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A NEW 3D SCANNING-AIDED PROCEDURE IN CUTTING TOOL DESIGN

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1. Introduction

According to the growing demands on quality in modern production process, it is necessary to design a tool, which will precisely remove the burr off the castings. The burr represents a rough edge or area remaining on material, such as metal, after it has been cast. A tool is able to remove the burr all around the edge and not only in the areas of accumulated material that has been squeezed out (e.g. places where the material is being poured into the mould). Hard metal with a razor thin burr is hazardous and needs to be removed in order to have a smooth surface. Usually, all traces of the burr have to be removed.

A new process of tool design by using 3D scanning-aided technology has been invented by using rapid prototyping principles. The result is a precise profile of a tool consisting of a series of stair-step curved cutters connected together. The burr geometry is usually of rather complicated form and enables the workshop the effective cutting with these tools.

The main demands of designing process is getting the precise position of 3D burr line from a real casting that differs from the CAD model due to material shrinking during cooling. When designing one of the burr tools, the programmer tries to design any tool so it has just enough relief to afford the necessary clearance. The request is to preserve as much tool rigidity as possible and stable enough that such tools will not deflect unpredictably during machining. Previously used procedures were inadequate and didn't meet the quality standards while the new principles in designing of tools significantly improve the efficiency of production.

2. Requirements on the measurement system

The initial step of the proposed method is to enable digitization of a complete measurement object's surface at all the relevant places where the burr artifacts occur with the sufficient lateral resolution. Since objects made of a large variety of possible materials could be expected, with various sizes and geometrical properties (Fig. 1), the applied measurement method should not affect the surface of the measurement object in any way that would alter its volumetric definition. It should be capable of measuring locations of measurement points with the uniform lateral distribution in the complete objects volume, thus making the definition of the relevant information possible without the additional effort on the measurement side during measurements of objects with complex surface features (and to eliminate the need for additional measurements). Uniform distribution of measurement points also provides the same measurement uncertainty on the whole measurement volume, which is required by the manufacturing process that will follow. Additionally, the possibility of simple measurement sensor accommodations to various measurement volumes, as well as the lateral resolution of measurement points is required.

Hence, a digitizing method that provides flexible spatially dense digitization of measurement points on the object's surface is required, regardless of the measurement object size, material and geometrical artifacts complexity.

Figure 1. Mechanical parts of various shapes

3. 3D scanning principles

In order to measure the entire geometry of complex objects, reference targets are attached to the object and their coordinates are determined by photogrammetry. These targets define the object coordinate system in the particular referent relative sensor to object position. Typical types of sensors consisted of projector and the two cameras provide over-determined mathematical triangulation model. Fundamental problem with structured light projecting technology is in the correspondence problem, since to obtain triangulation points one needs to locate for each pixel in left image *m* the corresponding pixel in the right image *m*' (Fig. 2).

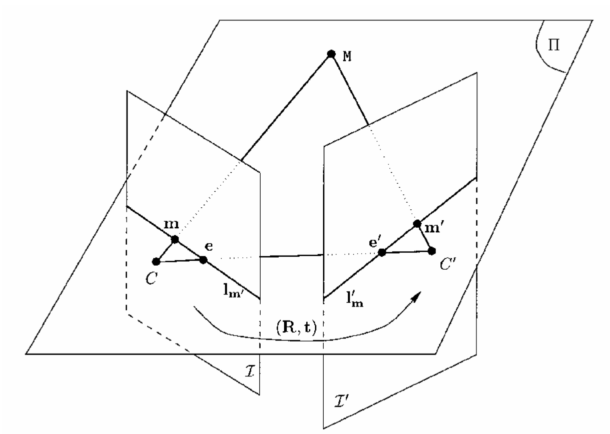

Figure 2. Principle of triangulation

The sensor consists of two cameras and a projector. Projector purpose is there just to provide the unique definition of object points, hence for a dual camera system projector doesn't necessarily has to be calibrated. Different fringe patterns that are projected onto the object of measurement are observed (Fig. 3). If the optical transformation equations are known, the 3D-coordinates for each camera pixel can be determined automatically and in high precision.

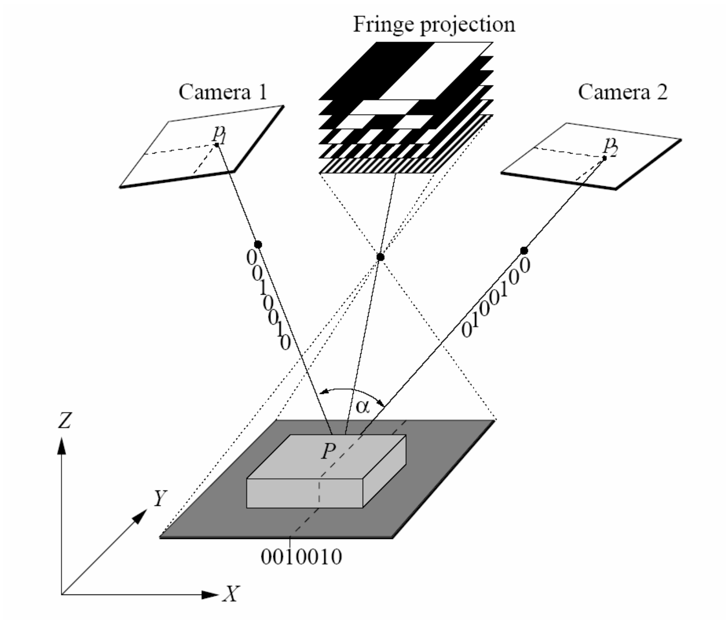

Figure 3. Fringe projection and image capturing by two cameras

The fringe projection sensor ATOS produced by GOM mbH satisfies the above requirements set by the shape and size of possible measurement objects via projection of visible, non-coherent structured light to the object surface (Fig. 3).

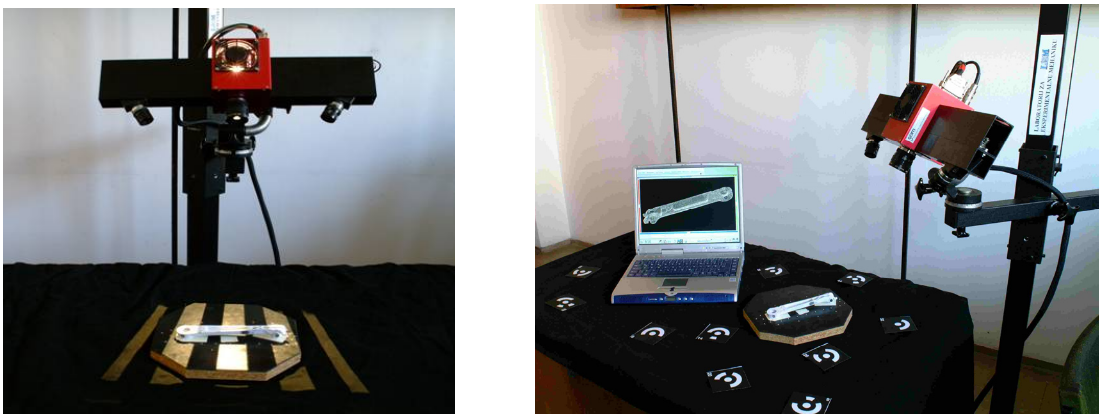

Figure 4. 3D-scanner ATOS produced by GOM mbH

4. The measuring process

The first step of the method is scanning a casting so a 3D digital image is obtained. Collecting and capturing the raw data from the scanned object provides the generation of the initial geometry data as a 3D cloud of points. The imaging technology requires multiple scanning from different views in order to create a complete object 3D active image. Scanning can be done by rotating the object or moving the sensor around the object. The single views are recorded with the sensor, which can be positioned on a tripod in the free-hand mode. The views are transformed automatically into the object coordinate system using the reference targets. Their 3D-coordinates are determined in the sensor coordinate system and then transformed into the global coordinate system. The same transformation is used to relate the surface points to the object coordinate system.

The results of scanning are numerous points that represent surface of the casting. The digitization of the complete surface of a 1:1 model of a steering wheel (Fig. 5) takes approx. five hours plus additional two hours for the processing of the recorded images.

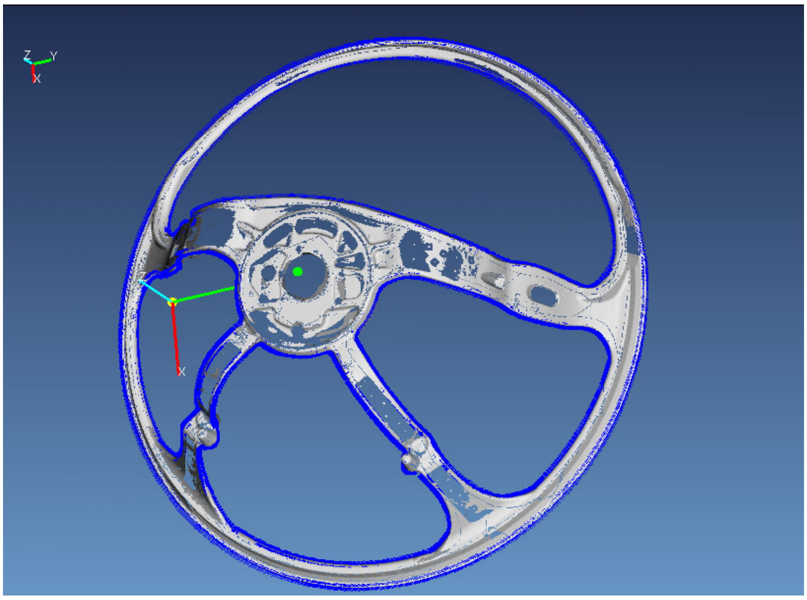

Figure 5. Steering wheel digitized as a 3D cloud of points and emphasized burr line

Cloud of points can be also used in a process of reconstructing of a surface of machine part and can be use in rapid prototyping production.

5. Burr line extraction

Areas interesting for the design of characteristic tool curve are only those that contain the burr line (Fig. 6). Each point is 3D positioned inside the measuring error and is within the requested accuracy of 0.05 mm.

After scanning, it is necessary to analyze the cloud of points and extract points that are in the burr neighborhood (Fig. 3). The techniques for extracting characteristic points are strictly defined by the invented procedure while the number of steps depends on the shape of the casting and the number of tool cutters.

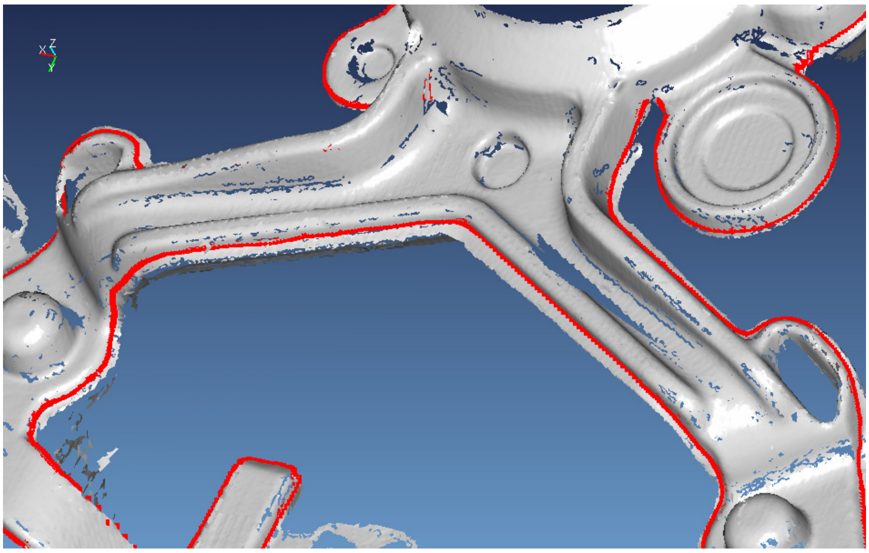

Figure 6. Detail view of the scanned area in burr vicinity

Two crucial facts have to be determined: the area on which the casting is leaning on and the direction of the tool path. It is necessary to choose a base plane (perpendicular to the tool path) on which the characteristic points are projected (Fig. 7).

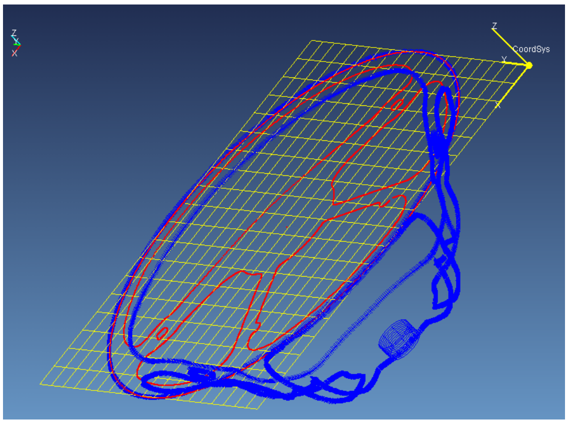

Figure 7. Points projected onto base plane

Short lines are interpolating through the points projected onto the base plane and thus simulating the resulting curve of a DXF format. File can be transformed in a form, which is a direct input for the CNC machining centers that will produce the tool cutter for removing the burr (Fig. 8).

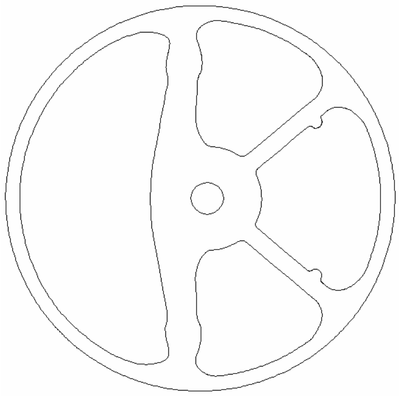

Figure 8. Projection of the cutter curve

Usually, casting should lie against its backside in a saddle form basis and is important factor for achieving high accuracy of tool positioning. The construction of surfaces can be done by extraction of areas from the cloud of points and interpolating skin through them (Fig. 9). The surfaces can be also exported into the formats, such as IGES or STEP that are recognizable by the tool production CNC machine center.

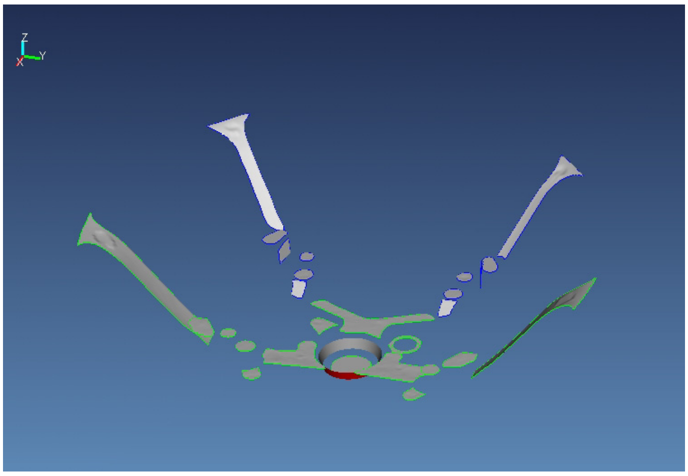

Figure 9. Designed surface of a saddle form basis

6. Steps of invented design procedure

Obtaining the points at burr vicinity starts with constructing free-hand sketch of 3D line by using the interactive mode "Point in Cloud", which ensures snap to the closest point in the point cloud. A new cloud created by projection of 3D line onto the point cloud in *normal to cloud* direction is extracted as a burr line.

Parts of cloud that are used to create base plane are selected by drawing a selection boundary on the screen. The base plane enables the best approximation to the specified points that defined the plane. If there is noise in the point data, "Automatic Point Rejection" can be used for omit points that are outside of a specified tolerance.

"Project to a plane" operation projects every point from extracted cloud along burr line to its closest point on the base plane.

The new planar curve is created within the specified tolerance. The number of controlled points of the curve is the same as the number of data points of the point cloud.

"Fitting surface" operation fits a surface to each given point cloud. Parameters like tension, smoothness, and standard deviation can also be varied for getting the required surface

7. Conclusion

A new 3D scanning-aided technology in tool design represents a new method in rapid prototyping. The method has been invented in *Laboratory of Experimental Mechanics, Faculty of Mechanical Engineering and Naval Architecture,* Zagreb*,* and has been applied regularly in *Alatnica-Bagat*, Zadar. The method is gained high standards in tool design. Its characteristics are:

- The progress of the measurement from view to view is visible on the monitor;
- The measuring system automatically repeats the measurement if necessary;
- The measurement volume can be individually adapted to the user's needs.
- Highly complex geometries can be defined;
- High accuracy and outstanding repeatability;
- Simple implementation in tool design procedure;
- Huge potential of practical use;
- The time required for the tool production is significantly reduced.

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