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Mechanical Design of the Bicycle Inner Tube Valve Positioning Tool Based on the Reverse Engineering Methodology

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Abstract ***– Reverse Engineering (RE) methodology is used for the acquisition of the required manufacturing or design data of objects/products which do not have blueprints or technical documentation, or the data are lost, obsolete or withheld. This methodology is widely spread and applied in product development and manufacturing. Thus, the RE techniques were and continue to enhance and develop from manual measurements to utilizing 3D scanning technologies. The Reverse Engineering approach described in this paper will show the practical example of mechanical design of the positioning tool for inner tube valves in the assembly production phase. This tool's geometry must adequately correspond to the valve geometry to ensure its proper positioning and furthermore transferring to the valve applicator. Since there is no technical documentation of the valve available the Reverse Engineering methodology must be applied.***

Key words: ***Reverse Engineering, Product Development, Inner Tube, Positioning Tool – the end of the valve trail***

I. INTRODUCTION

Reverse Engineering (RE) represents an engineering methodology by which, product development process goes in reverse order. In comparison with (Direct) Engineering where the starting point is technical documentation or a drawing, the final product is the concept's base of Reverse Engineering.

Primarily, RE approach is used to deconstruct, analyze, and acquire knowledge about the way in which an observed object function. More often Reverse Engineering, or in some literature, Back Engineering, is used to regain the design data, remanufacture/recreate, multiplicate or enhance the existing object/product when there is no technical documentation available, CAD model or drawing based on the existing or even damaged/worn physical model.

The area of use is massive and Reverse Engineering could be applied for physical machines, aircrafts, architectural structures, military technology, biological functions related to how the genes work, software development, etc.

There are authors which used Reverse Engineering concept for rapid design and development of helmets for motor bikes and electric bicycles while optimizing the product development process, reducing the product development cycle, improving efficiency and ergonomic use conditions [1]. Some researchers conducted a case study upon the use of 3D scanning for RE and quality control on the practical example of 3D printed metal cylinder with complex internal geometry [2]. Also, another research was obtained with 3D scanner techniques to analyze working performances of milling tools based on reverse engineering [3]. Others used this methodology for verification of the physical design for nanoscale technologies [4].

"Hybrid" Reverse Engineering approach is combined with finite element analysis (FEA) for estimation of shear modulus of a continuous multifilament yarn model for simulation of the ballistic behavior of the yarn on its fabrics [5]. Consequently, the RE was conducted to reconstruct the experimental plate in order to numerically recreate the tribological experiment and analyze the contact heat transfer between mechanical surfaces by finite element method (FEM) [6].

This concept of Reverse Engineering was adapted for medical purposes and applied for recreating a human fibula by the anatomical features [7].

The newly examples of RE applications are described in the software development and engineering for code review [8] or for a creation and verification of safety-critical software [9].

This paper provides a Reverse Engineering (RE) approach to obtain the original design specification of the mechanical component – specifically, the foot of the valve for the inner bicycle tube in order to create and manufacture the positioning tool – the end of the valve trail for the proper valve positioning inside the applicator which is responsible for the valve application on the inner tube profile during the assembly production phase.

II. CASE STUDY

The goal of this paper is to present the results, conclusions, and good practises obtained in the previus reserch where we had applied a Reverse Engineering approach to acquire the original design specification of the existing mechanical component (valve for the inner tubes) for the design of the assembly tool – valve applicator [10]. Now, same methodology is going to be applied to help design the necessary positioning tool often called “the end of the trail”.

The inner tube production has couple stages, such as: preparation, assembly, and vulcanization stage. Each stage must be correctly performed in order to produce good, reliable, and safe product. For this paper’s purposes the assembly stage is of interest.

The assembly stage in the inner tube production process has two operations: butt weld joint of the inner tube profile and valve application. The valve application operation is performed in couple steps (hole creation on the upper side of the profile, cleaning of the area around the hole and valve application), but there is process which is responsible for the valve transfer from the cylindrical container to the valve applicator (Fig. 1). The valves are placed in the container which, by the proper device, vibrates and makes valves to move alongside its sides on the metal trails. On the exit of the container there is plastic trail in which the scope of the valves falls leaving the bottom of the foot of the valve upwards. Furthermore, identical metal trail follows and accepting the properly turned valves. Beneath this trail is another vibrating device which allows the translator valve movement. At the end is the positioning tool – “the end of the trail” which can carry only one inner tube valve at the time (sensor defined movement/vibration) (Fig. 2). Carrying tool takes the valve from the positioning tool and send it inside the valve application tool.

Fig. 1. The inner tube valve transfer unit as part of the machine for the inner tube assembly process.

The working surface of the positioning tool must have the exact geometrical characteristics as the foot of the valve. This way valves are properly positioned and taken by carrying device (vacuum supported). The way on which the valve is taken from the positioning tool will define the way of its positioning inside the valve application tool. Ergo, it will define the position of its application on the inner tube profile. Any deviation or beveling of the valve inside the applicator will reflect on the inner tube profile and lead to scrap occurrence.

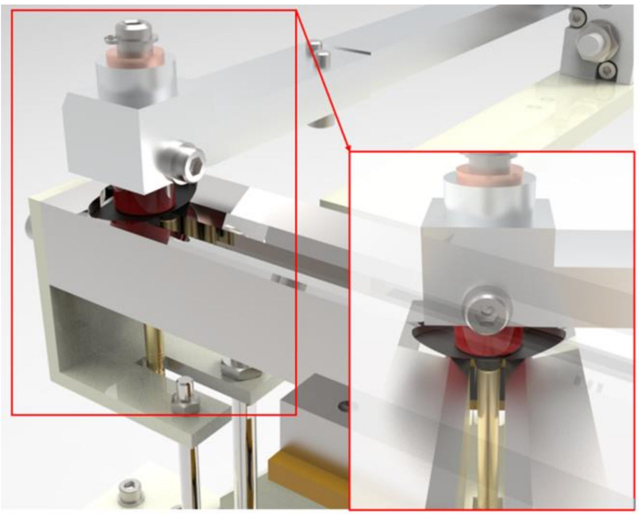

Fig. 2. The inner tube valve transfer unit picturing the proper position of the inner tube valve inside the positioning tool.

Generally, the Reverse Engineering framework consists of a couple of phases which are based on the same concept but may differ in different literature. Basically, part digitization, feature extraction, and CAD modeling are mandatory [11].

The Reverse Engineering framework used in this research is represented on Figure 3.

A. Part Digitization

Part digitization process represents the initial RE phase which main goal is to acquire point coordinates from observed object’s surface and to transform its physical state to a point cloud. The result of this phase is a cloud of, in this research, 3D data points.

In order to accomplish the point cloud of an object the scanning technique must be chosen, object might need preparation, and the actual scanning must be conducted.

The optical 3D non-contact scanner, HDI Advance R4X [12], was used for geometrical data acquisition. This way multiple scans (“pictures”) from different angles and positions are taken and then manually combined by translation and rotation of the individual scans to form the digital representation of the inner tube valve. Given the fact that the foot of the valve is made of rubber and the scope was not in the focus of the observation, the preparation of object was not necessary.

After the proper scan is made the point processing (pre-processing) phase could be obtained by importing the raw point data cloud, reducing the noise, "cleaning" the imperfections, "hole filling", and reducing the number of points to generate the better mesh on the surface model [2].

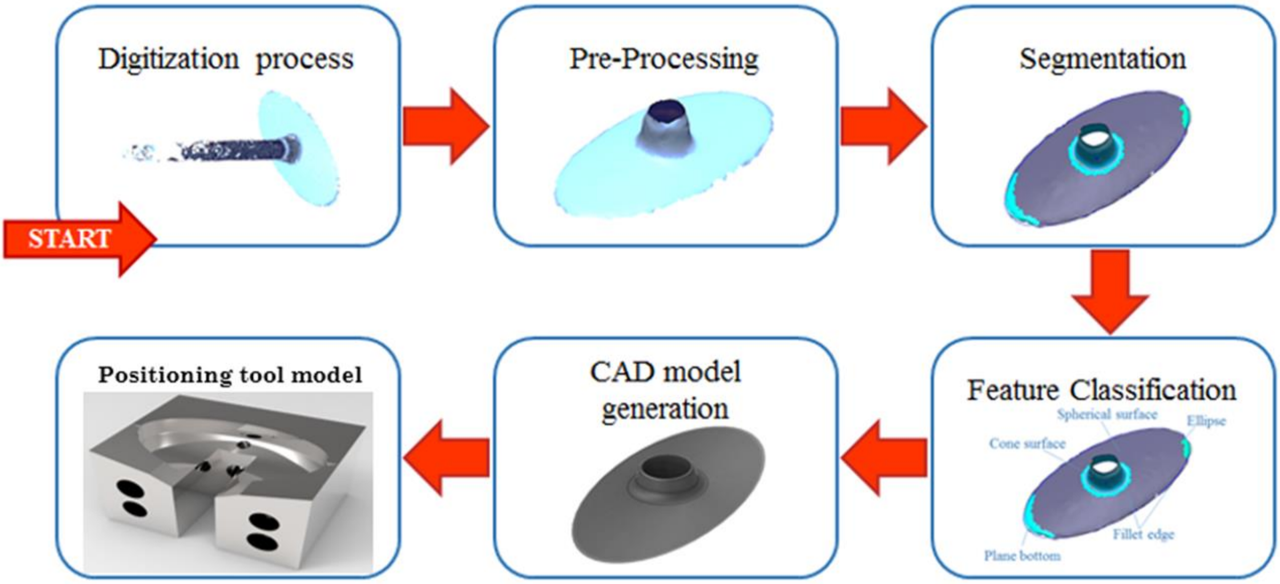

Fig. 3. The Reverse Engineering Framework: CAD model reconstruction of the foot of the inner tube valve regarding the positioning tool 3D CAD model generation.

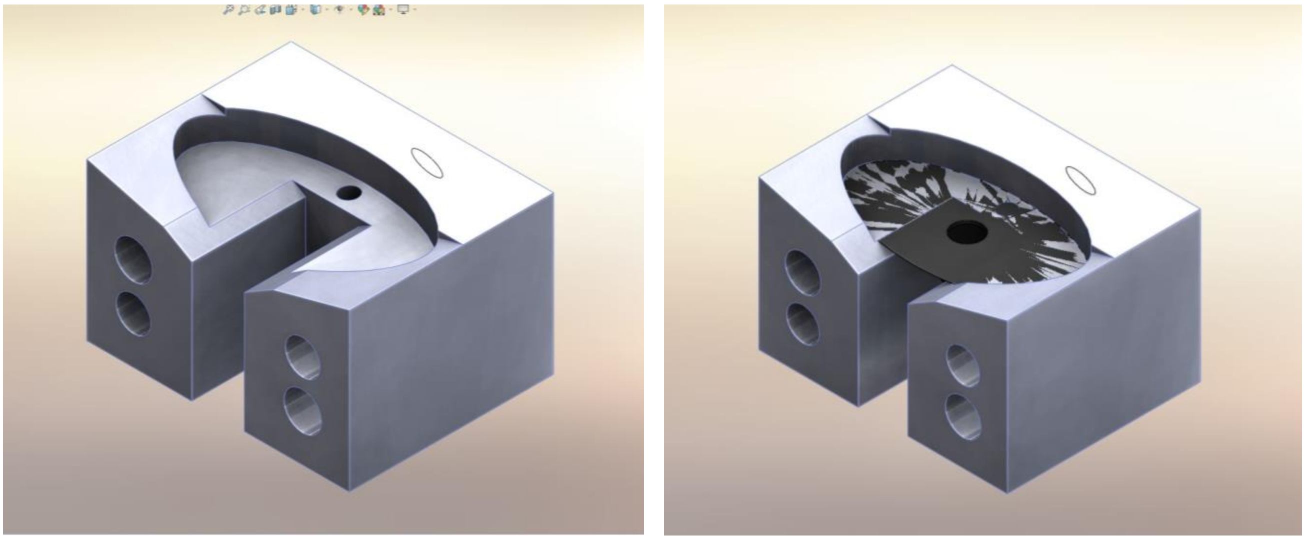

Fig. 4. The positioning tool's geometrical characteristics definition of the working surface by subtraction of the foot of the valve acquired by RE methodology.

B. Feature Extraction

Before the feature extraction process is carried over, the preparation of the mesh object, from the previous phase, must be done by dividing the regions into separate identical groups. The output of the surface segmentation phase is labeled points belonging to a particular region [11].

Since the valve scope is not important it must be erased, and the segmentation is only applied on the valve foot [10].

Feature classification can help in 3D CAD model generation and its geometrical corrections by exporting the segmented model into some 3D CAD modeler. Feature classification refers to recognition of some standard 3D CAD features like extrude or revolve options, then surface recognitions – elliptic or spherical, etc.

This model of the foot of the inner tube valve could now be used for the definition of the geometrical characteristics of the working surface of the positioning tool.

C. CAD Modelling

The final step of the RE methodology is finished by 3D CAD model generation of the inner tube valve foot. But, regarding the presented framework, the 3D CAD modelling phase is not the last.

The basic idea was to determine the geometrical characteristic of the foot of the inner tube valve in order to apply them on the working surface of the positioning tool – “the end of the trail”.

The 3D CAD model of not fully defined positioning tool (object with overall dimensions, mounting features, etc.) could be combined with the 3D CAD model acquired by the RE methodology and the working surface could be extracted (Fig. 4). Thus, the best possible position of the inner tube valves inside the positioning tool is ensured.

The Figure 5 shows the final 3D CAD model of the positioning tool – “the end of the trail” in comparison with the inner tube valve.

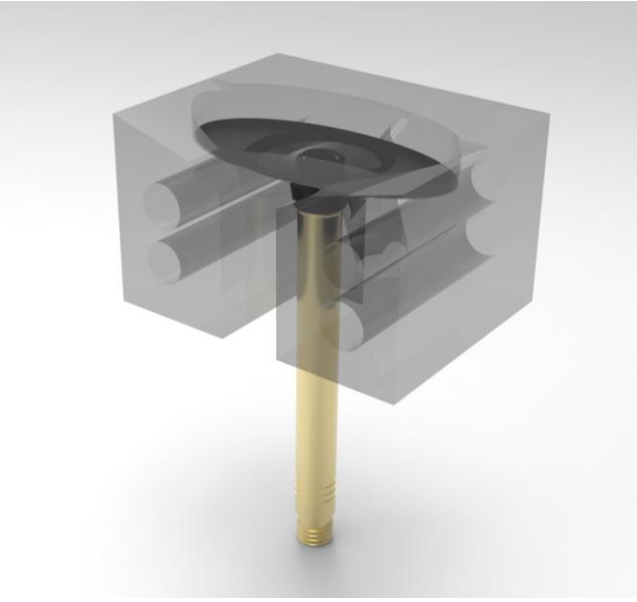

Fig. 5 Final 3D CAD model of the tool – valve positioner (“the end of the trail”) in comparison with the inner tube valve.

After the 3D CAD model is finished, the technical documentation could be created.

III. CONCLUSIONS

This paper describes the applicability of the results described in our previous research on this field which obtained the 3D CAD model of the foot of the inner tube valve and furthermore defined the tool for the valve application [10]. Consequently, the results are tested and verified during the inner tube production process. Those results have initiated the need to proceed with this methodology and cover the whole assembly process.

The reverse engineering approach was, also, used, in this research, to design the working surface of the inner tube valve positioning tool – “the end of the trail” based on the previously defined geometrical characteristics of the foot of the inner tube valve.

The outcome of this paper is the required manufacturing documentation – technical drawing and numerical manufacturing code.

As previously described, the importance of using the proper positioning and applicating valve tool is crucial to ensure the proper valve application on the inner tube profile and to eliminate the risk of scrap occurrence during the assembly phase of the inner tube production process. The production test results have shown that the errors induced by irregular valve positioning and application have reduced significantly.

Thus, the sustainable RE framework should be developed to cover all types of inner tube valves currently in production and to create a standard for future dimensions inside the inner tube industrialization process.

Future endeavors will also involve the enhancement of our scanning technique, improvement of the mesh generation and explore the other potential applications of RE methodology.

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