet metal blank also on the Y axis, retaining elements (indicated by the green colour in figure 7) can be used, fitted in different positions.

Fig. 7. Retaining plates both on X and Y axes.

2.4 Modular fastening system and tool-holder working unit

Figure 8 presents the modular fastening system and tool-holder working unit. Each of the figures presents the active elements positioned on the support structure.

Fig. 8. Modular fastening system and tool-holder working unit.

Figure 8.a depicts the situation where the largest size of the blank will be used, while figure 8.b and 8.c present two combinations which allow the use of different blank sizes.

3 Fitting the modular working unit for incremental forming

The most used technological equipment used for incremental forming are CNC milling machine-tools and industrial robots [3, 7-8] (figure 9).

Fig. 9. Incremental forming layout a) on CNC milling machine-tool b) on industrial robot.

From figure 9 it can be noticed that while for CNC milling machine-tools the incremental forming layout must be positioned horizontally, for industrial robots it has usually to be fitted in vertical position. Consequently, different layouts must be used for each type of technological equipment.

The proposed modular working unit can be fitted either horizontally or vertically on the technological equipment, as presented in figures 10 and 11.

Fig. 10. Modular fastening system and tool-holder working unit, fitted on CNC milling machine-tool (horizontal position).

Fig. 11. Modular fastening system and tool-holder working unit, fitted on industrial robot KUKA KR 210 (vertical position).

4 Conclusions

The work presented in this paper describe a modular fastening system and tool-holder working unit for incremental forming. The main advantages of the proposed solution are the that different sizes of sheet metal blanks can be accommodated on the system, in a flexible manner and the system can be fitted either on horizontal or vertical position, in order to be used on every type of technological equipment (CNC milling machine-tool and industrial robots). Some preliminary tests indicated a 100% increase in the productivity of the process. Of course, the productivity is heavily influenced by the shape and size of the processed part, which determines the forming time, but one has to keep in mind that auxiliary time (time to fix/remove the part from the machine) has also a great contribution to the overall processing time. Further work will be oriented to finalize and implement the proposed solution.

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