

# Design and manufacturing of a fixing device for incremental sheet forming process

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**Abstract.** In incremental sheet forming processes, the expensive dedicated tool are avoided and replaced with a cheap and simple fixing device which support the sheet metal blanks. The current paper presents how a fixing device used for single point incremental forming device is designed, FEM simulated and manufactured. The fixing device can be used for parts with a cone frustum and pyramidal frustum made of DC05 deep drawing steel. The forces developed in the process and the device displacements were estimated using FEM simulation. The device components were manufactured using a CNC machines and the physical assembly is also presented in the paper.

## 1 Introduction

In the modern world all the products tends to be more and more customized being produced in smaller batches than before. As result, the industrial manufacturers have to be able to accomplish the market demand by using modern and flexible production processes for products manufacturing at a reasonable quality and costs. In terms of cold pressing processes, a flexible and in the same time a low cost production process is incremental sheet forming (ISF). It is easy to be implemented and is suitable for small batch production series, rapid prototypes or unique products from different sheet metal forming industries [1]. In ISF, the sheet metal blanks are gradual deformed by a simple forming tool and it uses or not a blank support. When any blank support is used, the process is called two points incremental forming (TPIF) because there are two or more contacts points between tools and sheet. If the sheet is deformed only by the forming tool, without any blank support on the other side of the sheet, the process it is called single point incremental forming (SPIF) [1-2]. One of the major advantages in comparison with conventional cold processes is that the ISF processes are avoiding the expensive and complicated tools necessary to be designed and manufactured. It is called die less process even if it is not totally true [2]. If for TPIF implementation is needed a blank fixing device, the negative shape of the part or a simple local blank support, that are easier to be designed and more easy to be manufactured. The SPIF process is simple, the sheet metal blank is clamped in a fixing device, and the forming tool which follows a predefined path, produces the local plastic deformation, step by step, until the final shape is obtained [1]. Thus, it can be said

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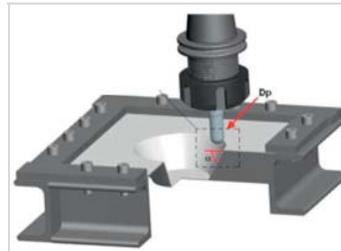
that ISF are die less processes whereas only a simple fixing device and a forming tool are necessary to be implemented, especially when usually, with an common design of the forming tool and fixing device allow to perform different shapes.

## 2 Fixing device design

In the literature were found many types for the sheet metal blank fixing device, designed according to the necessary stiffness, part dimensions or the manufacturing equipment chosen to be used for processing. In figure 1 are presented four configurations of the fixing devices that were used in practice. Figures 1a and 1b represent fixing devices used for CNC milling machines. The device form figure 1a [3] is manufactured from blocks at a certain height, to allow the part deformation in forming direction, and the device from figure 1b [4] is a set of "U" profiles assembled to obtain the device frame and a fixing plate which clamp the sheet metal blank on those profiles. In figure 1c [5] is presented a fixing device for CNC lathes compounded from a set of circular plates between which the blank is clamped. A fixing device positioned in vertical direction is presented in figure 1d [6] and it is used in incremental deformation using industrial robots.



a) manufactured from blocks;



b) with "U" profile frame;



c) manufactured from circular plates;

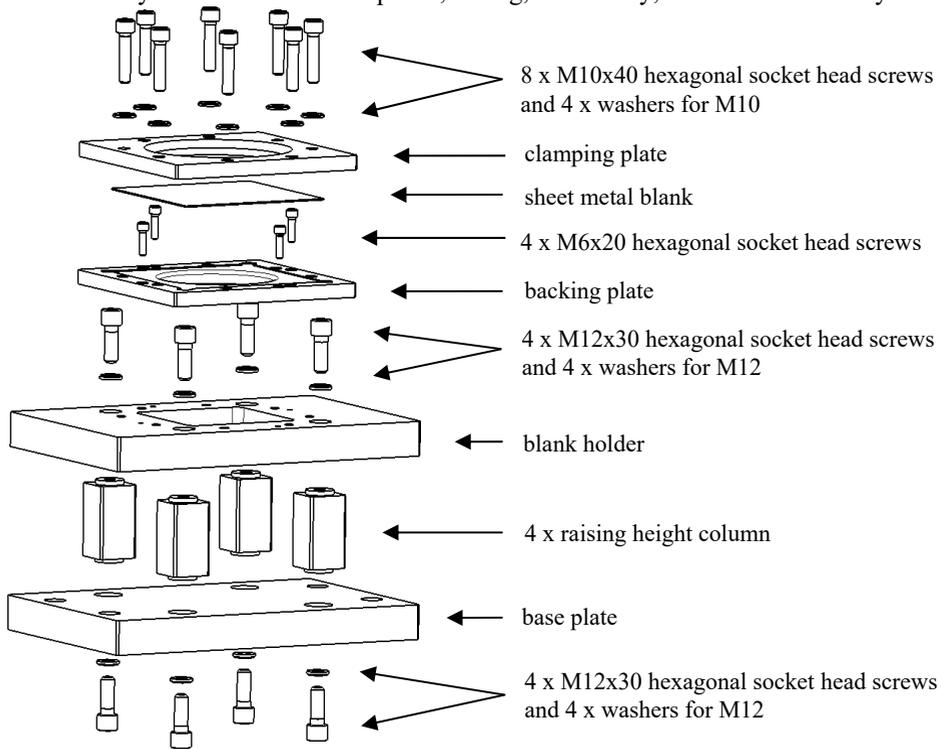


d) with vertical position;

**Fig. 1.** Different configurations of fixing device.

The device that are presented in this paper is designed to be used for future research on incremental forming of cone frustum and pyramidal frustum shapes made from DC05 sheet metal steel with 1 mm thickness. For the considered parts the research activities will be developed using the 3 axes CNC milling machine VICTOR V CENTER 55. In figure 2 is presented an exploded view of the designed fixing device using the computer aided design (CAD) workbench from CATIA V5. Similar with other fixing devices [7], this is composed from a set of plates: blank holder, backing plate and clamping plate, which are all raised at a certain height by four columns on the base plate. The base plate, the blank holder and all four columns are assembled using eight M12 screws. On the blank holder is mounted the backing plate and fixed in position by four M6 screws. The sheet metal blank sits on backing plate and it is fixed and held wide by applying pressure with the clamping plate being tight with eight M10 screws. The backing plate sustains the sheet metal blank near the flange area, improving in this way the part dimensional accuracy in this area [2, 8]. If the part shape that has to be processed is changed, only the backing plate has to be

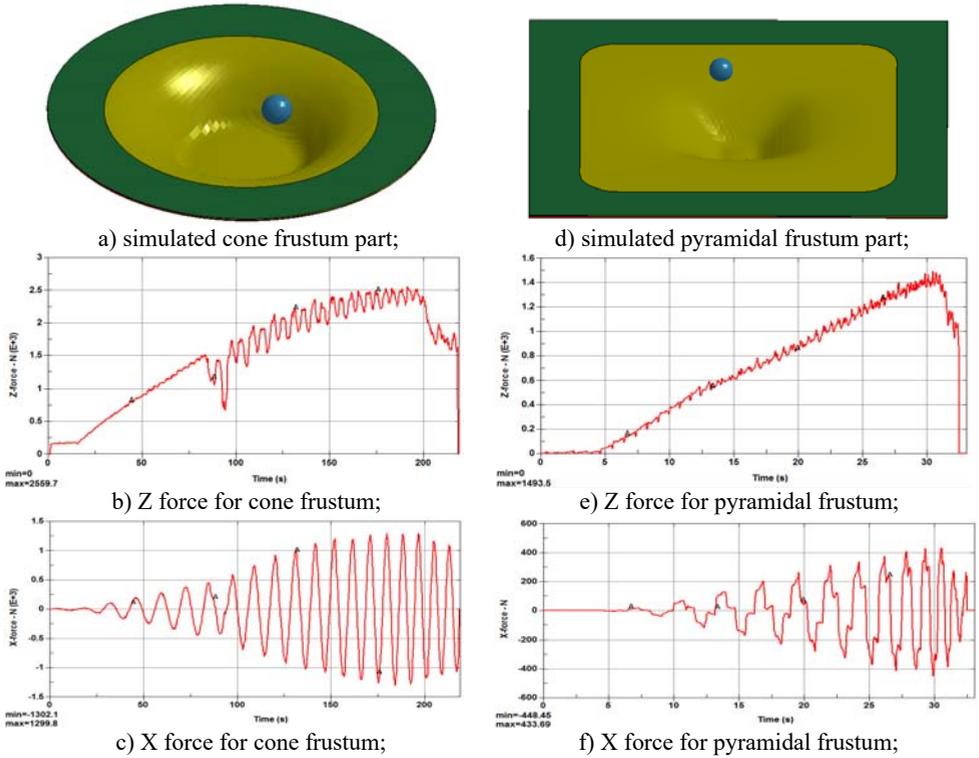
redesigned according to the top contour of the new shape, and replaced in the device assembly. The base plate and the blank holder were bigger than the other plates because in case of longer part processing, those plates can be modified according to its dimensions, without the necessity to manufacture new plates, saving, in this way, materials and money.



**Fig. 2.** Fixing device components, exploded view.

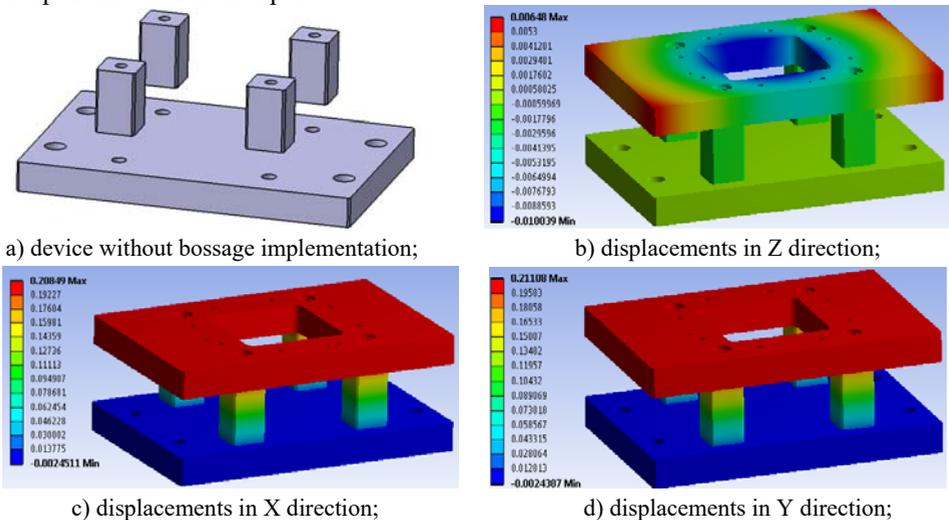
### 3 Fixing device simulation

One of the ISF processes issue, especially for SPIF with no blank support, is the parts dimensional accuracy. Many authors suppose that the dimensional precision of the parts manufactured using SPIF process are more over  $\pm 0.5$  mm, accuracy tolerance required for most of the industrial applications [2, 9]. This processing precision depends of many aspects [1] including the fixing device rigidity. When it is mounted on the CNC milling machine table, the device assembly must support the action of the process developed forces in all directions, X, Y and Z. Before start the device components manufacturing, the assembly was numerical simulated in order to achieve the displacements on each direction. The necessary forces for cone frustum and pyramidal frustum parts manufacturing were obtained using FEM simulations. The FEM models were prepared using ANSYS APDL software system and were run using an LS-DYNA explicit solver [10-12]. Many simulations were done for various parts dimensions that can be deformed using the designed fixing device. The results for the biggest parts successfully deformed for both shapes are presented in figure 3. The maximum force values were obtained for cone frustum part as follow: Z force = 2559.7 N, X force = 1302.1 N, Y force = 1204.1 N. Because X and Y forces have almost equal values, only the plot for X force is presented in figure 3.



**Fig. 3.** Obtained forces from numerical simulation process.

To ensure a safety device stiffness, these values have been approximately doubled. Therefore, the fixing device was forward simulated by applying in all direction these increased forces: 5000 N for Z direction and 3000 N for X and Y directions. To decrease the solving time of each simulation, only the base plate, the columns and the blank holder was introduced in the FEM models, certainly this parts assembly reflect the whole device stiffness. The base plate is assumed to be fixed on the CNC machine table, and the forces acts upon the blank holder part.



**Fig. 4.** First fixing device configuration.

The first device simulation was done on its first design stage, but because the results were not satisfactory because of displacements (figures 4 a, b, c and d) a new improvement was implemented on the geometry. On all four columns were provided with a cylindrical bossage on each extremity that fits on some dedicated holes provided on the front faces of the base plate and the blank holder, the parts with which they are assembled (figure 5a).

This improvement was adopted to avoid sliding between the columns and the base plate / blank holder, where passing hole are designed to allow the fixing screws assembling. As can be seen in figure 5, the maximum displacements in each direction for the improved device design are smaller than in the first configuration:  $\approx 0.004$  mm displacement in Z direction and  $\approx 0.005$  mm displacement in X and Y directions. Because of a better stiffness especially for X and Y directions, it was decided to be forward manufactured the device configuration with bossage on each column and holes on the base plate and blank holder.

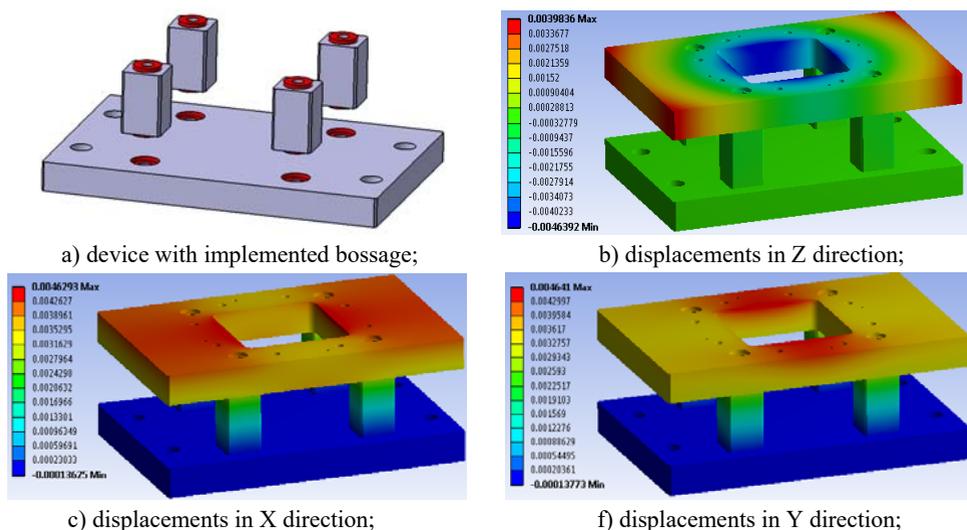


Fig. 5. Improved fixing device configuration.

## 4 Fixing device manufacturing and assembly

The main components of the fixing device were manufactured starting from laminated steel blocks with different thicknesses. Starting from a 35x35mm square profile bar, the column ends were machined using a lathe. The base plate and the blank holder were machined from a thick sheet metal blank with 30mm thickness, while the backing plate and the fixing plate were processed from a 12mm thickness sheet metal blank. All the plates, in the first time, were machined near the final dimensions using abrasive water jet technology on a MAXIEM 1530 machine. Later the plates were milled on a 3 axes VICTOR V CENTER 55 CNC until the final dimensions were obtained. As is presented in figure 2, the fixing device components were assembled in a final stage using standard metric screws. The physical device is shown in figure 6.



**Fig. 6.** Fixing device physical assembled.

## 5 Conclusion

A fixing device of sheet metal blanks for single point incremental forming processes was designed by the authors. It can be used for cone frustum and pyramidal frustum parts manufacturing, made from DC05 deep drawing steel sheets with 1 mm thickness. The device components were designed in such a way, that if the parts which have to be manufactured are changed in terms of shape or dimensions, only the backing plate has to be replaced and the base plate and the blank holder has to be redesigned and modified. The main components of the assembly which support the developed forces during the forming process was numerical simulated in a first stage, and some improvements were adopted in a second stage, to ensure a better stiffness and lower displacements values on all directions. All components for the improved device configuration were manufactured and a final physical assembly are presented in the paper.

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