

A NUMERICAL APPROACH TO THE ESTABLISHMENT OF A SHEET METAL FORMING PROCESS TECHNOLOGY

BRANIMIR BARISIC¹, MIORIȚA UNGUREANU², M. CAR³

Abstract: A numerical approach to the establishment of a sheet metal forming process technology based on process forming energy evaluation, optimized modeling as relates to CNC programming and the definition of forming technology has been presented in this paper. The sheet metal forming energy evaluation, by means of finite element method, has been used to assess the dependency of the energy consumption on the variation of parts shapes before the elaboration of their developed shape prior to their machine production. The modeling approach is used for creating a model with the ultimate purpose of making a developed shape of sheet workpiece in order to make a CAD format for transfer to software for production. DC 01 (EN 10130 –Cold Rolled Steel Sheet and Strip for Cold Forming) was used as the production material and different parts for sheet metal forming have been chosen. Sheet metal forming technologies (punching, nibbling, marking, embossing, beading, tapping, extruding, punch marking and bending) for production due to their material savings, and increasingly reduced processing time are taken in the account in these investigations.

Keywords: energy evaluation, sheet metal forming, strain energy, modeling

1. APPROACH TO ENERGY EVALUATION

1.1. Finite element method (FEM) analysis

The FEM analysis of different forming technologies, in order to obtain the most appropriate parts was performed using ABAQUS 6.4-1 software. A model creation was made by means of ABAQUS/CAE module. The DC 01 sheet material is modeled by an elastic part and anisotropic plastic part by the use of Hollomon-Ludwik's power law input as [1]:

¹ *Assist. Prof. D.Sc., Department of Industrial Engineering and Management, Faculty of Engineering, Vukovarska 58, 51 00 Rijeka, Croatia, Branimir.Barisic@riteh.hr*

² *Assoc. Prof. PhD., North University of Baia Mare, Dr. V. Babes 62/A, 430083 Baia Mare, Romania, miorita.ungureanu@ubm.ro*

³ *Faculty of Engineering, Vukovarska 58, 51 00 Rijeka, Croatia, Zlatan.Car@riteh.hr*

$$\sigma_f = 381.6 \cdot \varphi^{0,113} \quad (1)$$

where: σ_f - true stress; 381.6 – strength coefficient; 0,113 - strain hardening exponent; φ - true strain.

The tools are described as rigid axisymmetric body. That means that lines and curves that define the die and punch were interpreted as rigid unmovable body. They are fixed with a determined point on them. It means, there were used a geometrical way for description of tools. Further, the material is assumed to be rigid-plastic and it obeys the von Mises yield criterion. The elastic characteristics of material are governed by Poisson's ratio and modulus of elasticity.

To predict the consumed energy in forming process numerical modeling of strain energy was done. On the basis of subroutine that determines the total load placed on the workpiece components, the strain energy curve has been constructed. By means of numerical integration at this curve, the strain energy (W) is calculated. Thus, results of strain energy of different workpiece components were obtained. Abaqus relationship for determining of strain energy (W) is [2]:

$$W = \frac{1+\nu}{3E} \cdot q^2 + \frac{3}{2} \cdot \frac{1-2\nu}{E} \cdot p^2 + \frac{n}{n+1} \cdot \frac{\alpha}{Ek_{f0}^{n-1}} \cdot q^{n+1} \quad (2)$$

where: q - the Mises equivalent stress; p - the equivalent hydrostatic stress; ν - Poisson's ratio; φ - true strain; α - yield offset in the sense when $\sigma = k_{f0}$.

Example of the use of strain energy evaluation on a given examples of control board stand and DVD holder

In the figure 1 the best result from the numerical simulation of strain energy for the example of bending of front wall of control board stand is shown. In the figure 2 the best result from the numerical simulation of strain energy for the example of bending of front wall of DVD holder is shown. It could be displayed a plot of model showing the strain energy at the end of the analysis. The plot options to customize the appearance of strain energy can be used [3].

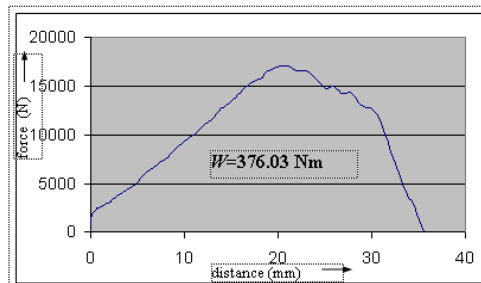


Fig. 1. Strain energy for the bending of front wall of control board stand

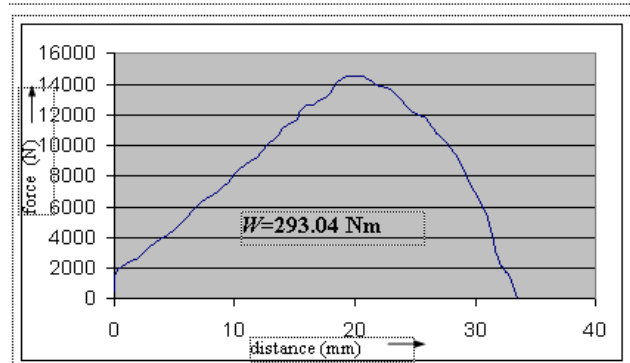


Fig. 2. Strain energy for the bending of front wall of DVD holder

2. APPROACH TO OPTIMIZED MODELING

2.1. Analysis by means of SolidWorks

Optimized modeling i.e. preparation for forming has been done with SolidWorks software. *Sheet Metal* tool palette in SolidWorks software facilitates the formation of sheet metals. Sheet metals can be bent, prolonged or reduced, formed with holes, given added radius to the edges, basically everything that is needed to model the workpiece as necessary.

Bend Allowance is a term for the amount or the length of material that needs to be added in order to gain the desired dimensions after bending. During bending, the inner part is the part that is overloaded on pressure, and the outer on tensile strain. Between these two parts there is a neutral line that is not overloaded and that doesn't change its length. Because of this quality, we use it for calculating the length that is added during bending, and its length represents the length that we are searching for. The position of the neutral axes depends on the conditions of bending, and it is expressed as the K- factor [4]. During the process of modeling, it is important to define the correct relationships between the touching points of the workpiece. The distance on the edges is great, which would create some problems during the creation of this part by welding. SolidWorks contains functions that facilitate both the recognition of such errors and their correction. By selecting the function *Base Flange*, a profile in the plane front will be made by the use of simple tools for sketching and dimensioning. In *Base Flange* function the 3D component requires defining, to do so a table with bending radii is inserted so that solid-works can draw the correction factors from it. All bending will automatically be solved with given radii; this is also a proof for quickness of the approach, (only half of the shape is done in order to cut time by using the *Mirror* function). Side back and front walls are developed with an *Edge Flange* function; which is in many ways similar to the *Base Flange* function. For the drawn sketch of bended edge, the radii are selected from the bending table and the edge is finished. The necessary loosening on places of contact; the entering of one part in another are done

with classical *Extrude/Remove Material* functions. Further bendings are done with the advanced *Miter Flange* function. Another function used is *Hem*, and with it we can define endings on the sheet metal, in various shapes, and in the example the *Tear Drop* shape was used. Now that the model has been made, it is very easy to make a developed shape with the order *Unsupress Flat Pattern*, and as such to save it in the IGES format that is ready for transport to ToPs software for creating NC code.

2.2. Example of the use of Sheet Metal function on a given examples of control board stand and DVD holder

Example for correct and non correct defining of touching points of the control board stand is presented in figure 3 and figure 4.

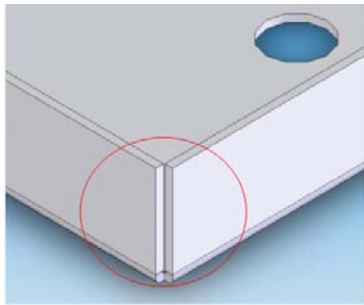


Fig. 3. Example of touching points of metal shows correct distance

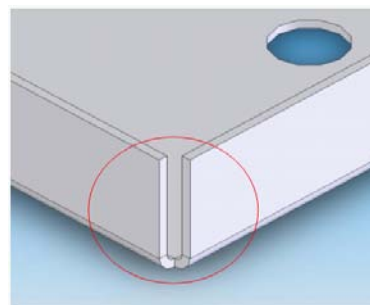


Fig. 4. Example of touching points of metal shows the failure

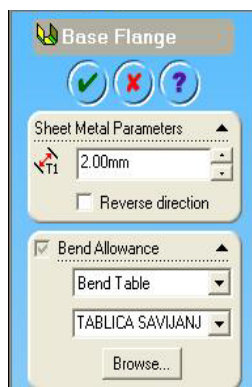


Fig. 5. Example of the wall thickness and Bend Allowance

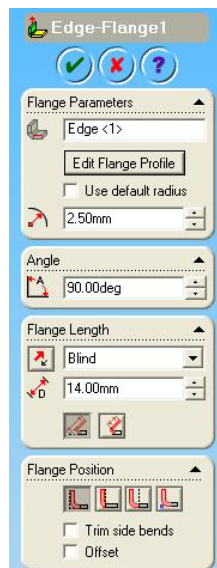


Fig. 6. Example of Edge Flange function

In the case of Base Flange function at Property Manager tool for control board stand the wall thickness and Bend Allowance were chosen (Fig. 5).

Example of Edge Flange function choosing for control board stand is presented in figure 6.

The control board stand is modeled as an assembly of four parts (only the plate without the buttons). These parts are: control position 1, cover position 2, base position 3,

Now that the parts of control board stand have been modeled it is very easy make a developed shape of each part by means of *Unsupress Flat Pattern* function. In figure 9 the developed shape of control of control board stand is presented.

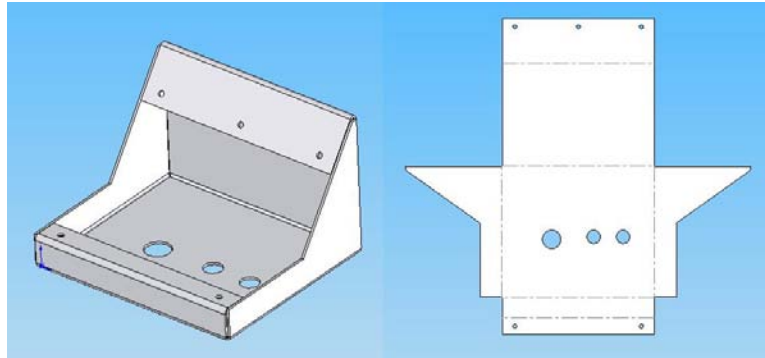


Fig. 9. Developed shape of control

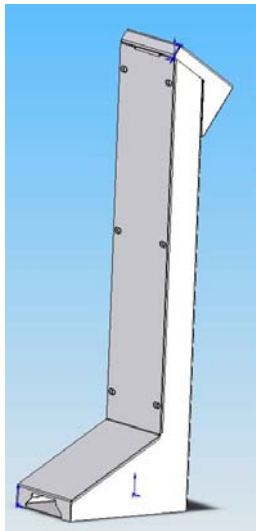


Fig. 10. Outline of control board stand after optimized modeling and assembling

Outline of control board stand after optimized modeling and assembling is presented in figure 10.

For determining of different shape of holes on sheet metal *Hole* function can be used. In figure 11 the example of *Hole* function using on modeled DVD holder is presented.

For making of different open ends *Cut-Extrude* function can be used. In figure 12 the example of *Cut-Extrude* function using on modeled DVD holder is presented. Now that the model of DVD holder has been made it is very easy make a developed shape with the order *Unsupress Flat Pattern* function. In figure 13 the developed shape of DVD holder is presented.

The purpose of SolidWorks modeling is creating a developed shape of sheet metal products before it production on presses [5, 6].

3. APPROACH TO CNC PROCESSING

3.1. CNC processing by means of ToPs

After the model shape has been developed and as such to save it in IGES format it is possible to it for ToPs software in order to make CNC program.

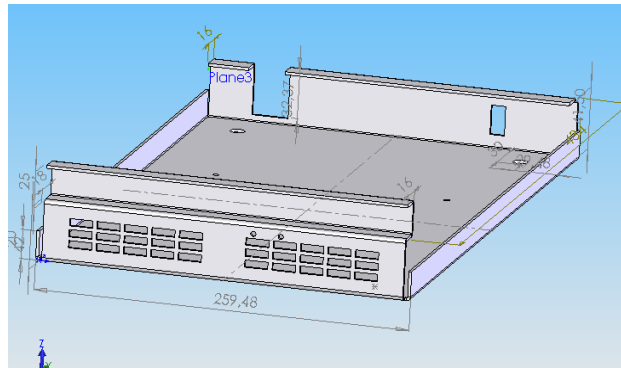


Fig. 11. Modeled DVD holder by means of *Hole* function

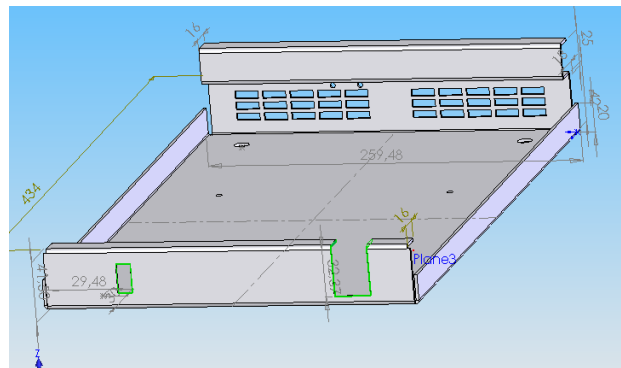


Fig. 12. Modeled DVD holder by means of *Cut-Extrude* function

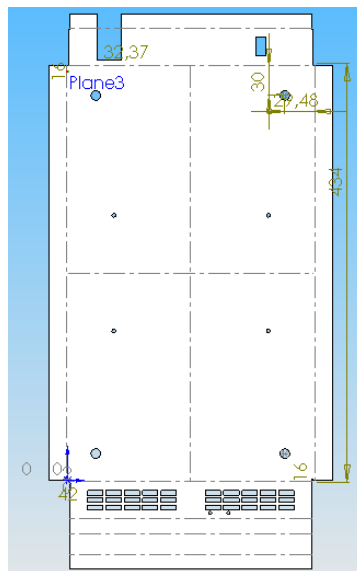


Fig. 13. Developed shape of DVD holder

ToPs (TRUMPF Programming System) software is used for creating of programs for machines in order to produce sheet metal workpieces [7]. The hardware platform ToPs doesn't require anything more than a PC with a Windows operative system. ToPs can generate fast, process insured programs by the use of working optimization. With CNC program it generates clear plans of setups that include detailed information in connection with times of done work and needed tools. The data for different workpieces production are inserted from 2D CAD system trough Standardized IGES display. ToPs system has the capability to make drawings by combining the functionality of CAD with macros for geometry that is specific or rarely used or often used so that it insures that the drawings are generated fast and efficiently. The following steps are used in drawer production:

- Step 1: Creation of drawing in ToPs or importing of drawing from some of CAD programs that support IGES or DFX formats;
- Step 2: Configuration of sheet metal for maximal usage and parallel defining of the working process, after that the generation of CNC code follows;
- Step 3: Transfer of program on the control machine unit [8].

ToPs 300 system has the capability to make drawings by combining the functionality of CAD with macros for geometry that is specific or rarely used or often used so that it insures that the drawings are generated fast and efficiently. Insertion of drawing can be also made from ToPs 600 system for bending technology. ToPs, analyzed every drawing while taking in consideration the incoming work operations. Open contours become closed, added elements deleted, and contours transitions smoothed [6].

ToPs, chooses the correct suction heads and insures that the workpieces are properly placed. Operation of loading of the sheet metal for parts and unloading the skeleton are also programmed with the help of ToPs. At automatic acceleration programming the acceleration values of the axes have been optimized in favor of considerable increase in productivity with the TRUMPF forming machines (TC 5000 R). The considerable influence the masses to be moved have on the acceleration was the reason for this optimization. The fully automatic execution of a program trough the machine requires loading the correct tools from tool storage into linear magazine. For this purpose of workpieces forming, the tools are managed in table work. The tool setup list is generated by pressing a button for the program to be executed. The tools are displayed in the tool setup list with all identification characteristics such as ID number, tool dimensions, tool station etc. A tool setup list can also be created for the loading of the external tool memory TRUMATOOL 40/70 (Fig. 14).

All tools which are needed for the execution of a CNC program are entered in the tool requirements list. The operator can have displayed which and how many tools must be available. Further lists show the tool changed and the identification characteristics of not only single tools, but all tools in overview. The list can be edited directly. Caused by the geometrical dimensions of the tool adapter and clamps, areas are established in the immediate proximity of the workpiece clamps, where machining

cannot be carried out.

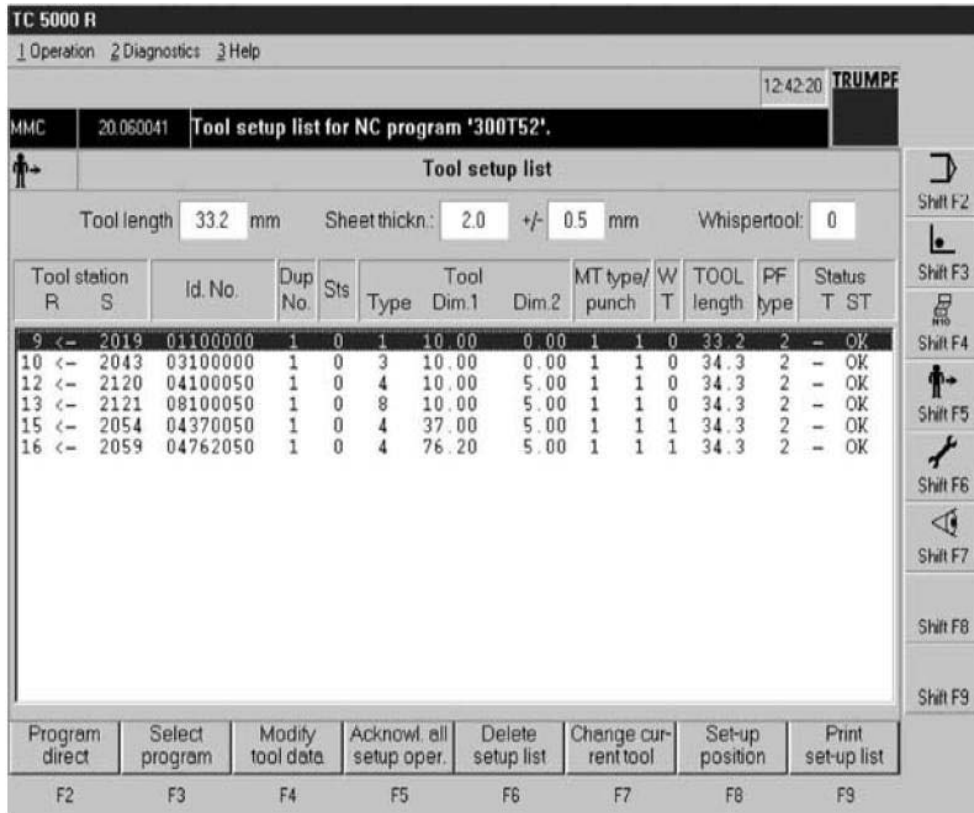


Fig. 14. Trumatool 40/70

These so-called clamp dead areas must be observed without fail when programming. This not only applies to feeding break-troughs and contours to the sheet, but also to the approach of positions close to the clamp dead area. The process with opened clamps, when repositioning, is only permitted outside the dead area in x-direction. Multitools bring about larger clamp dead areas due to the eccentric arrangement of their single tools. Several forming functions and the positioning of the sheet for drawer are CNC-controlled. The CNC control coordinates the drives to ensure the synchronization of separate travel motions and the exact alignment from the coordinate guide (workpiece positioning) and ram (punching stroke). At workpieces forming, it is mostly the case that several, often identical, parts are produced from one sheet. First, the tool inserted into the tool adapter machines all equal elements of the sheet. Then the next tool is inserted. The machine only separates the single workpieces with a tool the sheet has been completely formed. After everything is set up (paths, tools, number of workpieces, etc.) simple clicking on generate insure the CNC program for machine.

3.2. Forming technology used for DVD holder and control board stand

3.2 1. Punching

Punching includes the forming of an outer shape and the forming of an inner shape (perforating). When punching, the break-trough in the parts of drawer corresponds exactly to the geometry of the punch. Row of holes, circle of holes, and hole grids are produced by offsetting the drawer according to the specified dimension after every single stroke. The machine that was used to make the control board stand is the press of the Trumpf company, and the model name is Trumatic 200. It is a numerically controlled machine with very high speeds for main and feed movement. The maximum diameter of a punched hole can be 76.2 mm. The speed of punching, i.e. the number of punches per minute, depends on several parameters: the speed of tool movements (axis), the length of the tool, the thickness of the sheet metal and the hole distance. Highly dynamic jig fixtures receive the plate and according to the given parameters they move it with speeds of up to 100 m/min. The machine is designed in such a way that the worked plate is easily removed, and the cut piece is also rejected and it doesn't remain on the machine. With this machine, it is possible to cut out, cut off, punch and to carry out many other operations [8].

3.2 2. Nibbling

Nibbling represents the piece by piece separation of material along a randomly formed nibbling line by a multitude of punching. In doing so, the distance from the hole to hole is smaller than the dimension of the punch. In this process, the produced parts are advanced step-by step in the required feed direction while the punch constantly moves up and down (continuous stroke rate). The feed control assures that the workpiece is stopped shortly before each lowering of the punch into the workpiece surface. The next step of feed commences as soon as the punch is above the part surface again. Trough continuous repetition of this process, the forming of the required drawer shape is divided into a score of small, individual cuts [4].

3.2 3. Bending

All bending will automatically be solved with given radii according to the table with bending radii inserted in SolidWorks software at Base Flange function. It means so that program can get the correction factors from the table with bending radii and use it in forming technology. Bending for listed examples of DVD holder and control board stand is executed on a bending machine Schiavi Hfb 50-20. After metal forming on a Trumatic machine, the parts are sent for bending. Bending is executed on a bending machine with the assistance of an operator that holds and rotates the part. After positioning, the bending begins. After the first bend, the machine automatically follows the CNC program and sets the boundary conditions for a second bending, and

this continues until the operation cycle is complete. In free bending, there is no need for a change in equipment or dies to secure a different bending angle, the reason for this being that the angle of the bend is determined by the punch of the upper tool [4].

3.2 4. Other forming

Also, different forming processes by which the sheet metal is formed as extruding, lower cutting, beading, and tapping have been applied in this research. Also, at punching the process as: marking, embossing and punch marking have been used.

4. CONCLUSION

The paper presents a numerical approach to the establishment of a sheet metal forming process technology based on strain energy evaluation by means of FEM, optimized modeling by means of SolidWork software and CNC programming by means of ToPs software. The strain energy approach has been used to assess the dependency of the strain energy on the variation in input shapes of parts before the elaboration of their developed shape in SolidWork software prior to their forming process.

The optimized modeling is used for creating CAD model with the goal of creating a developed shape of sheet workpiece in order to CAD model format transfers to ToPs software for production on machines.

SolidWorks software for modeling of different parts and ToPs software for creating of NC programs for machines due to their increasingly reduced processing time and material savings are promising tools in computer environment at sheet metal forming. Also, Abaqus software for evaluating strain energy has a useful implementation regarding reducing of energy consumption and do energy savings.

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