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INTEGRATION OF 3D SCANNING TECHNOLOGIES IN THE DESIGN OF SURFACES OBTAINED BY TESSELLATIONS

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Abstract: *This paper focuses on the reverse engineering process for a sheet experimentally deformed after rolling process. The first step was to perform a detailed 3D scan using a high-performance Artec Space Spider scanner, which offers high precision. The next step, based on the scanned model, involves post-processing the model in Artec Studio, followed by exporting it to Geomagic Design X for generating the surfaces of the 3D model. Finally, the processed model is introduced into Altair Inspire to generate the wall obtained by tessellation of the studied pattern.*

Key words: *Reverse engineering, 3D modelling, 3D scanning, Altair Inspire, Artec Studio*

1. INTRODUCTION

Reverse engineering (RE) represents an important field for modern technology, being an efficient and high-performing method for analyzing and recreating an existing product in digital format. This method involves a careful study of the components to understand the principles and manufacturing techniques used in the initial product's creation. Thanks to 3D scanning technology, this technique has been revolutionized in recent years, allowing for the creation of 3D models much more quickly by capturing complex geometries with high dimensional accuracy.

Over time, reverse engineering methods have evolved significantly due to advances in computer and digital technology over the past century. Traditionally, manual measurements and disassembly of existing products were carried out using hand tools to determine diameters, depths, etc., and to manually create the design [1]. This process was efficient and accurate for simple applications but became increasingly complicated when applied to complex geometries, such as curved or uneven surfaces. With the development of new technologies, the collected digital data has become more precise, thus meeting the increasingly complex and nonlinear requirements of free-form product models. The same principle applies to quality control, where manual measurements have been replaced by modern measurement technologies [2].

Reverse engineering (RE) plays a crucial role in reducing production time within the manufacturing cycle. Essentially, RE can be described as a systematic process that extracts design information from an existing product. Although products from various industries, including software, defense systems, medical and rehabilitation equipment, consumer electronics, and others, can be subject to reverse engineering, our work focuses on the geometric models of products [1].

It can be applied in various fields, such as automotive engineering, aerospace engineering, defense systems, and medicine and rehabilitation [3]. Reverse engineering also finds its application in the 3D scanning of parts created through rolling, a plastic forming process in which material is compressed between two or more rolls, altering its shape and size according to the desired specifications. This processing method is widely used in the industry for the production of elements with complex geometry and superior mechanical properties.

3D scanning is a process of analyzing a solid three-dimensional object by collecting

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information about its shape and, sometimes, its color. The collected data is transmitted to specialized software associated with the scanner. Once the data is entered into the software, it is analyzed and reconstructed to create a CAD-type 3D model.

The obtained 3D models can be edited and reproduced either through 3D printing or by classical mechanical methods. 3D scanners use various scanning technologies, each with its own limitations, advantages, disadvantages, and costs. Common limitations include difficulties in scanning shiny, transparent, or repetitively patterned objects.

Among the 3D scanning technologies are: laser triangulation, photogrammetry, structured light, contact-based scanning, laser pulse and magnetic resonance imaging

The scanning process is simplified in Fig. 1.

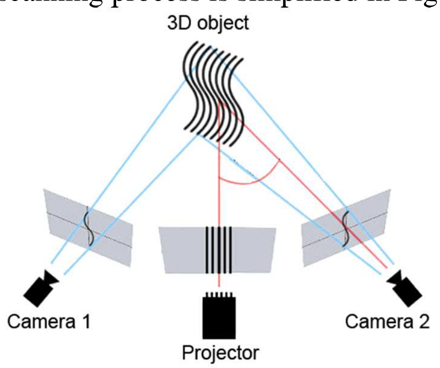


Fig. 1. 3D scanning process [5]

The developed workflow is shown in Fig. 2. The steps taken in the reverse engineering process are based on the 3D scanning procedure, post-processing of the 3D model, and creating the final product.

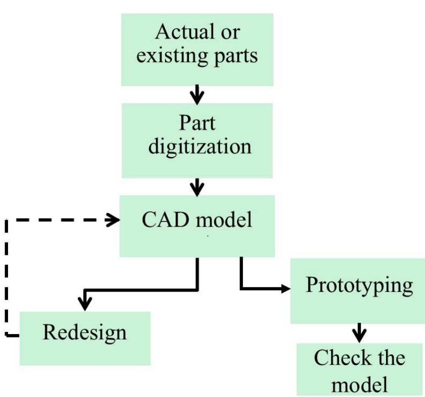


Fig. 2. Work scheme developed

2. REALIZATION OF THE 3D MODEL

2.1 The 3D Scanning Process

To perform the scanning of the experimentally deformed sheets after rolling, an Artec Spider scanner and Artec Studio 17 Professional scanning software were used. For optimal scanning and high precision, the Artec Spider scanner was mounted on a tripod and the piece to be scanned was placed on a turntable, as shown in Fig. 3.

Fig. 3. Preparing the model for scanning

The preview obtained before starting the recording process for the 3D model (Fig. 4).

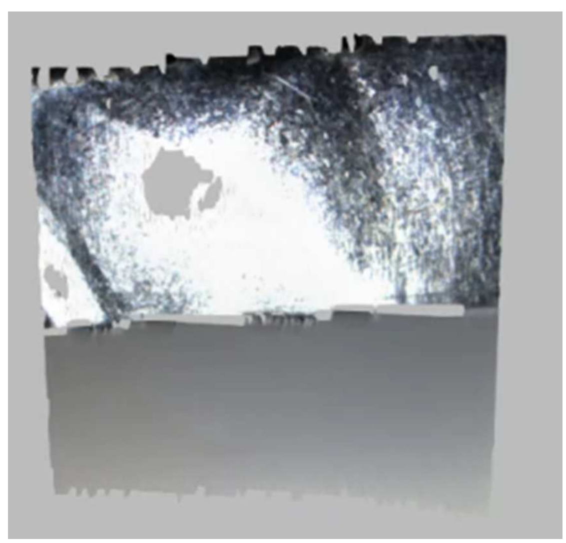


Fig. 4. Model preview in Artec Studio

After completing the scanning of the part, the “stop” button is pressed, and the entire model is displayed in Fig. 5, showing the result after the scanning process is finished.

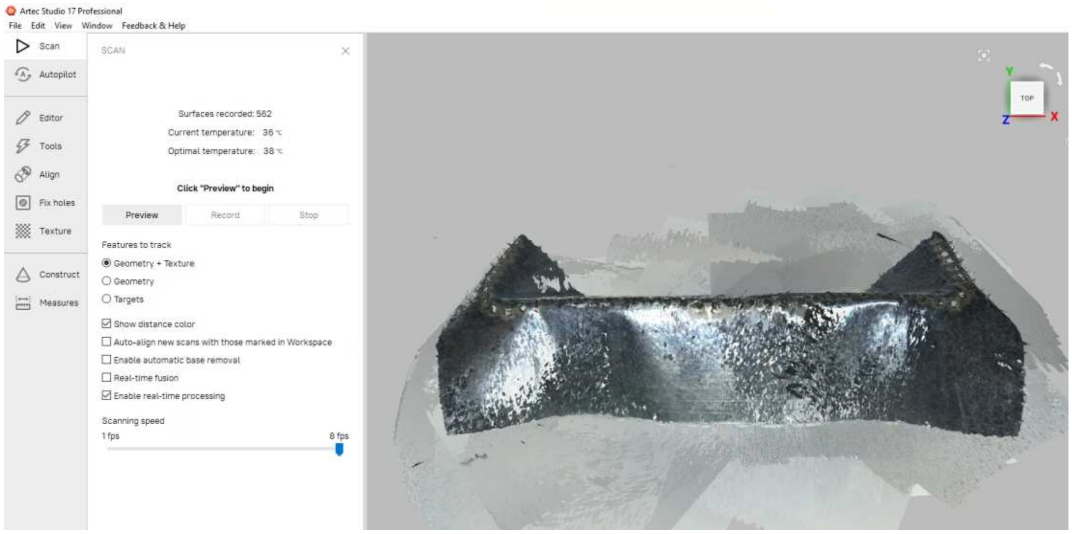


Fig. 5. The scanned model without processing in Artec Studio

The result of the scanned model, prepared for processing (Fig. 6), after removing the base and other unwanted elements.

Fig. 6. Scanned model ready for processing

The final step in processing the scanned part involves using the commands "*Tools – Smooth Fusion*" and "*Tools – Sharp Fusion*" (Fig. 7).

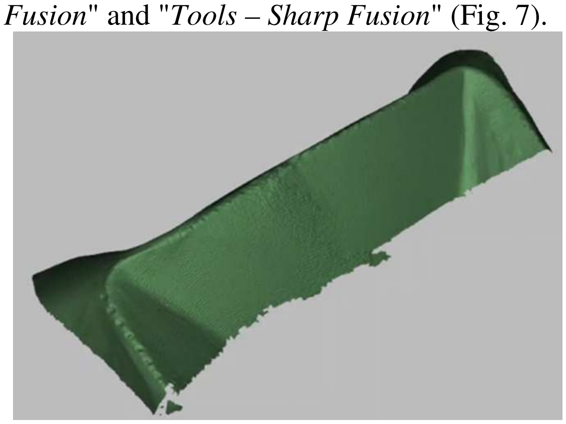


Fig. 7. Scanned model after processing in Artec Studio

The final model, obtained after executing all the commands, is shown in Fig. 8. This model will be exported in CAD format to be imported into Geomagic Design X.

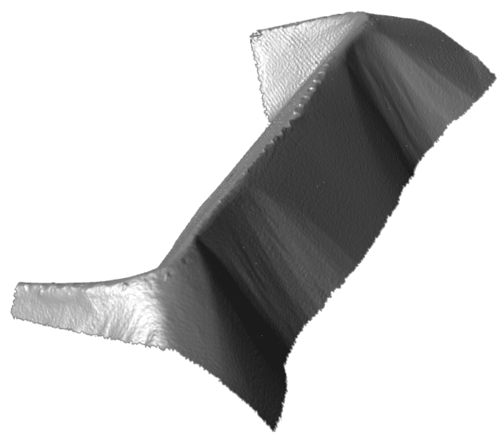


Fig. 8. Final scanned model

To address the reflective nature of the shiny sheet metal, a special spray called AESUB Orange was applied before scanning. This spray provides a white coating with a layer thickness of 2-6 µm and a scanning time of 4-8 hours, ensuring optimal data capture. The improved scan results, shown in Fig. 9, demonstrate the spray's effectiveness in enhancing digital reconstruction quality.

Fig. 9. Scanned piece after applying AESUB orange

The result of scanning and processing the part using AESUB Orange spray is shown in Fig. 10.

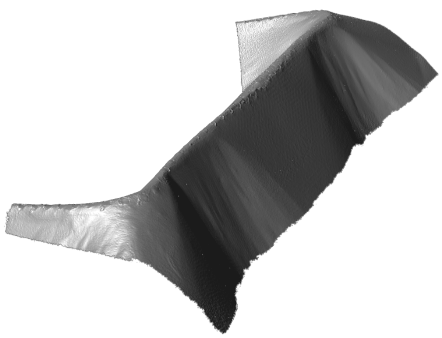


Fig. 10. Final scanned model after applying AESUB orange

2.2 Postprocessing Process

After processing the model in Artec Studio, the exported model will be imported into Geomagic Design X.

To fill in areas where the edge of the part was not scanned properly (Fig. 11 a), the command "*Polygons – Fill Holes – Editing Tools – Full Fill*" will be used, and the result is shown in Fig. 11 b.

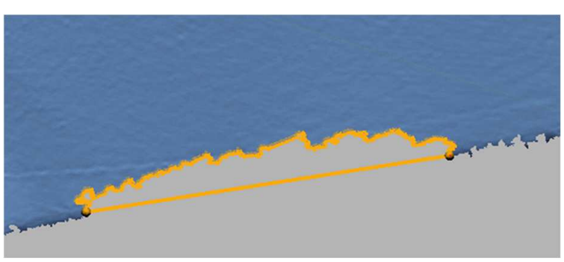
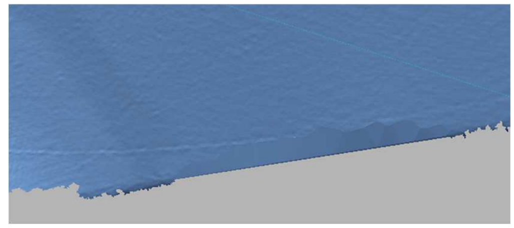


Fig. 11 a. Fill piece edges



b

Fig. 11 b. Result after filling part edges

To smooth the areas where laser-cut holes were present, the command "Paint Brush Selection Mode and Polygons – Defeature" was used, and the final result is shown in Fig. 12.

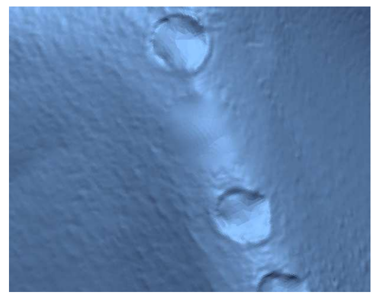


Fig. 12. Result after smoothing part

The final result is shown in Fig. 13.

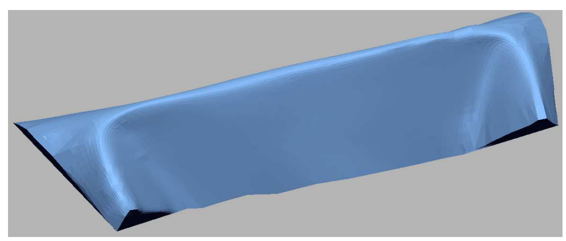


Fig. 13. Final result after generating surfaces

2.3 Creating the 3D model

The modeling tool Altair Inspire, as seen in Fig 14, was used in order to import and construct a wall using the tessellation method on the given parts. In tessellation geometric shapes are repetitively arranged in an optimal configuration, resulting in minimum material use and the maximum mechanical load bearing capabilities. The "*Move*" command was used to accurately reposition much of the parts to form the required wall. This gives room for enough variation, as the design can be altered to the required shape and still serve its purpose during construction. The wallfashioned also shows how greatly tessellation can aid in the effects of weight reduction and improving the structure of a lightweight construction as is common in architectural, engineering and industrial design fields.

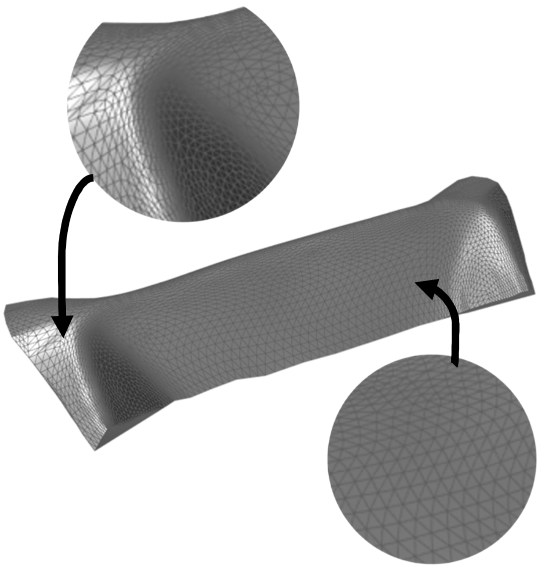


Fig. 14. Model exported from Geomagic Design X

The final result is shown in Fig. 15.

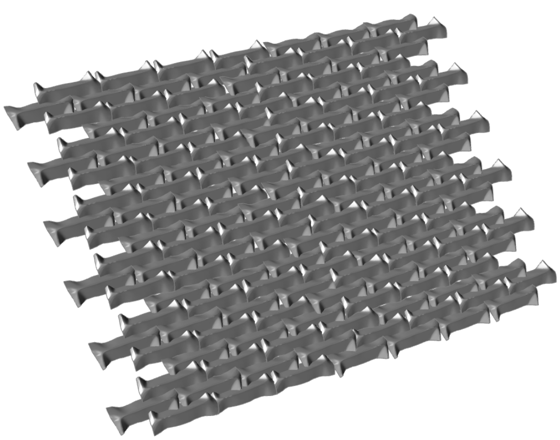


Fig. 15. Assembly in Altair Inspire

3. POSSIBLE AREAS OF APPLICATION

Using the principle of tessellations, various planar or curved surfaces can be covered. These tiles can serve as decorative patterns or have practical functions, such as providing durable and waterproof coverings for pavements, floors, or walls. Historically, tessellations have been used since Ancient Rome [5], as well as in Islamic art, such as in Moroccan architecture and the geometric decoration of the Alhambra Palace. In the 20th century, M.C. Escher [6] frequently used tessellations in his works, both in Euclidean and hyperbolic geometry, to create artistic effects. Tessellations are often used for decorative effects in quilting. They also form a class of natural patterns, such as the hexagonal networks of honeycombs.

Curved surfaces have been used relatively recently for various structures, such as: solar panels [7,8] and solid constructions from unfolded surfaces, including tessellations [9], machine models and large-span roofs [10], decorative art and urban furniture [11], and packaging boxes [12, 13].

4. CONCLUSIONS

Computerized techniques are used to find manufacturing solutions for freeform surfaces but are associated with customized manufacturing methods. Dedicated programs have been employed in the digital design of deformed surfaces as well as specific CAD software.

Starting from the assembly created in Altair Inspire, we aim to develop a future research direction in which we intend to analyze the acoustic properties of the obtained surface to discover whether it acts as a sound amplifier or a sound absorber.

The manufacturing possibility would involve 3D printing of the tessellation and creating a silicone mold in which forms would be produced using epoxy resin. This would lead to much larger production and shorter production times for the products.

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Integrarea tehnologiilor de scanare 3D în proiectarea suprafețelor obținute prin teselații

Această lucrare se concentrează pe procesul de inginerie inversă pentru o tablă deformată experimental în urma procesului tehnologic de roluire. Primul pas a fost acela de a realiza o scanare 3D detaliată folosind un scaner performant Artec Space Spider, acesta oferind o precizie ridicată. Următorul pas, pe baza modelului scanat, se realizează o postprocesare a modelului în programul Artec Studio, ulterior fiind exportat în programul Geomagic Design X pentru generarea suprafețelor modelului 3D. În final, modelul prelucrat este introdus în programul Altair Inspire pentru a genera peretele obținut prin teselarea modelului studiat.

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