International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 04 Issue: 07 | July -2017 www.irjet.net p-ISSN: 2395-0072

# MODELING AND MANUFACTURING OF AN AEROSPACE COMPONENT BY SINGLE POINT INCREMENAL FORMING PROCESS

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**Abstract -** *This work gives a comprehensive account of the single point incremental manufacturing process . It provides a basic approach to the idea of numerical control and describes the various elements, tools and machines that come under its ambit. The report encompasses the various CAD/CAM techniques used in the manufacturing cells before final production run of a component. It highlights the Single point incremental forming , used for manufacturing the aerospace component for a rocket. It gives an overview on Modeling and manufacturing processes to make the component and analyzing various factors using software's like SOLIDWORKS, ANSYS and MASTERCAM. In Single point incremental forming, the final geometry is generated by the envelopment of all positions assumed by a simple forming tool which deforms a clamped blank. No dies are required differently than any conventional sheet metal forming processes. Although Incremental Sheet Metal Forming (ISMF) concept allows increasing the flexibility and to reduce set up costs, such a process has a negative effect on the shape accuracy by initiating undesired rigid movement, elastic spring back and sheet thinning. Emphasizes the necessity to control process parameters to improve final shape accuracy. To attend to this aim, a finite element analysis is performed in order to study the influence of forming strategy on stainless steel alloy sheet metal to be manufactured by Single Point Incremental Forming. The results will allow to have a better knowledge of parameters effect on parts manufactured by SPIF with the aim to improve their profile accuracy.*

***Key Words***: Sheet Metal Forming,, Solidworks, Static Structural Analysis and Manufacturing.

## 1. INTRODUCTION

The most famous and common manufacturing process in many industrial and civil sectors is sheet metal forming which are capable of producing good quality complex part with modern technology. Sheet metal forming based on presses is a widely used manufacturing process, being well developed nowadays. Finished products have good quality, are geometrically accurate and parts are ready to be used. It is used for large batches, which amortize tooling cost, producing large quantities of components during a short time interval. However, the possibility to use conventional stamping processes for small batches or personalized prototypes is naturally very expensive.

In Research and development processes, prototype manufacturing is an important step in product development. Consequently, it is important to shorten the product's life cycle and costs in its initial development. As a result, the Incremental Sheet Forming (ISF) technology is a new possibility to decrease the cost problem in small volume production. It introduces the use of metallic or polymeric sheet for small batches production in an economic way without the need of expensive or dedicated tools. The study and development of this process have been growing over the last years.

Producing prototypes in some manufacturing processes may consume a lot of money and time to tryout, especially if specific dies are required as it is the case of sheet metal components. As a result, a new technology called Incremental Sheet Metal Forming (ISMF) has been developed. The process can be performed on CNC machining centers using simple forming tools to incrementally deform the sheet until the part is produced. The main point of this process is to reduce the lead time of tooling development and investment cost. ISMF has an ability to form difficult complex parts economically, not requiring specific dies and expensive tool set up. Furthermore, ISMF can be performed in a wide range of materials such as steels, polymers, thermoplastics, titanium, etc. Although the process requires higher manufacturing times when compared to conventional forming process, it is suitable for producing complex parts in small batches, such as prototype parts for aeronautical and automotive applications

### 1.1 INCREMENTAL SHEET FORMING PROCESS

Incremental sheet metal forming process using single point tool was created by Leszak in 1967,which later on well known as Die less Forming. Later in 1994 Matsubara had developed an Incremental Backward Bulge Process, where sheet is clamped on downward moveable rig at the center of blank is supported by a post. Forming tool is control by CNC providing rotating tool movement that describes trajectories to obtain final desired part in either symmetrical or nonsymmetrical geometry. Concept of incremental forming process has been developed to use on CNC milling machine by Jeswist and Leach, where no backing plates was used. Moreover, Kitazawa had later on improved an Incremental Stretch Expanding process as shown in figure 1.1, where CNC lathe machine is used with steel rod hemispherical forming tool tip. Blank is clamped with the chuck on lathe machine, according to blank and tool rotation relationship effect this

process to have limited to symmetric geometry Strong Point of Incremental forming is the simple process which consumes shorter steps to produce parts. The process will first start with the design in Computer Aided Design (CAD) Program and then transfer to CNC Machine and select suitable backing plate and clamping jig. After processing only some finishing are required hence the process is as simple in figure 1

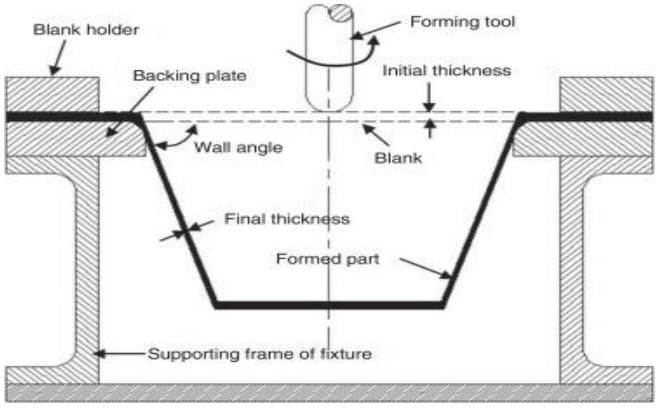


**Fig -1**: Incremental Stretch Expanding Process

The product of this process can be made directly from 3D CAD model to finished product without any dedicated die or tools. Therefore, the ISF process offers the rapid prototyping advantage of short lead time, high flexibility and lower cost for small batch applications. The process of incremental forming starts with clamping a sheet with the rig and set the forming tool into position. Once the machine starts, the forming tool spins and move follow the trajectories in order to obtain the desired part. Then the part can be used without any additional process. The work piece can typically be used for molding, prototype or components. Most of the ISF application are medical products, aeronautical application and automotive as a prototype. The Incremental Sheet Forming mainly divided into three different types, Single Point Incremental Forming (SPIF), Incremental Forming with Counter Tool and Two Point Incremental Forming (TPIF)

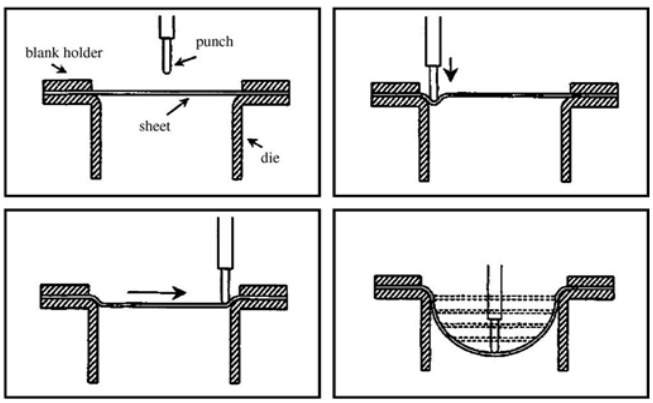


**Fig -2**: Simple Steps of Incremental Sheet Forming

## 2. MODELING

Modeling of aerospace component is carried out using Solid works software. Component should be clamed to a fixture in order to perform single point incremental forming process, so a fixture is modeled in Solid works

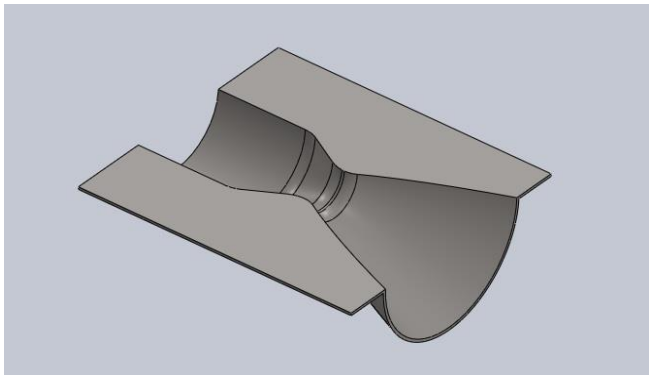

**Fig -3**: aerospace component

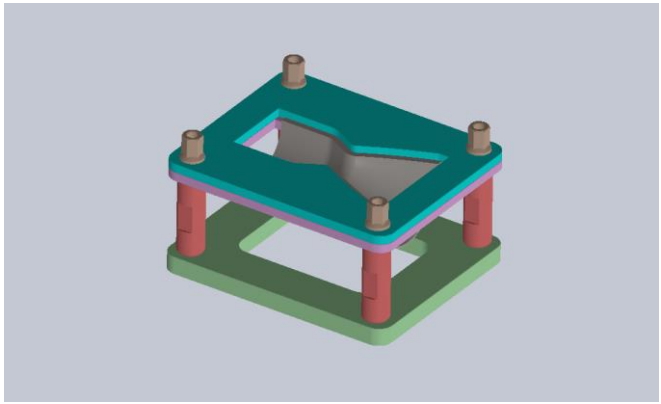

**Fig -4**: fixture assembly

## 3. STATIC STRUCTURAL ANALYSIS

Static structural analysis is performed on the fixture because , during application of the fixture, due to forming load stresses are generated and due to which deformation of fixture is occur. Combined effect of stress and deflection of fixtures geometrical errors are to be produce in component. to avoid this problem before any manufacturing of the fixture analysis is to be carried out.

Meshing is basically the division of the entire model into small cell so that at each and every cell the equations are solved. It gives the accurate solution and also improves the quality of solution .Within the solution domain under the Adaptive Mesh Refinement segment, the Maximum Refinement Loops and Refinement Depth is taken. Within the Patch Confirming Method domain the method is taken as Tetrahedrons. For the convergence plot, the maximum allowable change was considered. The whole geometry is selected for mesh generation and total number of nodes and elements are observed respectively.

**Table -1:** Element Mesh Data

| | |
|---|---|
| Nodes | 394476 |
| Elements | 219439 |
| Element Size | 4.0 mm |
| Method | Tetrahedrons |

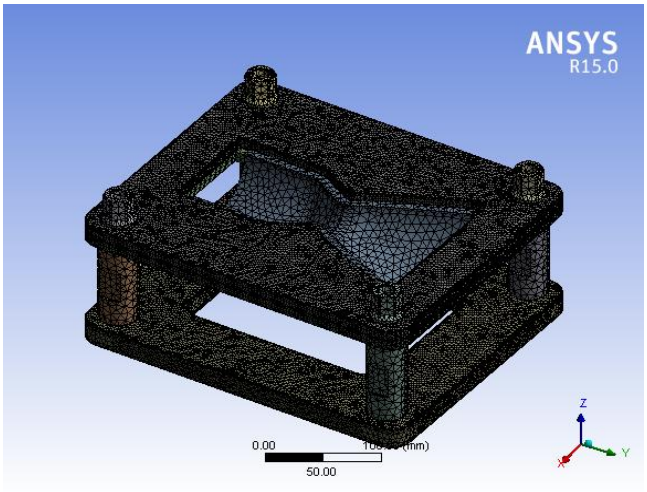


**Fig -4**: mesh

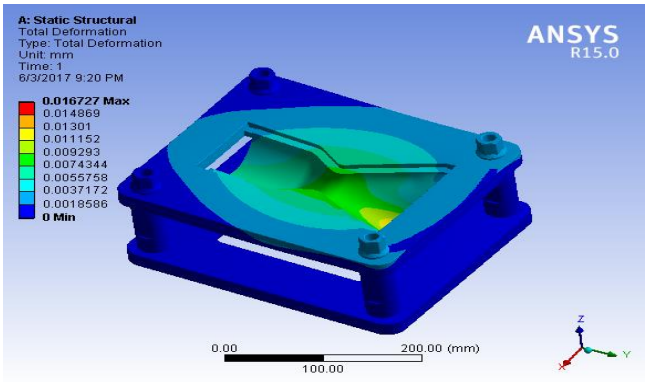


**Fig -5**: Deformation

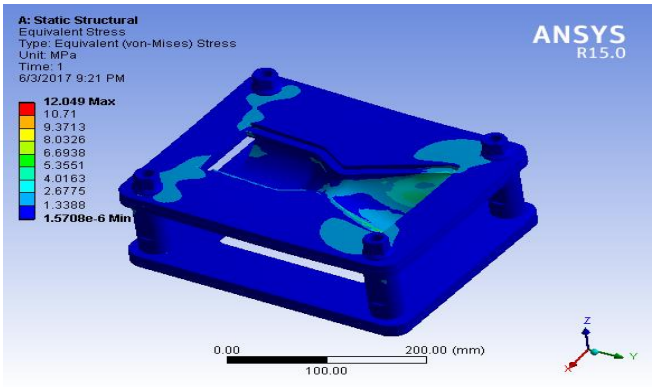


**Fig -6**: Von-misses Stress

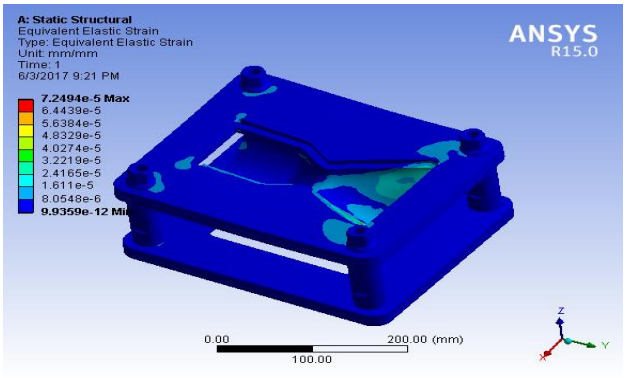


**Fig -7**: Equivalent Elastic Strain

**Table -2:** Deformation, Stress, Strain with various forming Loads.

| Force (N) | Deformation (MM) | Max Stress (MPa) | Min Stress (MPa) | Max Strain | Min Strain |
|---|---|---|---|---|---|
| 500 | 0.011152 | 8.0326 | $1.047*10^{-6}$ | $4.832*10^{-5}$ | $6.623*10^{-12}$ |
| 750 | 0.016727 | 12.049 | $1.570*10^{-6}$ | $7.249*10^{-5}$ | $9.935*10^{-12}$ |
| 1000 | 0.022303 | 16.065 | $2.094*10^{-6}$ | $9.665*10^{-5}$ | $1.324*10^{-11}$ |
| 1250 | 0.027879 | 20.081 | $2.617*10^{-6}$ | 0.00012082 | $1.656*10^{-11}$ |
| 1500 | 0.033455 | 24.098 | $3.141*10^{-6}$ | 0.00014499 | $1.987*10^{-11}$ |

## 4. AEROSPACE COMPONENT MANUFACTURING PROCESS

Single point incremental sheet metal forming, also known as die less forming, is a new and innovative method of sheet metal forming. Here we have used a CNC milling machine as shown in figure below to manufacture the component. Milling cutter is replaced with the forming tool. The rod shape forming tool with a smooth hemispherical head of 10 mm diameter was clamped into the spindle of the milling machine. The sheet metal was fixed and positioned with the upper blank holder, which was pressed onto the lower blank holder. The whole support tool was inserted and fixed onto the worktable of the milling machine. While the tool presses and locally deforms the sheet directly under the tool head with a very small value of deformation, the blank holder and fixture remain fixed during the entire forming process. The

tool follows to the predetermined tool path and gradually forms the sheet metal in a series of incremental steps until the final depth is reached.

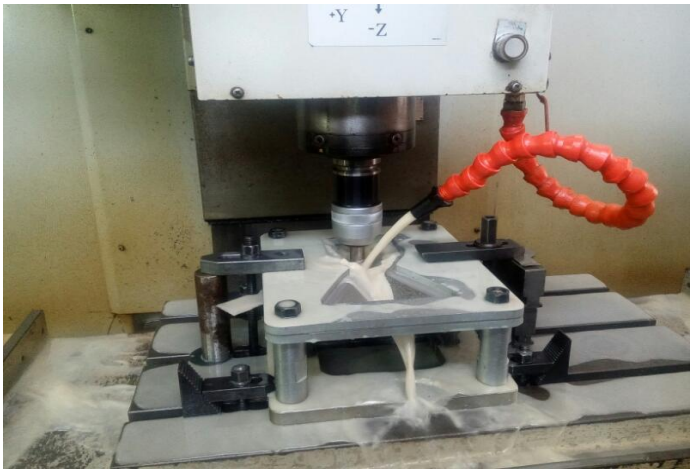


**Fig -7**: Experimental setup (CNC)

## 5. CONCLUSIONS

Incremental forming technique has been explored for forming sheet metal components made of Stainless steel. The finite element analysis has been carried out to study the deformation, stress and strain in stainless steel sheet metal. From the above table we can conclude that the Fixture can with stand the forming forces without any maximum deformation.

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