International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 08 Issue: 10 | Oct 2021 www.irjet.net p-ISSN: 2395-0072

A REVIEW ON COMPUTER AIDED DESIGN AND MANUFACTURING OF SHEET METAL BENDING & PIERCING OPERATION

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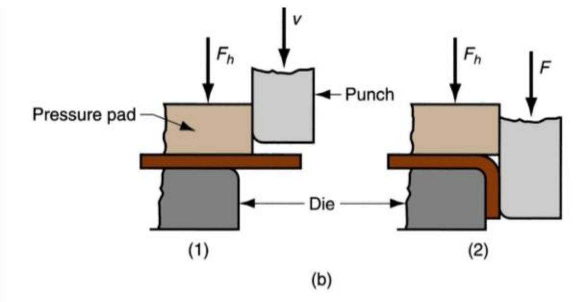
Abstract - *A computer is a tool that is being used extensively to increase productivity in many aspects of our life whether they are business applications, scientific applications or engineering applications (including CAD and CAM). Here, we consider the two most common processes of the manufacturing industry i.e., bending (process for transforming straight length into curved for eg., sheets into drums, curved channels etc.) and piercing (economical process for making thin-walled round objects, saving drilling and boring of parts). The geometric modelling is done in SOLIDWORKS v19. Engineering analysis necessary for reviewing and evaluating the designs is carried out in ANSYS v2019R3. SOLIDWORKS CAM is used for the generation of tool paths. Advancements in CAD hardware and software result in greater accuracy, quicker design calculations and analysis, higher productivity and increased manufacturing efficiency. CAD and CAM consider and coordinate among all functions starting from product definition, modelling, analysis, review, evaluation and final presentation. Computer Aided Design and Manufacturing takes all these aforementioned parameters into account necessary to make these designs successful, which is the foundation of product reliability and maintainability.*

INTRODUCTION

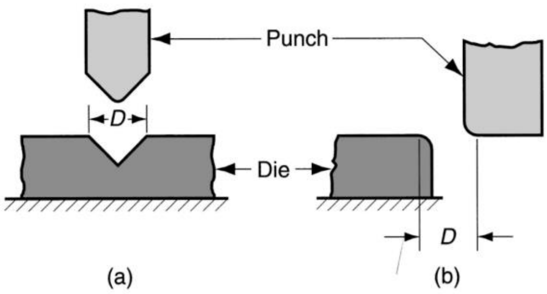
Sheet metal bending and piercing are the basic manufacturing processes.

The Bending operation involves plastic deformation metals. Uniform straining of the sheet metal is the final result.

In easy words, bending occurs when a section of the part is strained along the linear axis until the wanted result takes place. This bending operation does not only take place in a straight line but also along curved lines and paths. A vital observation must be noted about the features of the metal that is involved in bending operations.



It has already been established that tensile strength decreases towards the middle of the sheet metal thickness and zero along the neutral axis, but there was an increase in compressive stress from the neutral axis up to the middle of the bend. It is cogent to state that in bending operation, there is no cutting but a change in the configuration of work to get the desired product.

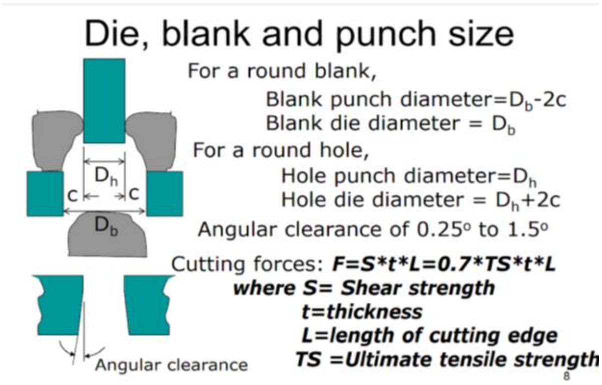


Maximum bending force estimated as follows:

$$F = \frac{K_{bf} TSwt^2}{D}$$

where F = bending force; TS = tensile strength of sheet metal; w = part width in direction of bend axis; and t = stock thickness. For V- bending, K_{bf} = 1.33; for edge bending, K_{bf} = 0.33

Piercing is a shearing process in which raw metal is pierced with a machine tool, resulting in the formation of a circular or other shaped cavity. As the work is pierced, the metal from the pierced hole is classified as scrap. Piercing machine presses a tool, known as a blanking punch, through the Part.



With the introduction of computer integrated design and manufacturing. The process of creating designs and then proceeding to generate toolpaths for NC machines all being done from the same system and in some cases same software. This is the power of modern tools present for the manufacturing units.

LITERATURE REVIEW

[1] From the study conducted, which had taken into account BHF.i.e.Blank Holder Force and is of immense practical application in processes like stamping, the paper has also discussed how variables like surface finish, lubrication, part geometry, blank material and press characteristics as in (Ahmetoglu et al..1992), conclusion on application of BHF control for elimination of processes like tearing along with process of wrinkling. Description for a specific machine control strategy that had included a hydraulically controlled multi-cylinder BHF system in other words a blank holder system. Is a review paper for analysis of control parameters in manufacturing processes.

[2] Hardt (1993), the research paper had discussed modelling and control methods in the manufacturing process of stamping by taking control perspective into consideration, the entire methodology revolved around comparison of process objectives which comprised of quality, flexibility, and rate it was also accompanied by classical feedback system objectives like tracking disturbance rejection and stability. Emphasis was laid on using methods that already happen to exist on problems involving process independent methods, such as position-control and trajectory following of the tools, thereby only indirectly influencing the actual process output. By taking the proposed methods of direct approach as discussed in deformation transfer function or we can even take discrete tooling concepts for understanding the functionality of our to process more efficiently for modelling and control.

[3] Obermeyer et al. (1998) provided us with the information regarding open-loop and closed-loop control of the Blank Holder Force (BHF) which were analysed in detail both experimentally and theoretically and both were found in accordance with each other obtained by use of emit diagrams

[4] (Cao et al.,2001) Cao focused on discussing the development of stamping and how it is realised for manufacturing requirement especially for the process of stamping and how we can optimise it by taking all the challenges faced and improving the controllability and flexibility in order to develop a next generation system for the process of stamping.

[5] (Dejardin et al..,2010) Numeric Control or NC forming for production of Incremental sheet by use of dieless method as NC would improve our design models by making more accurate and precise complex geometries from 'n' number of shapes, underlying phenomenon for this is localised plastic deformation in the blank region of sheet metal, this method can be of great use while producing panels for comparatively smaller lot and as a prototype for sheet metal stamping.

[6] (Yongseob, Lim Ravinder Venugopal & A. Galip Ulsoy)" Advances in the Control of Sheet Metal Forming" To minimise the damage over the surface of die like tearing and wrinkling caused by physical modification for ex- grinding and welding, study was done on Die tryout parameters use to provide information for die geometry and BHF also how BHF should be altered in sheet metal forming. The die try-out procedure is time-consuming, with many cycles of trial and error, using FEM (closed-loop) we studied how to apply 3M's to our die formation

[7] (By Mr. Deepak Bharat Pawar Prof. G. S. Joshi Swapnil, Shashikant Kulkarni, Dr. V. R. Naik)" Process Engineering for Sheet-Metal Die Development" Functionality was taken as a major aspect in determining the design specifications, to ensure smooth transition from design to manufacturing process planning is the bridge to connect them optimally and produce a superior product. All the information and activities are considered for that are performed one after the other

[8] (By T.N. Wong, 2008) "Development of a knowledge-based automated process planning system". This paper presents a new productivity model and a methodology for improving the productivity of products by CAD/CAM integration. It defines productivity as the process sequence of the total number of produced parts to the total machine time required to produce those parts. In Addition, a methodology to improve Productivity of manufacturing products through integration of CAD/CAM. Using this system, machining processes and sequences can also be generated automatically.

[9] (By Sankha Deb, Kalyan Ghosh, 2011) "An integrated and intelligent computer-aided process planning methodology for machined rotationally symmetrical parts"

Using integrated CAM, the Process Planning was improved in two parameters, specifically speed and accuracy and worked upon aspects on selection of operation for machining and the planning to provide a initial set these two were automated through involvement of the discussed methodology.

[10] (Dr. Thomas R. Kramer, 2006) "Process planning for a milling machine from a feature-based design". Dr Kramer. tried to develop an entirely new methodology for inspecting the entire process flow during the manufacturing process of any object as in from the inspection to the final step, it also involved the machining process for any feature base design and way to automate it. Time reduction was another parameter discussed for a basic two-and-a-half dimensional component in an hour thereby saving half the original time ($T_o/2$), use of software like VWS that is run on an Sun computer and is written in LISP provides automation through a process plan and the same was discussed for milling a machine to make a set design tool/part.

OBJECTIVE AND METHODOLOGY

The objective of this paper is to show how deep computers have penetrated even in an industry like sheet-metal manufacturing which seems to be more about SOM (strength of materials).

For this reason, we have chosen two of the most common processes: Bending and Piercing.

AIM

To review all the aspects of computer aided design and manufacturing. With the current tools available and the upcoming advancements.

Our study will focus on sheet metal operations which is one of the most common manufacturing processes in the automotive industry.

Currently there are three major domains in the complete process from design to manufacturing:

1. DESIGN
2. SIMULATION
3. GENERATING TOOL PATHS AND CODES FOR NC MACHINES (i.e manufacturing)

We have chosen Bending and Punching operations for this review and designed a part for which we'll prepare Die and Punch for both operations.

First using solid modelling then simulation and finally CAM.

We'll show each step-in detail for our part.

SOFTWARES AND PROCEDURE

For designing we have used SOLIDWORKS for simulations and results ANSYS and for generating tool paths SOLIDWORKS CAM.

1. The first step is to design a sheet metal part for which we'll prepare the Dies and Punches using solid works
2. Then for this sheet metal part we'll prepare the Die and punch for each operation.
   1. The first step is the punching operation, for which we have designed a punch with two extrusions to complete the punching of two holes in a single step.
   2. Then the edge bending operation will take place from both sides and our part will be ready.
3. To test the validity of our designs for dies and punches we will use ANSYS explicit dynamics.
4. Finally, to create these designs we'll use numeric control vertical milling machines and develop tool paths for the same.
5. Finally, we are going to create the Codes for the machine for these tool paths.

DESIGN

The part we have chosen is very simple and like a handle which is used in various products and transporting services.

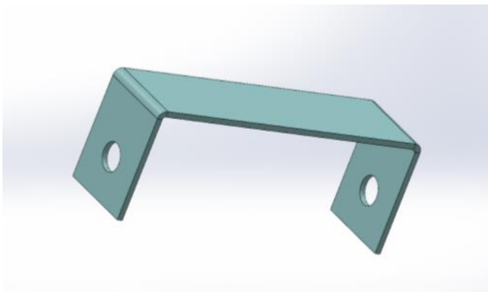


Fig1: sheet metal part to be constructed.

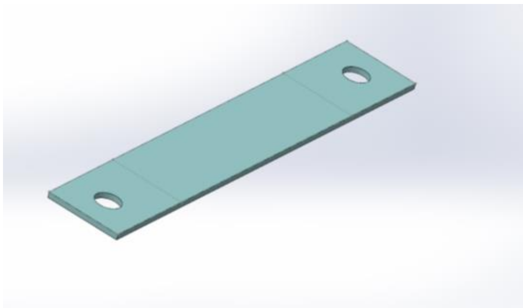


Fig1.2: Flat profile of the sheet metal part.

To make this part Solid works sheet metal workspace was used.

The workspace provides integrated flatten features which helps in the visualization of parts.

To construct this part with sheet metal operation:

1. Firstly, there has to be a piercing operation as we can't do it after the edge bending process.
2. Once the piercing operation is completed, we can then do the Edge bending operation.

SIMULATION IN ANSYS

STEPS TO CREATE THE SIMULATION:

1. First the IGES files were formed and then imported in the ANSYS explicit dynamics.
2. The die and punch were transformed into rigid bodies as we don't want any deformation to take place in these components. (Complementing the actual die and punch materials, this also saves us calculation time)
3. The Die was then fixed with respect to ground.
4. The punch was given the vertical downward displacement.
5. The contact between sheet and die is bonded.
6. In the analysis, we have added total deformation and Equivalent elastic strain.

These steps were carried out for Both the operations and results are as shown.

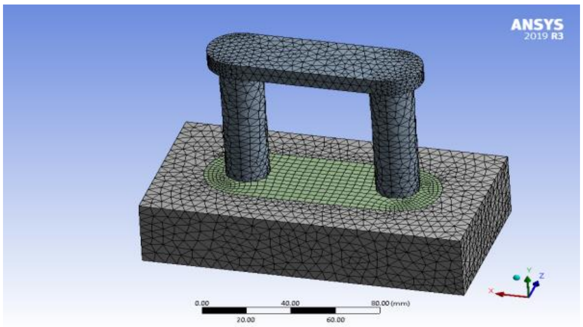


Fig 2.1: meshing for piercing process in ANSYS

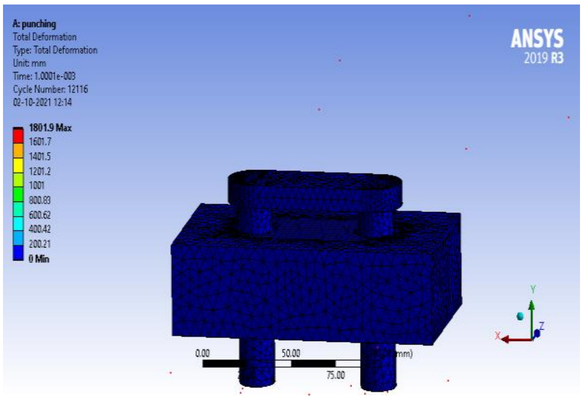


Fig 2.2: Total deformation of piercing in ANSYS explicit dynamics.

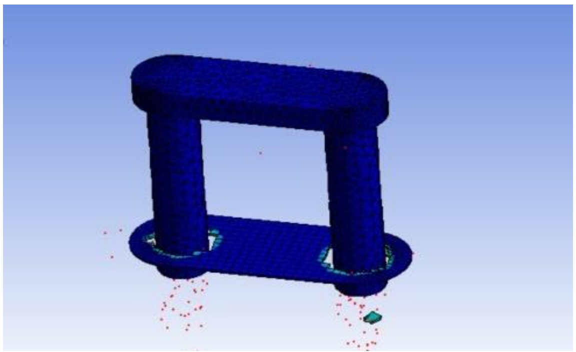


Fig2.3: Equivalent elastic strain, it shows holes being c

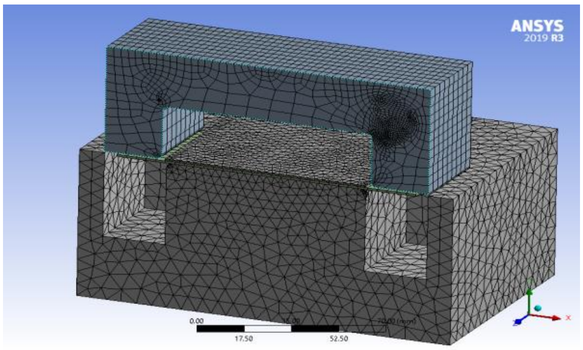


Fig 3.1: Meshing of double edge bending process in ANSYS.

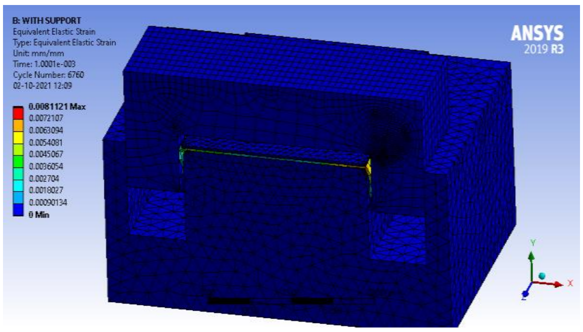


Fig 3.2: Equivalent elastic strain for double edge bending

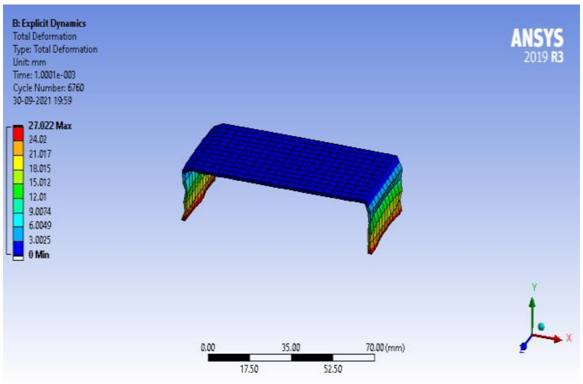


Fig 3.3: Total deformation of sheet after bending.

7. After calculations these were the deformation and Strain results for our sheet metal part.

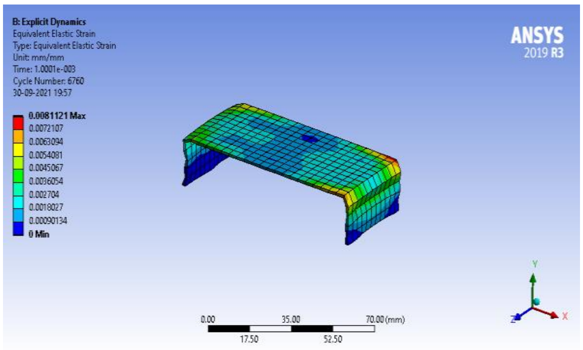


Fig 3.4: Equivalent elastic strain of sheet.

CAM IN SOLIDWORKS WORKSPACE

STEPS TO GENERATE TOOL PATHS FOR NC MACHINE

1. First the machine has to be defined.
    1. In this step further, we must define the machine which we are using.
    2. The tool set to be used, here we can also add our custom tools.
    3. Finally, to choose the post processor.
2. After defining the milling machine, the 2nd step is to get an efficient stock which our die will be carved out.
3. The third step is then to choose the correct coordinate system. This has to be logically correct because based on this coordinate system the tool will come from the Z-axis.
4. Solid works has a great feature recognition system, which helps to extract the machinable features for the chosen machine and tools. With just few clicks we immediately get all the features to be done.
5. Now we know all the features to be machined. The next step is to generate the toolpath for each of those features. Again, this step is assisted by Solid works and can be executed with one click.
6. The final step is to get codes which are for the machine, for this we need to post process and save the file in the desired location. This code file can be opened in the notepad.

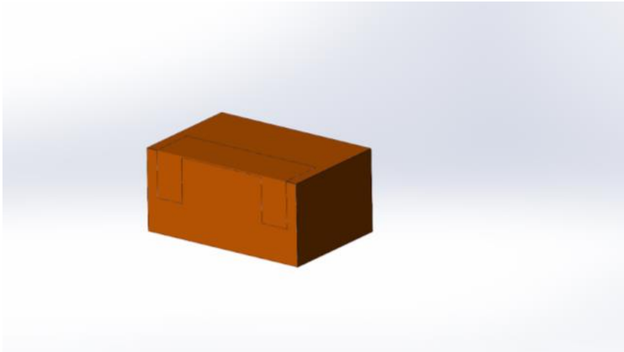


Fig 3.5: Stock for DIE.

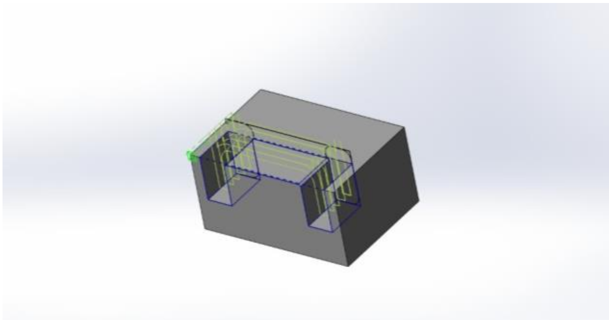


Fig 4.1: Tool path for rough milling.

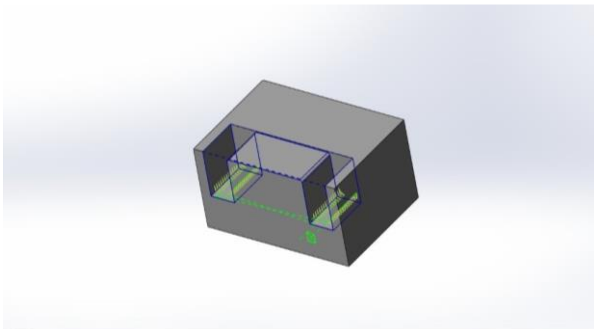


Fig 4.2: Tool path for rough milling at corner.

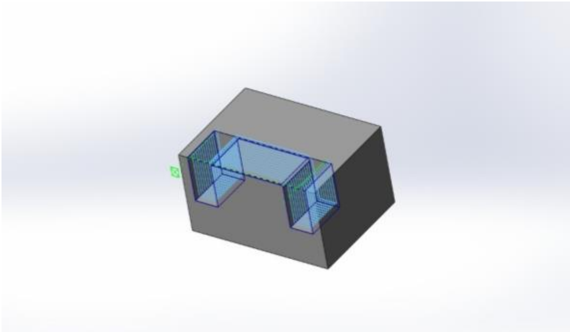


Fig 4.3: Final profiling of contour mill.

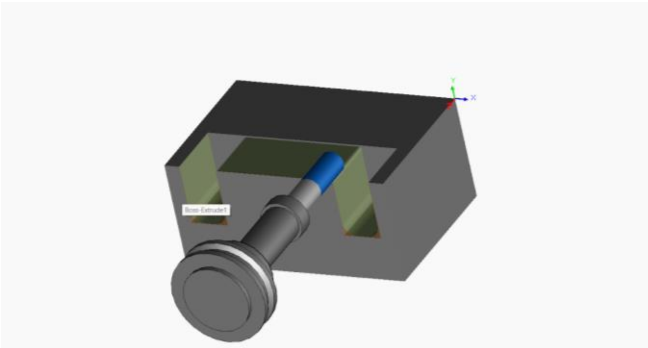


Fig 4.4: Rough mill with tool.

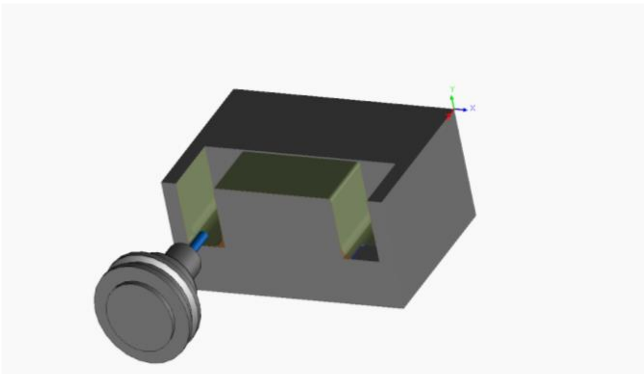


Fig 4.5: Rough mill at bottom face.

RESULTS OBTAINED

These are codes generated using Solid works CAM.

Here we have mentioned the codes for the same.

O0001

N1 G21

N2 (16MM CRB 2FL 32 LOC)

N3 G91 G28 X0 Y0 Z0

N4 T04 M06

N5 S4378 M03

N6 (Rough Mill1)

N7 G90 G54 G00 X-125.352 Y20.

N8 G43 Z102.5 H04 M08

N9 G01 Z92. F122.323

N10 G17 Y8.162 F489.293

N11 G02 X-113. Y13.648 I12.352 J-11.162

N12 G01 X-37.

N13 G02 X-24.648 Y8.162 I0 J-16.648

N14 G01 Y20.

N15 Z84.062 F122.323

N16 Y8.162 F489.293

N17 G03 X-37. Y13.648 I-12.352 J-11.162

N18 G01 X-113.

N19 G03 X-125.352 Y8.162 I0 J-16.648

N20 G01 Y20.

N21 Z76.125 F122.323

N22 Y8.162 F489.293

N23 G02 X-113. Y13.648 I12.352 J-11.162

N24 G01 X-37.

N25 G02 X-24.648 Y8.162 I0 J-16.648

N26 G01 Y20.

N27 Z68.188 F122.323

N28 Y8.162 F489.293

N29 G03 X-37. Y13.648 I-12.352 J-11.162

N30 G01 X-113.

N31 G03 X-125.352 Y8.162 I0 J-16.648

N32 G01 Y20.

N33 Z60.25 F122.323

N34 Y8.162 F489.293

N35 G02 X-113. Y13.648 I12.352 J-11.162

N36 G01 X-37.

N37 G02 X-24.648 Y8.162 I0 J-16.648

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N38 G01 Y20.
N39 Z60. F122.323
N40 Y8.162 F489.293
N41 G03 X-37. Y13.648 I-12.352 J-11.162
N42 G01 X-113.
N43 G03 X-125.352 Y8.162 I0 J-16.648
N44 G01 Y20.
N45 G00 Z102.5
N46 X-131.75
N47 G01 Z92. F122.323
N48 Y-31.75 F489.293
N49 X-123.25
N50 Y-3.
N51 G02 X-113. Y7.25 I10.25 J0
N52 G01 X-37.
N53 G02 X-26.75 Y-3. I0 J-10.25
N54 G01 Y-31.75
N55 X-18.25
N56 Y20.
N57 Z84.062 F122.323
N58 Y-31.75 F489.293
N59 X-26.75
N60 Y-3.
N61 G03 X-37. Y7.25 I-10.25 J0
N62 G01 X-113.
N63 G03 X-123.25 Y-3. I0 J-10.25
N64 G01 Y-31.75
N65 X-131.75
N66 Y20.
N67 Z76.125 F122.323
N68 Y-31.75 F489.293
N69 X-123.25
N70 Y-3.
N71 G02 X-113. Y7.25 I10.25 J0
N72 G01 X-37.
N73 G02 X-26.75 Y-3. I0 J-10.25
N74 G01 Y-31.75
N75 X-18.25
N76 Y20.
N77 Z68.188 F122.323
N78 Y-31.75 F489.293
N79 X-26.75
N80 Y-3.
N81 G03 X-37. Y7.25 I-10.25 J0
N82 G01 X-113.
N83 G03 X-123.25 Y-3. I0 J-10.25
N84 G01 Y-31.75
N85 X-131.75
N86 Y20.
N87 Z60.25 F122.323
N88 Y-31.75 F489.293
N89 X-123.25
N90 Y-3.
N91 G02 X-113. Y7.25 I10.25 J0
N92 G01 X-37.
N93 G02 X-26.75 Y-3. I0 J-10.25
N94 G01 Y-31.75
N95 X-18.25
N96 Y20.
N97 Z60. F122.323
N98 Y-31.75 F489.293
N99 X-26.75
N100 Y-3.
N101 G03 X-37. Y7.25 I-10.25 J0
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N102 G01 X-113.

N103 G03 X-123.25 Y-3. I0 J-10.25

N104 G01 Y-31.75

N105 X-131.75

N106 Y20.

N107 Z92. F122.323

N108 Y-31.75 F489.293

N109 X-123.25

N110 Y-3.

N111 G02 X-113. Y7.25 I10.25 J0

N112 G01 X-37.

N113 G02 X-26.75 Y-3. I0 J-10.25

N114 G01 Y-31.75

N115 X-18.25

N116 Y20.

N117 Z84.062 F122.323

N118 Y-31.75 F489.293

N119 X-26.75

N120 Y-3.

N121 G03 X-37. Y7.25 I-10.25 J0

N122 G01 X-113.

N123 G03 X-123.25 Y-3. I0 J-10.25

N124 G01 Y-31.75

N125 X-131.75

N126 Y20.

N127 Z76.125 F122.323

N128 Y-31.75 F489.293

N129 X-123.25

N130 Y-3.

N131 G02 X-113. Y7.25 I10.25 J0

N132 G01 X-37.

N133 G02 X-26.75 Y-3. I0 J-10.25

N134 G01 Y-31.75

N135 X-18.25

N136 Y20.

N137 Z68.188 F122.323

N138 Y-31.75 F489.293

N139 X-26.75

N140 Y-3.

N141 G03 X-37. Y7.25 I-10.25 J0

CONCLUSION

The entire process from the Design to the Manufacturing end is completed all on computer-based software which summarize our aim which was to show the Design and manufacturing processes being assisted by Software.

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