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Computer Aided Design and Manufacturing Evaluation of Milling Cutter when High Speed Machining of Hardened Steels

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Abstract

This paper presents the influence of CAD modelling and CAM simulation advanced techniques for hard milling technology. The main aim of simulations is the ability and importance to improve and optimize hard milling process even before the real production of its own products, because their manufacturing process is rather expensive. The reached results present us roughing and finishing process of hard milling and milling strategy or generation of tool-paths in CATIA V5. All simulations of milling experiments show that the proposed clear-up tool path works well in the real cutting process and can improve the machining efficiency of the machining process. At the same time, the manufacturing must have the advanced process equipment and method due to the requirements of the design performance and machining efficiency. Finally, hard milling simulations in CAD/CAM system CATIA V5 were performed in order to determine and evaluation of suitability of the proposed shapes of the hard milling product.

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Keywords: high speed machining; CAD/CAM; milling strategy; milling cutter

1. Introduction

The current market requires manufacturing companies to deliver their products to market as soon as possible at the lowest price and high quality. Cycle of part innovations is constantly reduced. These requirements can be effectively achieved only through the use of advanced information CAE (Computer Aided Engineering) technology to help us implement increasingly stringent demands on productivity and quality in the design and production [1, 2].

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Nomenclature

CAD	Computer Aided Design
CAE	Computer Aided Engineering
CAM	Computer Aided Manufacturing
CATIA	Computer Aided Three dimensional Interactive Application
CL	Cutter Location (Data)
CNC	Computer Numerical Control
HM	Hard Milling
HSM	High Speed Machining
HRC	Rockwell hardness
a_e	width of cut [mm]
a_p	depth of cut [mm]
f	feed rate [mm]
v_c	cutting speed [$m.min^{-1}$]

According to the investigation of these authors [4, 5, 6, 7], so-called CAE systems are used for implementation of the requirements in manufacturing practices, which are intended for the development and design of products, graphic modeling, structural analysis of the components, to the programming of production activities CAM (Computer Aided Manufacturing) [8, 9] and CNC (Computer Numerical Control) systems. The development of innovative products and their realisation by means of advanced manufacturing methods and process combinations is a key issue in international competitiveness. In the field of the new Rapid Technologies, represented today mainly through various Additive Manufacturing processes, the progress of the High-Speed Machining (HSM) technology is of remarkable and specific importance [3]. Today's trend component is machining in one setup, with minimal clamping. This is achieved by the time reduction of the final machining, while eliminating inaccuracies caused by manual switching of the part [14]. The introduction of computer graphics allows a computer to create pieces, handle and examine them. Universal application of computer aided systems brings significant benefits. CAM is most closely associated with functions in manufacturing engineering, such as process planning and numerical control (CNC) part programming [10, 13, 15]. Production of parts with complex shapes [12] with these technologies largely depends on the compressibility and the correct choice of conditions in sheet metal forming and milling. Accuracy and complete information about compressibility and other technological conditions influence the quality of final design. Authors used the technology of hard dry milling [3, 4, 6], to the manufacture of punch. In hard milling application are usually used coated [3] monolithic end mills or milling cutters with changeable cutting inserts made of H type cemented carbide, or very hard cutting materials.

2. CAD/CAM technology in machining and methodology of usage

For practical application of CAD/CAM systems is characteristic constructing of virtual 3D models, as it can see in the authors research [20], of parts which are designed in CAD (Computer Aided Design) system. The CAM produces program from this model [10, 16]. The usage of CAD/CAM is considered to be the most effective solution for the implementation of technological preparation of production of complex shaped parts. In general, this sequence of creation of CNC programs is realized by the following steps [4, 6, 17]. The first step is to import a CAD part, followed by the orientation of the model to the required position depending on the coordinates of the control system of the machine tool data (type of cutting tool, geometry), inserting data about process parameters (spindle speed n, feed f, depth of cut a_p), information about the cutting tool movement during the machining operation. After defining these parameters [5, 6] CNC program generates CLData (Cutter Location Data) file, which must be translated by postprocessor. Postprocessor processing can also be done in CAM system, if it is allowed by CNC system or its particular version. The CLData file is not directly usable in a production machine control system as an intermediary to create the CNC program, but it can be the input file for the program, transforming data entered into the structure corresponding to the machine control system. These programs [11, 18] are called postprocessors. Postprocessors transform general information directly from CLData [6, 19] and the output is usable CNC program for the selected machine. Postprocessors are usually independent programs that operate independently out of CAD/CAM.

3. Practical evaluation of CAD/CAM technology and results

Workpiece material was hardened surface (see Figure 1 where they are right on your desktop punch marked places well with the measured value in HRC). Of the measured values ranges about 52 HRC. On the workpiece of radii were all hardened to increase wear resistance as in the research of authors in paper [21].

When machining any die tool should always be based on valid data supplied by the structure or directly from the customer. These documents usually contain two types of data.

The data of C2, the data is referred to the positive displacement type (Solid) and are used in the 2D machining of the workpiece, which are the various sliding surfaces of the release, ports etc. On average, however, used in machining tool active surfaces, a 3D shape, different cutting surfaces (if the panel contains) holes for matric, etc.

The data C1 (NCM data), the data is printed type, formed by the standard parts, which are included in the planning methods. These data are then transferred and any changes shape. The data area is (always zero) vector sheet (indicates to us that is worked to zero or is counted material thickness), various cutting curves, release patterns, etc.. These data are used in the machining of 3D shape, patterns, etc. In Figure 2 it is seen so C1 area under which the shape, machining (workpiece) and punch in Figure 5 again NCM tree structure data. For us, as this is a correction, it is important to find a tree structure called the item. GEOMETRICAL SET of labeled CORRECTION with the latest date. In this case it is the item CORRECTION_19.2.2014 and then guided by the following standard parts (see Figure 3).

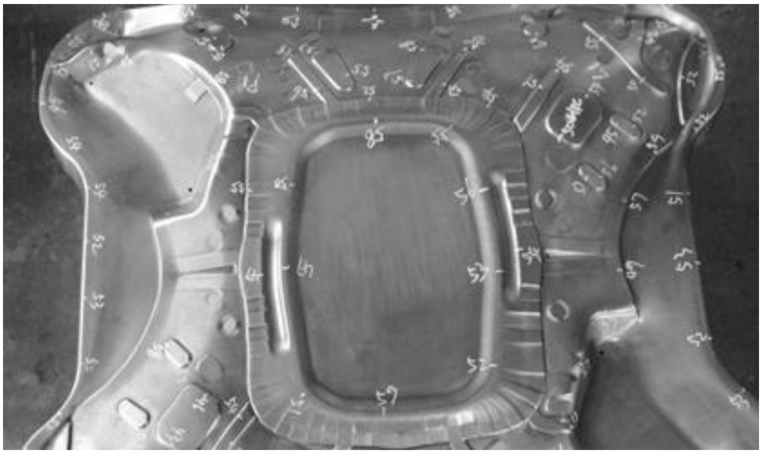

Fig. 1. the measured values of HRC hardness after surface hardening of workpiece by the flame.

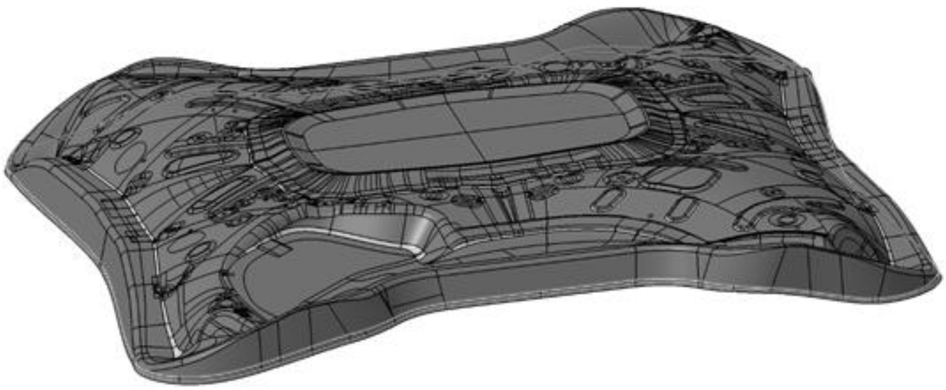

Fig. 2. the three dimensional surface C1 created in the CAD/CAM system CATIA V5 R20.

Figure 4 shows the areas we have C1, vector material, its direction from the surface determines whether we are machined to zero (not include the plate thickness) or moving the material thickness of the sheet. When measuring its size and divide by 100 we obtain the thickness of which takes the given area, we have further shown radii that are released. The data NCM find the value of these radii to be released in our case it is about 0.5 mm. Furthermore, the data can also be found dividing curve punch, which we used as a circumferential curve, in our corrections but it will not be addressed because in that part of the tool change occurred.

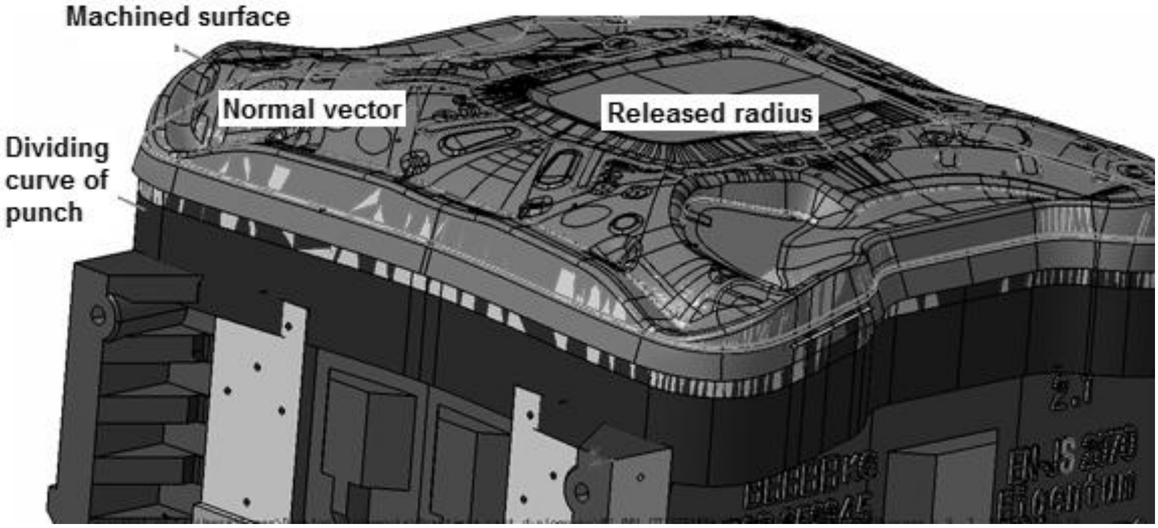

Fig. 3. Description of the NCM data used to punch machining.

3.1. Procedure and evaluation of proper milling strategy, achieved results

CNC program is created in a CAD/CAM system CATIA V5 R20. This system was selected by the authors mainly due to the fact that it is used by customers. When creating a program then must first load the necessary geometry to CAM interface. Afterwards, according to technical drawings (or under axial holes that are located on each part) to determine appropriate arrangement of grid system of axes X, Y, Z and then may start to choose the most appropriate means of machining strategies. The actual production program is divided into 5 different sub-programs.
These are the following sub-programs:
Sub-program: KON_PL - control machining by spherical milling cutter of Ø20 mm;
Sub-program: HR25G - roughing operations by spherical milling cutter of Ø25 mm;
Sub-program: DOK16G - finishing operations by milling cutter of Ø16 mm (material removal after cutter of D20);
Sub-program: DOK20G - finishing operations by spherical milling cutter of Ø20 mm;
Sub-program: DOK8G - finishing operations by milling cutter of Ø8 mm (material removal after cutter of D16).

Dividing of the CNC program for the sub-programs are implemented due to the fact that some machine tools have trouble downloading large data files. The CNC machine operator can thus gradually loading the individual operations.

Sub-program: KON_PL. In this sub-program there is seven milling control surfaces (see in Fig. 4) in order to determine the actual state of the forming tool. The forming tool (workpiece) was not over time scanning before adaptation. In this way it is possible to determine whether the workpiece is in the correct position. Previously it often happened that the locating holes were not in the correct position. It is in a way a kind of prevention of potential errors that could occur in the wrong job set-up, setting off the wrong plate thickness, etc. This control milling strategy is always transferred to places where is not yet interfered toolmaker, or places that have not been finally completed or otherwise machined.

Sub-program: HR25G. In this sub-program were implemented roughing (Fig. 5). The CATIA V5 R20 was used the so-called sweeping method (Fig. 6). Milling cutter was used spherical with a diameter Ø25 mm, cutting width was set to a_e = 1.5 mm. On the finishing part of the operation was left to shape machining allowance of 0.2 mm size.

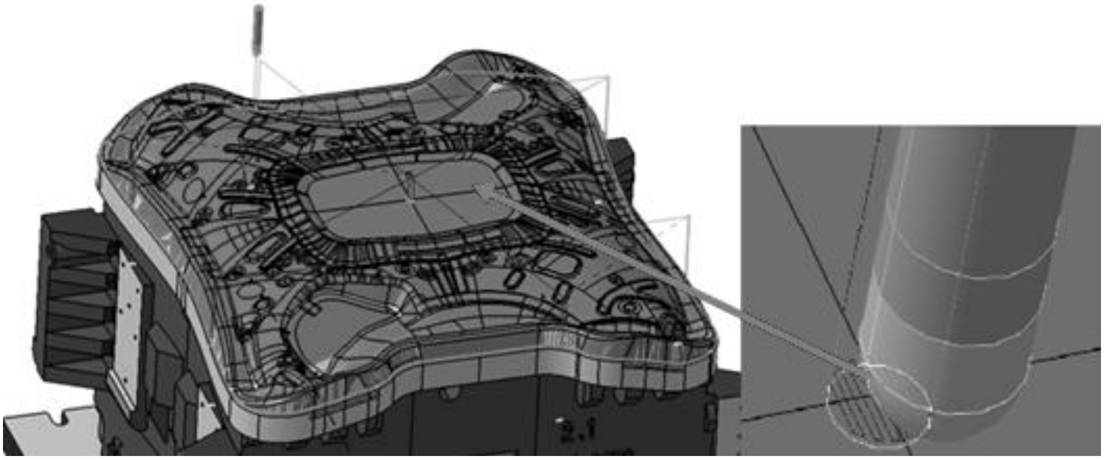

Fig. 4. simulation process of tool path of control milling in the CAD/CAM system CATIA V5 R20.

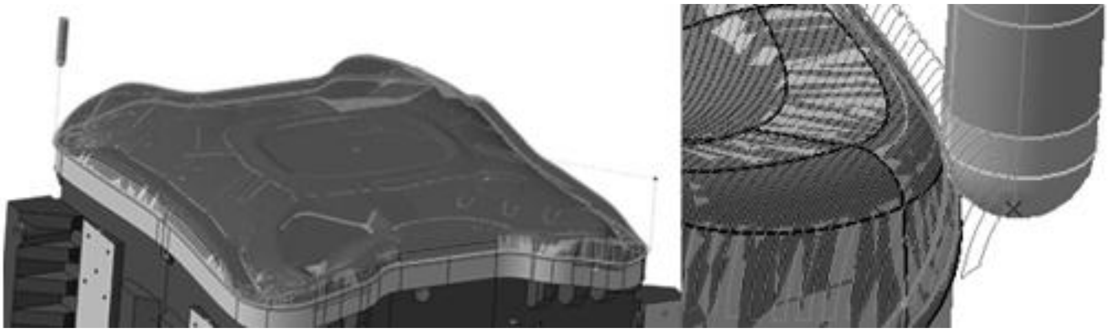

Fig. 5. milling cutter tool path strategy of roughing operation in the CAD/CAM system CATIA V5 R20.

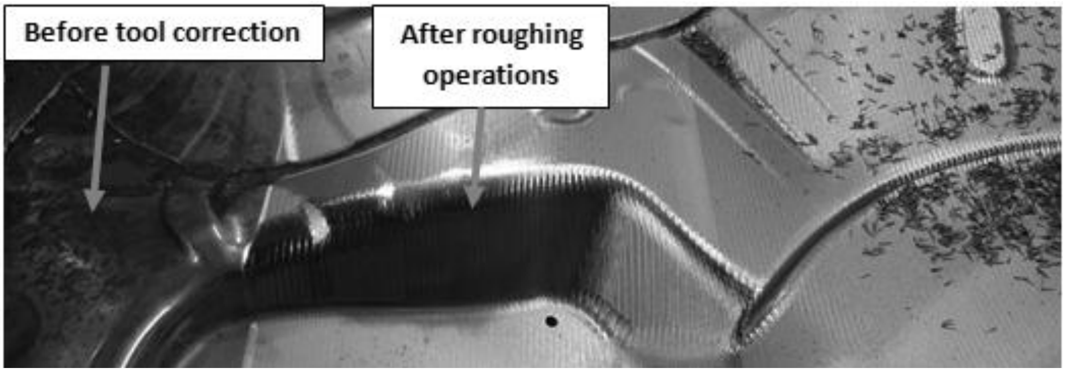

Fig. 6. tool paths (sweeping strategy method) after rouging of real workpiece in the CNC machine tool MECOF.

Sub-program: DOK16G - After roughing operations followed milling of radii. This operation is performed before copying the final shape of the contour of the workpiece because of, relief radii for finishing milling cutter (less wear out cutting inserts). In CATIA V5 R20 was used by the author first feature with the name Rework Area. With the analysis was performed across the surface of a selected program area where the previous milling cutter to its diameter could no longer get. It was subsequently used for that feature Contour-driven program, and as can be seen in Figure 9 of selecting the sites for machining. Then was used spherical cutter with a diameter Ø16 mm for machining. Practical milling was carried out by contour radius (Fig. 8) with a cutting width a_e = 0.4 mm.
Sub-program: DOK20G - after milling the respective radii followed by shape alone finishing copying milling. In system CATIA V5 R20 was also as the roughing of the sweeping method used (see in Fig. 9) but with a smaller diameter of Ø20 cutter and a modified milling width a_e = 0.45 mm. The result is a machined surface with a surface roughness of less than can be seen in Figure 10.

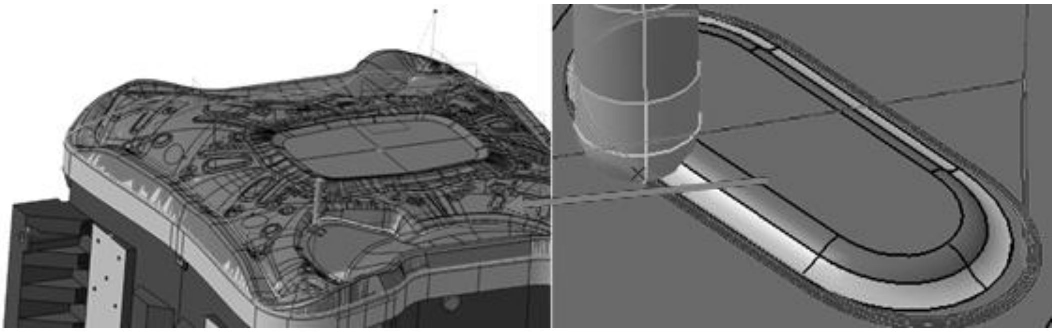

Fig. 7. tool path simulation of finishing strategy with 16 mm milling cutter machining in the CAD/CAM system CATIA.

Fig. 8. tool paths of 16 mm spherical milling cutter during surface finishing in the CNC machine tool MECOF.

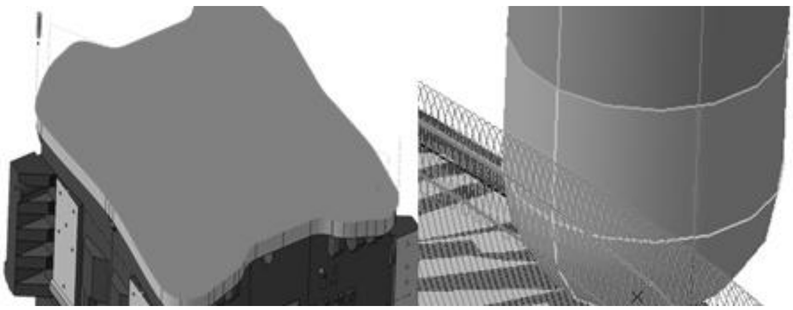

Fig. 9. strategy simulation of sweeping method with 20 mm milling cutter in the CAD/CAM system CATIA.

Sub-program: DOK8G. In this sub-program runs exactly the same technological process that was used in the sub-program DOK16G. The difference was the use of a spherical milling cutter with a diameter of Ø8 mm (see in Fig. 11 and Fig. 12) and adjustment of the width of cut on the value of a_e = 0.3 mm.

Fig. 10. an overview of the machined surface with 20 mm milling cutter in the CNC machine tool MECOF.

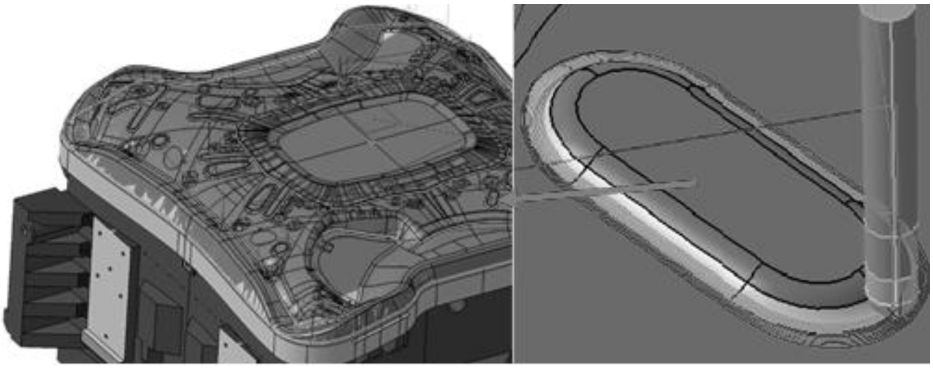

Fig. 11. tool paths simulation of finishing technology with 8 mm milling cutter in the CAD/CAM system CATIA.

Fig. 12. machined surface with 8mm spherical milling cutter in the CNC machine tool MECOF.

3.2. Tool wear of cutting inserts

As an examples of which can be seen in Figure 13, is a considerable tool wear of changeable cutting insert This tool wear is a mechanical origin due to the gradual attrition of the cutting edge of the workpiece to a point where the cutting edge excising. This deterioration was caused by the excessive feed rate *f* [mm], high local hardness of material and also non-constant cutting depth a_p [mm]. The punch (workpiece) was scanned and it occurred to shape correction in certain places. For this reason, remained more material for milling, therefore it was necessary to be monitored, which places more material mills and CNC machine tool MECOF in feed rate regulation. After these measures was then avoid of wear of cutting insert.

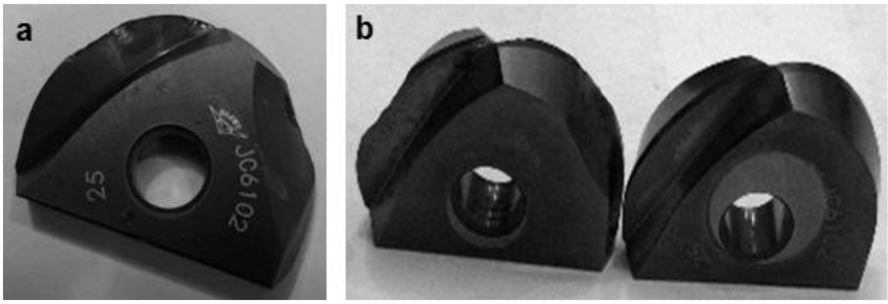

Fig. 13. (a) wear changeable wear cutting insert; (b) comparison of the new (right view) and wear (left view) insert.

3.3. Evaluation of results of surface quality of machined surfaces

Evaluation of the quality of machining (Fig. 14) was carried out on the device (scanner) LTD840 Leica Laser Tracker in combination with a laser scanner T-Scan, which forms the mobile device for production scanning. The laser beam is projected point after point by the high-speed hand scanner Leica T-Scan.

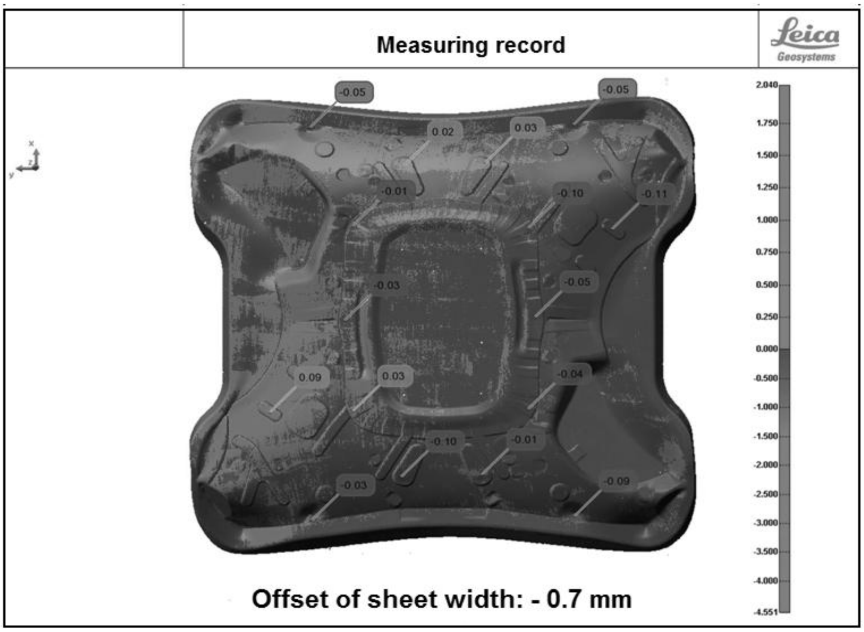

Fig. 14. view of the measuring report of scanned workpiece in the the Leica LTD840 T-Scan scanner.

This scanner uses so-called. flying dot technology (method of sweeping a laser beam) to digitize all types of surfaces. Deviations from the nominal size were caused by precision scanning, which was ± 0.1 mm. This accuracy is sufficient for the control, whereas the form is still under pressure hand incorporates image, which is obtained after assembly of all parts of the operation (in this case the tensile operations). Tops and bottoms are rubbed with a special color, and if you close the tool and differentiating one compact figure out how we paint the molding presses. Pressure image must the greatest be the correct functioning of the forming tool.

4. Discussion

In the process of experiments conducted by the authors was to optimize a specific machining process of forming tool. First was analyzed the successive operations of molding process. Subsequently, then was selected as an example of a specific part from the operation of the no. 20 of technological process of production (this is the second operation from drawing sheet). In this operation, there has been a change to the piece, fashioned punch a change in material thickness. Therefore, it was necessary to re-copy the entire shape. Machining process was first developed and optimized by means of CAD/CAM system CATIA V5 R20. It was necessary to define two types of data sets, namely: solid (data of volume type), the initial data structures and NCM data (data of sheet type). On these data were conducted various modifications and optimization. After loading of the data then was started machining process. Machining process has been performing with the NCM data. The first was done to simulate control milling strategy of surfaces on the punch according to which the CNC machine operator positions. Next, the shape of the rough machined to precision of 0.2 mm (with spherical milling cutter with a diameter of Ø 25 mm). It followed by the release of radius (spherical milling cutter of Ø 16 mm). Then was carried out the copy milling of the final workpiece shapes (spherical milling cutter with a diameter of Ø 20 mm), and the completion of radius (spherical milling cutter with a diameter of Ø 8 mm). In the process of machining were used milling cutters of types DIJET and KIENINGER with carbide changeable cutting insert. Cutting inserts were made of sintered cemented carbide of type H (Class for machining of hardened and difficult to machine steels). Implementation has already optimized of milling process and was carried out on a CNC machine tool of type MECOF (this is CNC gantry type of machine tool with control system HEIDENHAIN iTNC-530). Conformer punch was scanned after working a special scanner and then on it was created color-map with variations. Next, have a folding of the individual components, and the pressing of the blank control. Under such molding pulled out and measuring in the 3D measuring device were subsequently made further changes or assessments about the fulfillment of rights required a total conformer and thus the beginning of mass commercial production.

Conclusion

The main aim of investigation of authors was to design and optimize the shape of the part and simulate this process by the hard milling in CATIA V5. The main objective of the authors of this publication was practically implement and optimize the procedure of pressing tools from the beginning to final scanned and evaluation of the real part. This paper introduced a new methodology to determine the global optimum tool paths for free form surfaces. Unlike only geometric computational analysis of CAM system, the newly developed process of optimization includes mechanics of milling for the tool path generations. In the demonstrated free form surface, with the simulation and experimental results, it is shown that optimal paths can be achieved for free form surfaces with the novel approach. A part of the authors experiment was also to realize the three dimensional virtual simulation of machining technology of punch by the hard milling in the CAM Surface Machining module. Used advanced CAD/CAM CATIA proves the relevance and coherence of the new technologies, materials, machinery, progressive methods and information tools that enable more efficient use of starting materials to produces lower costs. One objective of the article was to suggest the possibility of creating CNC program production process components on a rotary chuck, or with minimal handling. This is achieved by shortening the time of the final machining while eliminating inaccuracies caused by manual switching of the workpiece. This paper presents a method of connecting High Speed machining technology HSC with the introduction of computer graphics contained in the CAD/CAM systems. CAM systems are used for preparing data and creating CNC programs for manufacturing components. The results presented in this paper can be further exploited in the process of teaching courses and programming CNC machines and technical practice for upgrading older solutions and processes of the main and additional times, while maintaining the dimensional accuracy of machine parts. In our future research plans e.g. comparing to the existing workshop CNC machining centers, have the presented simulation methodology have a number of advantages. First, with the same interpolation steps, the contour accuracy is significantly higher. Second, the programming module is easier to use more simple G code lines. And last, machining cost is lower because of the reduced machining time.

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