Study on Obtaining the 3D Model of a Groove Box Cam by the Reverse Engineering Method

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Abstract: *Reverse engineering is an important approach used to obtain objects starting from the same new or used physical objects. There are many techniques that are used in this regard and they are chosen depending on the type of part, its functional role and the accuracy with which it is desired to obtain the duplicate. One of the most commonly used copy / multiplication methods is 3D scanning. This paper presents a situation in which 3D scanning was not efficient and recourse was made to the reconstruction based on photography and measurements of a groove box cam, part of a machine tool. The goal was to obtain the 3D model of the part so that later, based on a CAM approach, the necessary part of the machine tool may be obtained.*

Keywords: *3D scanning, 3D reconstruction, groove box cam*

1 INTRODUCTION

Machine tool maintenance operations are common and regular, based largely on well-established routines and time intervals. During a maintenance operation, in addition to the checklist related to that operation, unforeseen problems may occur, the solution of which involves the replacement / reconditioning of the defective component(s). When, for various reasons, these components can no longer be purchased, the maintenance team must resort to unconventional methods for resolving the problem. One of these methods is reverse engineering (RE). This method has as a starting point something existing and usually the flow of technology is reversed than in the conventional approach, which starts from the concept, hence the name reverse engineering.

The reverse engineering method and means are used in the product development process (PDP) as well, [2] especially when it comes to free-form shapes. According to the same paper the reverse engineering method is an intermediary link between the physical mock-up and the process planning stage of the PDP and it hints at the automotive industry when first the clay model is devised and based on this physical model, the 3D CAD model is generated.

As a means of realizing the components through reverse engineering, one of the most common is the 3D scanning of the parts to obtain its 3D model. 3D scanning collects information about the part and depending on the quality of this information, a post-processing operation is necessary in order to obtain the 3D model as accurate as possible in relation to the purpose of the application. 3D scanning is followed by 3D model processing and manufacturing preparation. In addition to 3D scanning, in some cases other techniques are used to collect information about the object in question. Here we mention reconstruction techniques based on photography / photos. [4] extract from a single photo clouds of points, curves and implicitly 3D geometry in order to multiply by 3D printing lock keys. A similar study is [1].

[3], [5] start the 3D modeling of the item from 2D hand-made sketches. The usefulness of these studies is found both in the concept phases of form and in other stages of the product life cycle and are based on the same idea, i.e. digitization of points and curves on 2D surfaces (sketches, pictures, etc.) into 3D surfaces, the process being performed with a certain degree of automation, depending on each situation. The first result of this process is the 3D model of the part, being followed, as the case may be, by the manufacturing of the physical model by using different methods that include 3D printing, cutting, casting, etc.

The realization of the 3D model depends firstly on the quality of the information taken starting from something physical, so it directly corelates with peripherals and the correctness and accuracy of the sampling. In the next stage, the gathered information is processed. Then the transformation into a 3D model by using different methods is made. The process could be summarized in the diagram shown in figure 1.

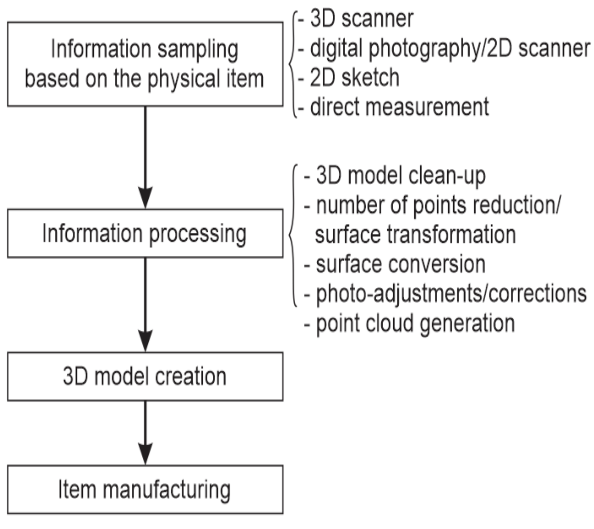


Fig. 1. Reverse engineering process based on digital techniques

Given the geometric and functional specificity of some components subjected to the reverse engineering process, we cannot say that there is a universally valid solution. This must be adapted to each individual case. This paper presents such a case and the two main approaches applied to obtain the 3D model.

2 CASE STUDY DESCRIPTION

The present study is based on the groove box cam part of the TOS W100A milling machine (figure 2), owned by RAMIRA S.A. company based in Baia Mare.

This part has the role of changing the direction of travel on the X, Y, Z axes of the machine tool and is mounted in the cover that protects the gear box of the machine tool (figure 3a). Within the profile made in this cam, a bolt slides, bolt which is mounted in the gearbox, as it is shown in figure 3b.

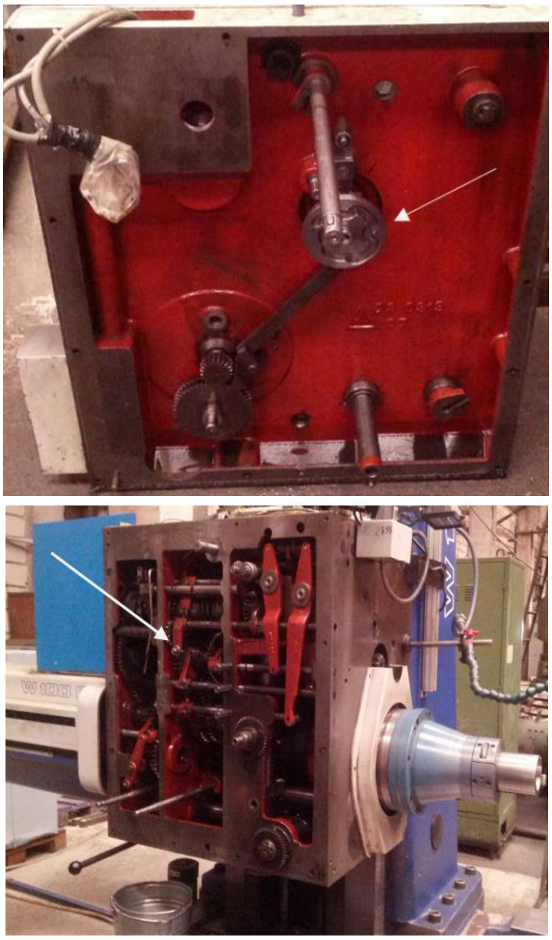
Fig. 2. Groove box cam the study is based on

Due to the repeated use of the machine tool, over time, wear of this component has been recorded. The cam is traversed by that bolt on the midline of the profile, the play between the bolt and the profile being approximately 0.05 - 0.1 mm. A more pronounced wear occurred in the areas with more pronounced inflections of the profile, i.e. on the stroke tips of the bolt. These wear areas prevented the proper operation of the machine tool, requiring replacement of the part eventually.

Given that the machine tool is quite old, a spare component could not be ordered, so it was decided to manufacture it within the company.

Because of the complex curvilinear profile of the cam, the recommended solution was machining on CNC machine tools integrated with CAM software. In this approach, the first step is to obtain the 3D model of the piece, as close to as it was at the beginning of its lifetime. This is always a challenge especially when no measurements were taken when the cam was new or in a usable condition.

The following subchapter presents the solutions adopted to obtain the 3D model required for the CAM software.



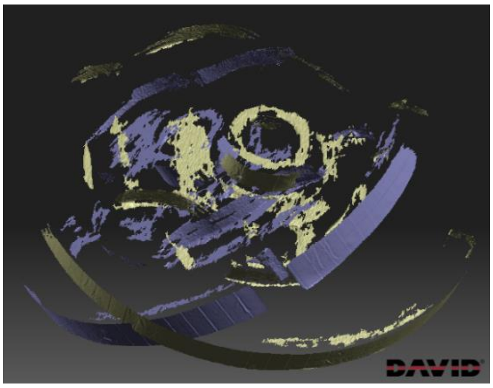
a.

b.

Fig. 3. Groove box cam mounting location

3 APPLIED TECHNIQUES FOR ITEM INFORMATION GATHERING. RESULTS

At first, an attempt was made to 3D scan the cam, using the David SLS2 Structured Light 3D Scanner and the David TT1 rotary table provided by the Technical University of Cluj-Napoca. Due to the flat profile of the cam and the glossy surface of the part, the quality of the scan was poor, the images being incomplete and the alignment of the scans being very difficult to achieve (figure 4).


a.

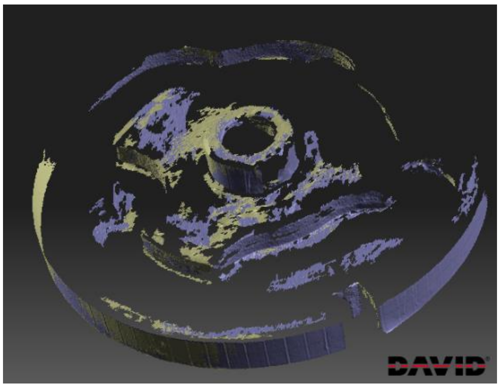

b.

Fig. 4. Initial results of the 3D scanning operation

The partial result of the scan is presented in figure 4 b. Subsequently, the surface of the part was matted by black oxide coating, the result being better but still unsatisfactory (figure 5).


a. Black oxide coated cam part

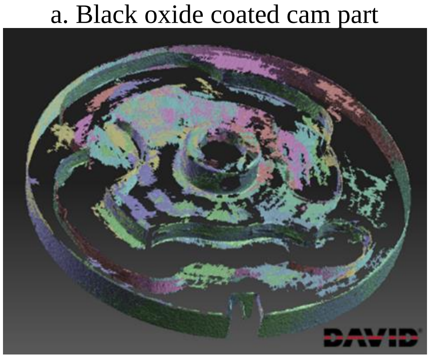

b. 3D Scanning result

Fig. 5. Results of the 3D scanning operation of the black oxide coated part

Due to the types of surfaces present on the piece, it was decided to reconstruct the item starting from a picture taken in a parallel plane with the face of the cam profile. This picture was transposed in the Autodesk Inventor Professional software and then scaled and calibrated based on the overall dimensions and those of the outer diameter of the central hub, surfaces which, not having an active role in the operation of the cam, did not change during the use of the machine tool. The alignment of the picture was made based on the key slot (figure 6).

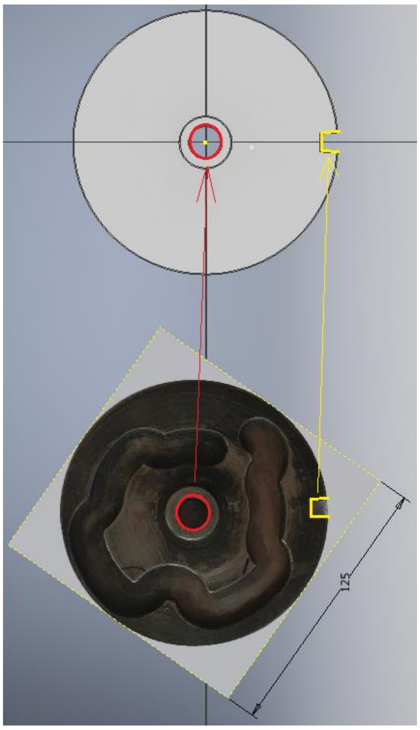


Fig. 6. Calibration and alignment of the photography in Inventor Professional software

The following stage was the reconstruction of the cam profile, in the worn form and then the calibration/adjustment of its width to match the initial profile. The adjustment of the profile was made knowing that the movement of the bolt is on the midline of the profile and that the profile had to be symmetrical in relationship to the middle line. Also, the width of the profile was measured in areas without inflections or with very small inflections, where the wear was insignificant, thus representing a benchmark for the entire profile.

After drawing, adjusting and calibrating the cam's 2D profile within the Inventor Sketch, by using the Extrude Cut command, it was embedded in the piece at the measured depth of 7 mm followed by the chamfering of the exterior edges. The results can be seen in figure 7.

4. CONCLUSIONS AND FINAL DISCUSSIONS

In the beginning of the paper it was mentioned that the reverse engineering process can use a multitude of devices and methods for gathering the necessary information for manufacturing. However, there is no universal solution which can be used in any situation.

This is especially due to a multitude of factors which include item type, material, functional role, precision, state of wear etc.

As it was presented in the case study, one of the most used methods for gathering information on the 3D part, the 3D scanning, did not return the expected quality of results. Of course, there are more high-tech 3D scanners which probably would have done a better job, but such devices are not always at hand and are quite expensive. The device being used is not the only thing that matters, as equally important, one must consider the operating software of the device which could make a big difference in processing the acquired information. In the case study, the time needed for the 2 scanning attempts was 80 minutes for the glossy surface and 70 minutes for the black oxide covered surface. This time includes the scanning process and the manual alignment of the scans.

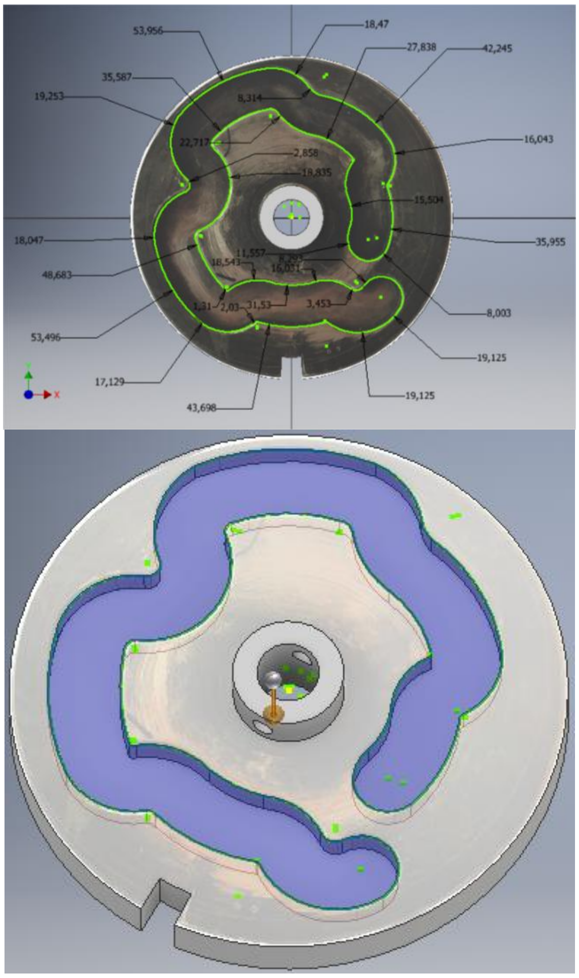


Fig. 7. CAM profile reconstruction and calibration

On the other hand, using the single photograph technique, combined with measurements taken directly on the item, taking into account the processing time of the photo, the modelling time and the 3D model generation, it took 45 minutes in total.

By analysing the 2 methods used in the case study, the results obtained, the time needed for each case, as well as the required instrumentation it's safe to say that the second approach is better from all the points of view.

Reverse engineering items like the groove box cam, which have a 2D profile could be easily done starting from a single photograph of the profile, correlated with direct measurements of the item, or combining it with the photogrammetry technique. However, there could be special cases in which better and/or faster results could be obtained using other methods.

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