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TECHNICAL CONSIDERATIONS UPON PERFORMANCE IMPROVEMENTS IN STAMPING PROCESSES BY IMPLEMENTING CNC AND REVERSE ENGINEERING TECHNIQUES

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Abstract: In the paper there are analyzed some technological development methods, respectively the way the stamping processes can be improved by implementing reverse engineering, CAD/CAM and CNC techniques. For sustaining the presented technical analysis and considerations, a case study which intends to point out the main technological aspects, advantages and disadvantages, related to sheet metal stamping processes on CNC centers comparatively to those on classical presses, is also included in the scientific content of the paper. Some obtained results and related conclusions are finally presented.

1. INTRODUCTION. PROBLEM STATEMENT AND STATE OF ART

Computer and information technology has significantly influenced the modern machine-tools structure. Without both reliable hardware and software support, it wouldn't be possible talking about rapid technological improvements, numerical control, CNC centers, flexible manufacturing cells or flexible manufacturing systems.

As in the case of any other manufacturing process, metallic parts production by stamping requires passing through a number of steps up to final product release, such as: part engineering design, operation preparing phase and the actual manufacturing process.

Due to the direct relationship between these processes, it is more efficient to do them simultaneously than sequentially. Nowadays, engineering designers use CAD/CAM (Computer-Aided Design / Computer-Aided Manufacturing) technologies to achieve fully compatible and associative digital models in product development activities such as conceiving, engineering design and technology design. CAD systems offer the possibility to save each technical drawing in digital format, that being extremely useful as the model can be immediately available for the operation preparing phase for manufacturing process. CAM systems are software tools, having a PC as functional platform and helping the numerical control programmer and operator to elaborate and deliver the numerical code that the machine-tool needs. In such conditions, it is necessary for the CNC programmer and operator only to input the information about the needed manufacturing operations and the CAM system will automatically generate the G-code program.

In the present stage of modernizing, development and progress, as perspective for machine manufacturing technologies, mechanical parts machining by stamping on CNC centers is one technological process that rightfully earned its important place among other methods by economical means and by providing adequate dimensional accuracy.

One particular area in the progress of stamping processes is represented by the correlation of CNC machining with late generation technologies such as reverse engineering (RE) techniques. Here it is talking about scanning the existing or pre-stamped part in order to generate a digital mock-up that will be a very accurate model of the physical object. That gives the opportunity to obtain a CAD model and to generate engineering documentation for an existing outsourced part in order to use them in further technology design or to compare the digital model with an originally designed one and analyze where there are differences, where did the faults come from, being possible to perform shape deviations analyses. Based on results and conclusions obtained after such

analyses, overall re-design can be done in order to eliminate shaping defects and to achieve desired physical part features.
As long as CAD has become a standard in the engineering design evolution, RE techniques become more and more popular among the mostly preferred methods of virtual 3D model reconstruction starting from existing physical models. The Reverse Engineering process basically involves to measure an object and to re-create it as virtual 3D model.
Three distinct phases are specific for a RE process, respectively as following: scanning, point cloud processing, usually known as clouding activity and finally the data export toward CAD software.
There are also two specific components of RE technology: hardware and software. The hardware is used for the acquisition of data, which in terms of 3D modeling means collecting data as points which will provide an accurate representation of the scanned physical object. The main methods for point data collecting are: with contact, non-contact and destructive. The software component of RE applications has the function to process and to transform the data that came from the hardware, in order to convert it into 3D models having the same geometrical features as the scanned physical object. Results obtained by data processing can be polygonal or NURBS (non-uniform rational B-splines) surfaces. Polygonal models, in DXF, STL or VRML formats, are used mainly in rapid prototyping technologies, in rapid tooling technologies, in simulation or in laser based milling. The NURBS surfaces are efficient on any CAD, CAM or CAE system, being really useful for modeling complex shapes or free-form shapes, in which case polygonal features are not enough for completely describing the object’s geometry.
Two of the known RE techniques involve segmentation and surface fitting. Depending on these two methods, we can organize data into sets of points and then fit onto them a NURBS surface for defining a CAD model. Difficulties appear when gathering points from regions that are very narrow or from very hardly accessible surfaces. In such situations, various interruptions or missing points can be encountered on the initial points cloud. Those problems are later treated by post-processing techniques. That is why multiple scanning sets are usually performed and then united, in order to achieve an accurate image corresponding to the scanned part.
Research studies developed in cold plastic deformation area are focusing on the type of machine-tool that is used, being performed qualitative and quantitative cost analysis, or analyzing the reduction of noise on CNC centers, but also shape deviations analyses are performed, [9].
Many researchers such as Broggiato, Campana or Gerbino had proven that the main aspects in cold plastic deformation are the choice of the most suitable method of analysis and definitions of comparative procedures between faults and good parts. The main research directions are focusing on operating conditions related to metal surface or the choice of the machine, in terms of low cost, multiple features and in-process quality control, [10].
This paper intends to present some technological development methods, respectively the way the stamping processes can be improved by implementing reverse engineering, CAD/CAM and CNC techniques. For sustaining the presented technical analysis and considerations, a case study which intends to point out the main technological aspects, advantages and disadvantages, related to sheet metal stamping processes on CNC centers comparatively to those on classical presses, is also included in the scientific content of the paper.

2. STAMPING ON CLASSICAL PRESSES

Stamping is one of the cold plastic deformation processes developed on stamping devices which has been significantly used over the last years. This process is influenced by several and diverse factors which can create problems during manufacturing, such as: physical or mechanical properties of the material, sheet metal thickness, dimensions and the shape of the contour to be cut, holes, cutting speed, semi-product lubrication, wear of active edges. These factors are negatively influencing the process, but the progress could not be stopped, high accuracy parts being obtained at fairly low production costs, [1].

For the coefficient of use and savings of material to be maximum, it is necessary to take into account some rules in sheet metal stamping, which can improve the process performances, such as: the technological process should result in maximum simultaneously obtained parts; the nesting on strips should be made in the manner to result an entire number of parts; for mass production it is indicated the use of laminated strips, of special metal sheets or of wide cut strips and not of narrow ones etc, [1].

After choosing the right nesting method and after determining the coefficient of use of material, there is further advancing to forces calculations and dimensioning of stamping device components. After all the steps required for engineering design of a stamping device for parts having certain dimensions and configuration are proceeded, the choice of mechanical press is made knowing the required brute force, that was previously calculated, needed by the press to operate.

There are few disadvantages in stamping processes on classical presses, such as: high qualification requirements for operators, for setting the machine-tool and its punchers; due to continuous feeding, the work area cannot be closed resulting in possible labor security problems; limitations due to complexity and over-sizing of parts; the need to obtain relatively complex parts by a minimum number of double-strokes (combined stamping devices) involves great investments both in tools and largely capable presses.

Therefore the classical presses are optimal only on simple geometry parts, with fairly acceptable deviations and mass production conditions.

3. PRINCIPLES FOR ANALYTICAL CHOICE AND PERFORMANCE INCREASEMENT FOR CNC PRESSING CENTERS

Machine manufacturing industry is strongly influenced by one manufacturer’s capability to adapt to technological changes or to rapid development of new products. Practice shows that human operators will remain behind computer terminals and will interfere in adapting robots and flexible systems to the organizing degree of production, in manufacturing planning and programming. That has made classical presses to be overtaken by CNC pressing centers.

So, the development of programming codes such as APT, EXAPT, TELESPT, IFAPT, MITURN, the use of computer controlled industrial robots, of computer controlled manipulation and transport devices used in logistic systems for work objects and tools, of conveyers, robocars and others, has made necessary the interconnection of remote operating machines in manufacturing systems, by computer means.

In order to fully take advantage of CNC pressing centers and to achieve the desired production plan, in the shortest period of time and with high accuracy levels, the sheet metal parts industry uses today CAD/CAM systems to assist stamping processes.

These CAD/CAM systems provide integration of engineering design, modeling, simulation, operation planning and numerical code generation for metal sheet processing, in conditions of optimal selection of nesting method with as low as possible waste.

One of the major features of numerically controlled pressing centers is productivity. Thus, in order to achieve maximum efficiency, a few aspects should be taken into account to be accomplished: lower times for cutting the metal sheets to the desired dimensions; several parts, not similar, nested on the metal sheet; regularly planned maintenance verifications; tool settings for further operations and combining multiple steps of processing in a single one.

Within an approach for choosing a CNC pressing center, a comparative analysis should be performed upon technical specifications, productivity and efficiency for several types of such machine-tools existing on the market.

Further on, a set of qualitative comparative considerations for some of the most popular stamping CNC machines from around the world.

Coma 567 (AMADA AMERICA INC), showed in Fig. 1, is a CNC pressing center, mechanically driven. It is capable of producing 55 tones brute force and may operate with sheet metal of maximum 1524 x 3658 mm. The turret capable of holding 44 punchers, reduces tool change time, manufacturing time, maximizes flexibility of the machine and reduces costs for punchers having two positions with auto indexation at 1.25”. This machine is developed for series and mass production, for manufacturing high dimensions sheet metal with large thickness. It provides effective machinability for parts with minimum initial settings and maximum use of the machine. Hydraulic based brakes offers steady maneuverability, constant values of forces and reduction of noise.

Fig.1. Coma 567, [4]

Pega 357 (AMADA AMERICA INC), showed in Fig. 2, known also by AMADAM 04PC, has been designed in 1989. Regardless of its age, this one is most used in thin sheet metal stamping industry. It has a load of 33 tones brute force and may operate with sheet metal of 1270 x 1830 mm. Maximum thickness of the stamped part may be 6 mm. It offers small dimensions, low costs, which makes it preferred by medium and small enterprises. The turret has punchers stations, two with auto indexation. It comes equipped with one microprocessor, diagnostic system, automatic repositioning system, hydraulics and it can see the difference between CNC code in mm or inches.

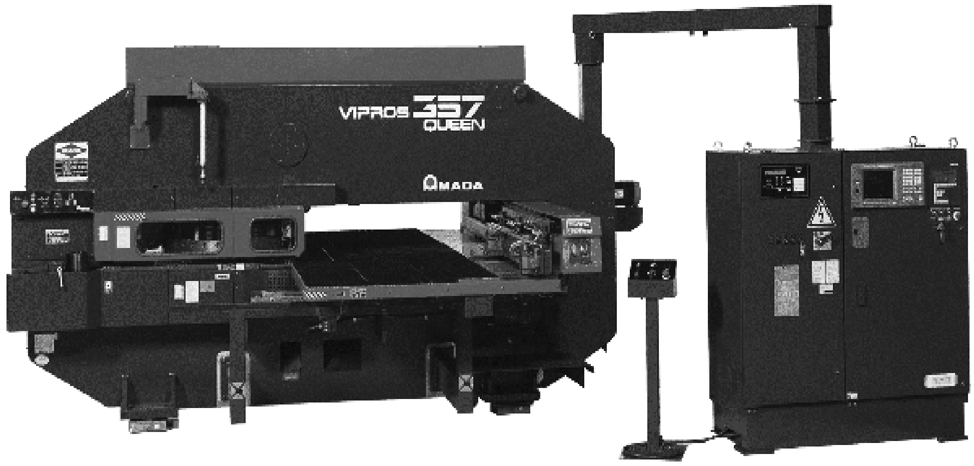


Fig.2. Amada 357, [3]

Fin Power Express A5-25 (Fin Power Group), showed in Fig. 3, is one stamping center for thin sheet metal, but with high accuracy values. It can only generate 25 tones brute force, but has the advantage of 8 mm thickness. It can withstand larger thickness, almost double as Pega 357. Operating system it is not limited to one option, the operator being able to choose between SIEMENS 840D and FANUC 16P. One advantage consists of possibility to automate the loading and downloading processes. It has only 20 stations on the turret but none with auto indexation.

Fig.3. Fin Power Express A5-25, [5]

Strippit 1250 H/30 (LVD Company n.v), showed in Fig. 4, is a CNC pressing center with 42 stations capable thick turret and 40 stations capable thin turret, both having up to four auto indexation stations with punchers up to 88.9 mm in diameter. It can perform on sheet metal 9.5 mm thick with 330 HP. The ram is hydraulic and it can control punch speed for better flexibility in mass production. Sheet metal can be 1250 x 2000 mm without the need for repositioning and it can withstand weight up to 358 Kg, this making it the only machine of its kind.

Fig.4. Strippit 1250H/30, [7]

Traumatic2000 ROTATION (Trumpf Group GmbH), showed in Fig.5, is a compact pressing center used in prototypes manufacturing, or in middle to small mass production. One of its advantages is low setting time and easiness in operation. TC 2000 R can perform with a blow rate of 900 punches per minute and up to 2200 punches per minute in case of marking operations. The blow rate is similar in punching as it is in stamping operations.

Fig.5. Trumpf 2000 ROTATION, [8]

All these CNC pressing centers are controlled by CNC codes, which are different from one machine to another. By generating code, we do not perform the actual stamping, but we

mark the lines for the operation to take place. Some of the codes in use today are as following: RADAN and Punch5 for Amada, Siemens 840d for Finn-Power, TRAUMATIC for LVD and JetCAM for Nisshinbo.
Among those what already have been presented above, there has been chosen to work on PEGA 357 with RADAN as the software for CNC code generation and SolidWorks as CAD modeling software.

4. CASE STUDY

In order to achieve the aim of this paper and to practically sustain what has been said before, there has been chosen to scan and produce a part, having the geometry shown in Fig. 6. The part is the back side of the main case of a PC (personal computer). The part is made of steel OL 37 according to SR EN 1653:2003, 1 mm thickness and manufactured both on classical presses and on CNC centers by applying reverse engineering techniques and using CAD/CAM technologies.

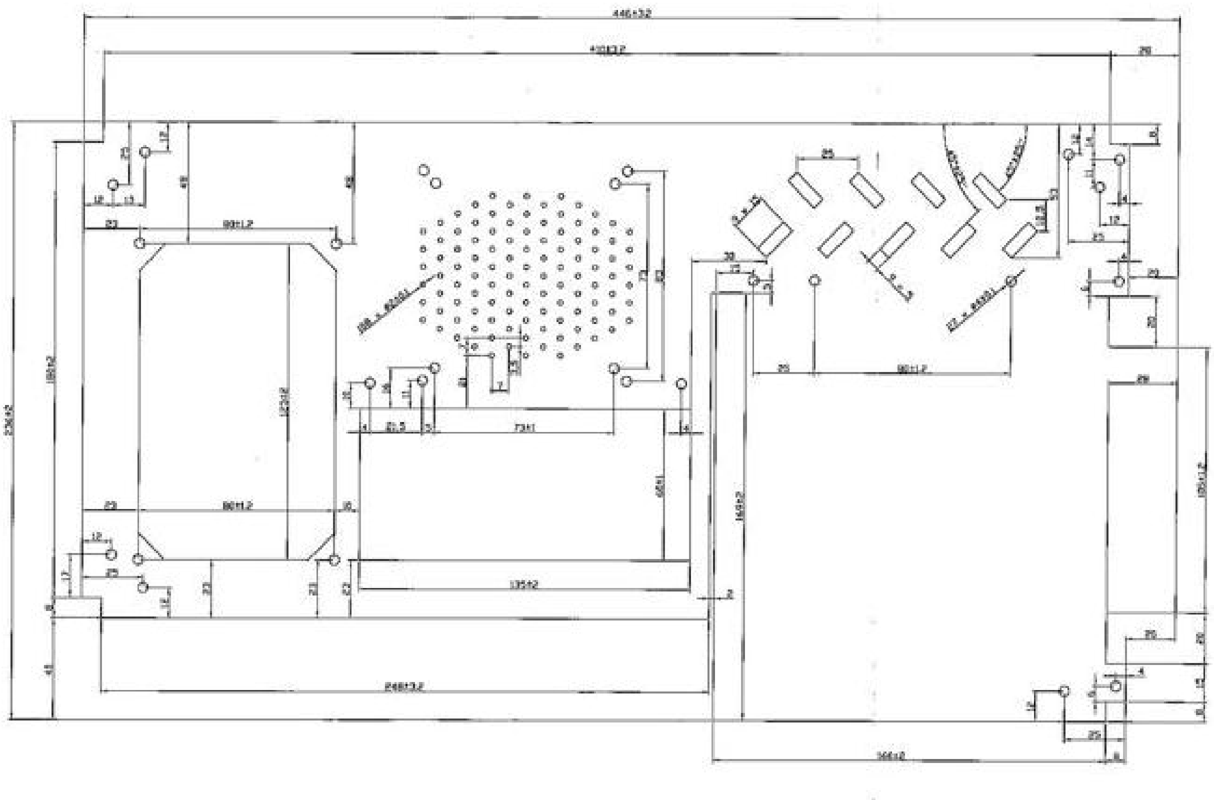


Fig.6. Part to be manufactured

The part to be manufactured by CNC pressing centers, already stamped and produced, is scanned accordingly to reverse engineering techniques, the data sets obtained as an image of the initial point cloud is afterwards processed by CAD/CAM for a digital mock-up and then, by RADAN means, generated into a fully functional CNC code for the machine to use.
The detailed process unfolds as follows:
The back side of a computer case is placed on a flat surface which is opaque, in order to be scanned. Using ISEL CNC based machine EuroMod (Fig. 7), the part has been scanned by selecting AUTO mode of processing.

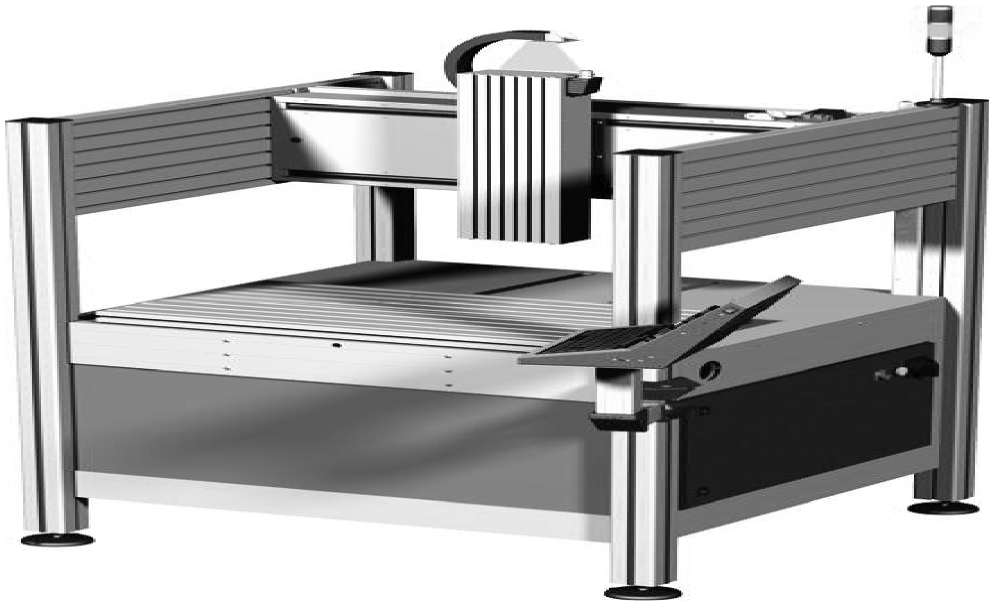


Fig.7. ISEL CNC Based Machine EuroMod

Five different scans have been taken in order to achieve five data sets. Thus, the initial point cloud has been obtained by uniting the five different sets. In this way most of the gaps or holes or even surface interruptions have been eliminated than performing just one scan. The point cloud has been then exported to Solid Works for processing to a fully compatible CAD design model. In this stage of the process, it can be performed product analysis (to illustrate the geometrical faults, or just shape deviations analysis).
Having processed the point cloud into a CAD digital model, it has been then exported to RADAN software for numerical code generation. The software has given the G-code for the CNC pressing center, the number of parts depending on nesting method and metal sheet dimensions; in the present case study there has been used 1000 x 1000 mm metal sheet.
An AMADA PEGA 357 pressing center has been used to produce the part. The main input data and also the used punchers are presented in Table 1 and respectively in Table 2.

Table 1. Input data for RADAN application

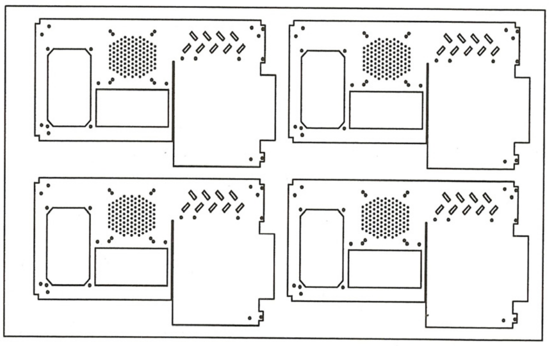
CNC based machine	AMADA PEGA 357 (RP1)
Drawing name	CAPAC SPATE COMPUTER
Drawing number	1
Data	Monday, 15 MARCH 2010, 11:56:18
Material	OL37
Material thickness	1 mm
Sheet metal dimension	1000 x 1000
Clamp position	1) 250 mm, 2) 750 mm

Table 2. Punchers used in the case study RADAN application

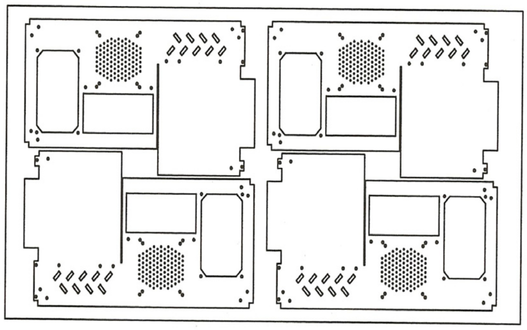
Tool	Type	Size [mm]	Angle [^{0}]	Tolerance	Tool no.
1	RECTANGLE	100 x 5	-	0.250	83100.05
3	RECTANGLE	30 x 2	90.000	0.250	33002
5	RECTANGLE	30 x 2	-	0.250	33005
11	RECTANGLE	85 x 5	90.000	0.250	38505
12	SQUARE	20 x 20	-	0.250	450
15	RECTANGLE	15 x 5	-	0.250	31505
18	DIAMETER	ϕ4	-	0.250	104
19	DIAMETER	ϕ2	-	0.250	102

Regarding the degree of material use, the value is smaller comparative to classical presses, its value being around 63.2%. The number of parts from the sheet metal is six, for a nesting variant in system of 2 x 3, the first part being considered reference and the distance between parts is 486 mm on *X*- axis and 276 mm on *Y*- axis. Operation time is 8.51 min per metal sheet.

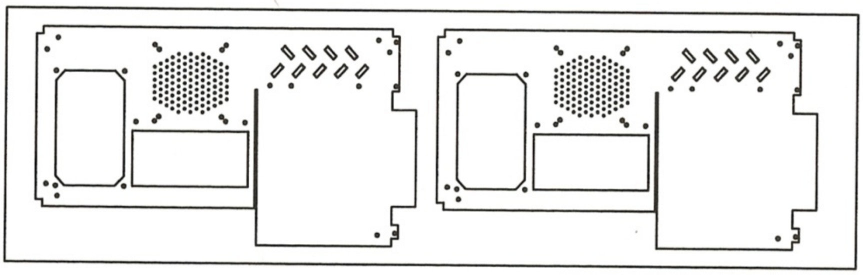
To point out the differences between the two considered stamping methods, there has been chosen to obtain the studied part also on a classical press. Thus, in Fig. 8, there are three nesting variants for the part from Fig. 6.



a) Variant 1



b) Variant 2



c) Variant 3

Fig.8. Nesting variants

Through calculations, in order to choose between one of the three cutting variants, one criterion would be the coefficient of use of the material, which has the following values: for

Variant 1 – 71.84%, for *Variant 2* – 79.83% and for *Variant 3* – 80.6%. There can be observed that optimal is *Variant 3*, the press being for cutting and punching.

5. CONCLUSIONS

The use of CNC technology by reverse engineering means and CAD/CAM systems stands out regarding accuracy, low production times, relatively low costs but, most of all, by the possibilities that is offering in detecting problem sources such as faults or nonconformities, or shape deviations analyses and in quick fixing possibility by CAD technology of the digital model, in order to eliminate any inconvenient that the part may have.

In productivity terms, we observe that CNC technology is better by the number of parts obtained and the values of the coefficient of use of material. Another advantage would be high accuracy and quality of the final products comparative to classical presses, this being possible by means of reverse engineering and CAD/CAM systems.

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