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GRAPHICAL MODELLING OF THE WORM SHAFTS OF SOME MICROMOTORS IN THE AUTOMOTIVE INDUSTRY

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Abstract: *Graphical systems are fundamental tools in various fields, being used to create complex three-dimensional models and two-dimensional representations of physical components. They are essential throughout the design process, from the conceptual phase and detailed arrangement of the parts, to strength analyses in order to define how to manufacture them. A specific example is represented by micromotors, which are essential components in certain mechanisms in the structure of vehicles. The paper presents the graphical modeling of the worm shafts of micromotor assembly from the structure of some mechanisms with role in adjusting the seats of some vehicles from the automotive industry. Thus, the paper offers a perspective on the design and manufacturing process, highlighting the importance of graphical representation systems and reverse engineering in the development and realization of complex components from the automotive industry.*
Key words: *automotive industry, micromotor, graphical modelling, CATIA, worm shafts, reverse engineering.*

1. INTRODUCTION

Graphical modeling is an essential field in engineering, allowing the representation and simulation of complex objects and systems in a virtual environment.

This approach has become essential in the process of designing, optimizing and analyzing various components and products. Graphical modeling methods include those based on curves and surfaces, which facilitate detailing and defining the three-dimensional geometry of the objects [1], [2], [3], [4].

The paper presents the graphical modeling of some micromotor worms from the construction of the seat adjustment mechanisms of some vehicles, Figure 1 [5], [6], [7], [8].

These elements have an essential role in ensuring mobility and comfort in motor vehicles.

They are also key components that manage the fine adjustments of the seat position, contributing to the overall ergonomics of the car and the driver's driving experience.

Fig. 1. Mechanism for adjusting the seats of some vehicles [6], [8].

In the last decades, the automotive industry has experienced an accelerated evolution, highlighted by an increase in requirements regarding energy efficiency, durability and the integration of advanced technologies [9], [10], this dynamic context imposing the need to develop mechanisms of increasingly sophisticated seat adjustment.

By integrating the graphical models of the micromotor worms already in the design and simulation phase, it opens the way for the use of correct gearing characteristics of all mechanisms, including the electric micromotor.

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This approach allows engineers to optimize not only the performance and reliability of the micromotor, but also to anticipate and effectively manage possible problems related to the non-functionality of various components. Thus, it contributes to the reduction of production costs and the overall improvement of the quality of seat adjustment systems in the automotive industry [11], [12].

This paper aims to provide a detailed analysis of the graphical modeling process of two micromotors within some automotive seat adjustment mechanisms, with an emphasis on technical, functional and design aspects. In the context of the rapid evolution of the automotive industry, where the requirements regarding energy efficiency and the integration of advanced technologies have increased significantly, it is necessary not only to develop sophisticated seat adjustment mechanisms, but also to apply reverse engineering concepts [13], [14], [15], the automotive industry having some specific advantages in the implementation of reverse engineering: automotive components are not very large and the assemblies are also not very complex.

By integrating this approach into the design process, engineers can benefit from precise scanning of micromotors, using advanced technologies such as Atos Core 3D scanning equipment [16], [17], which have become increasingly powerful, accessible and cost effective. The 3D scanning of micromotor worms provides a solid basis for further graphical modeling or can become an additional means of checking the correctness of graphical models, especially in the absence of adequate technical documentation.

2. GRAPHICAL MODELING OF THE WORM SHAFTS

The two worm shafts from the construction of the seat adjustment mechanism of some Audi and Mercedes cars are shown in Figure 2 and Figure 3.

The graphical modeling of the two worm shafts from the construction of the seat adjustment mechanism of an Audi car, was made according to the dimensions from the technical data sheet presented in Figure 4.

Fig. 2. Worm shaft from the construction of the seat adjustment mechanism of an Audi car [6], [8].

Fig. 3. Worm shaft from the construction of the seat adjustment mechanism of Mercedes car [6], [8].

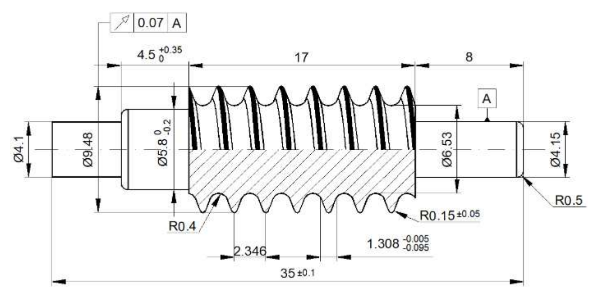

Fig. 4. The dimensions of the worm shaft from the construction of the seat adjustment mechanism of an Audi car.

The graphical modeling process involved the use of specialized *CATIA V5R21* software, the *Generative Shape Design* module, in order to transform these dimensions into a three-dimensional graphical model, facilitating a better understanding of the worm shaft geometry.

To begin, two points will be constructed in *XYZ* plane using the *Point* command: one point having coordinates *0*, *0*, *0* (*Point 1*) and another point having coordinates *0*, *7*, *0* (*Point 2*).

Afterwards, a line will be constructed in the *YZ* reference plane, using the *Line* command, with *Point 1*, previously constructed, as the reference point.

The length of the line will be exactly the length of the active part of the worm shaft from the construction of the seat adjustment mechanism of an Audi car: 17 mm.

Next, the helical flank of the worm shaft will be built, using the *Helix* command, starting with *Point 2* previously built, the pitch being 2.346 mm, Figure 5.

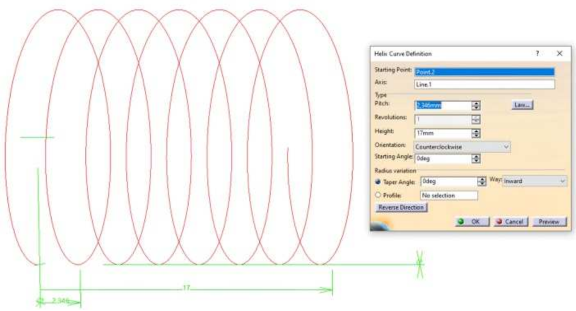

Fig. 5. Creating the spiral for modeling the active part of the worm shaft.

On the *XY* plane, a sketch is made on which a profile will be built that materializes the gap between the flanks of the worm shaft from the construction of the seat adjustment mechanism of an Audi car, Figure 6, having the dimensions shown in Figure 4.

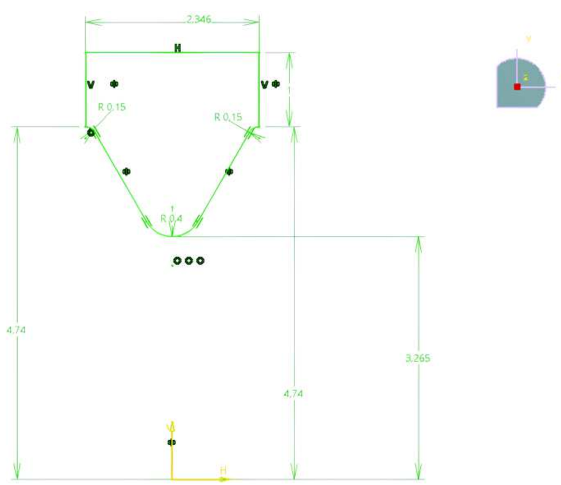

Fig. 6. The 2D creation of the profile that materializes the gap between the flanks of the worm shaft from the construction of the seat adjustment mechanism of an Audi car.

The dimensions were correlated based on the datasheet dimensions shown in Figure 4.

The graphical modeling process involved the use of a varied set of commands and functionalities available in *CATIA* computer-aided design software. The sketch was realized using 2D commands such as *Point* and *Circle* in order to reproduce the outline and essential dimensions of the worm shaft. Editing commands such as *Mirror* and *Trim* were applied to ensure symmetry and accuracy of sketch details. This process was the basis for the subsequent three-dimensional modeling of the worm shaft. In order to create the counter-shape of the helical flank of the worm shaft, the *Volume Swept* command was used, Figure 7.

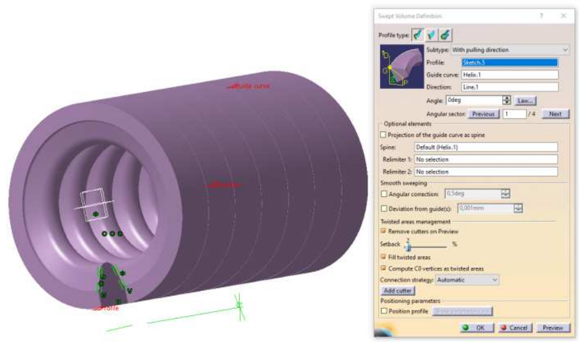

Fig. 7. 3D modeling of the helical area of the worm shaft.

This command allowed the 2D sketch to be translated into a 3D model, accurately reflecting the complex shape and structural details of the shaft. The command facilitated the generation of the helical geometry and allowed the parameters to be adjusted in order to ensure correspondence with the technical specifications from Figure 4.

By constructing a circle with a diameter of Ø9.48 mm on the *YZ* plane and using the *Volume Extrude* command, with the dimensions shown in Figure 8, the leg area of the worm shaft from the construction of the seat adjustment mechanism of an Audi car can be created.

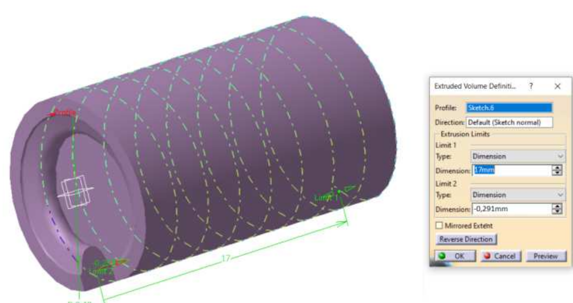

Fig. 8. Modeling the leg area of the worm shaft from the construction of the seat adjustment mechanism of an Audi car.

Using the *Remove* command from the

Insert -> Volumes module, the helical profile of the worm shaft from the construction of the seat adjustment mechanism of an Audi car is generated, Figure 9.

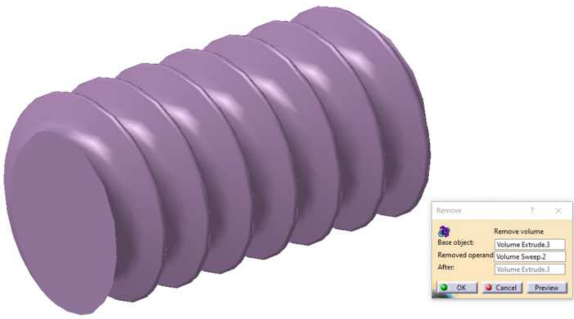

Fig. 9. 3D modeling of the helical profile of the worm shaft from the construction of the seat adjustment mechanism of an Audi car.

Next, the other component parts that make up the worm shaft from the construction of the seat adjustment mechanism of an Audi car will be modeled, using the 2D drawing command - *Circle*, as well as the 3D drawing command - *Volume Extrude*. The connections were made using the *Edge Fillet* command.

Figure 10 shows the virtual model of the worm shaft from the construction of the seat adjustment mechanism of an Audi car made in the CATIA software program.

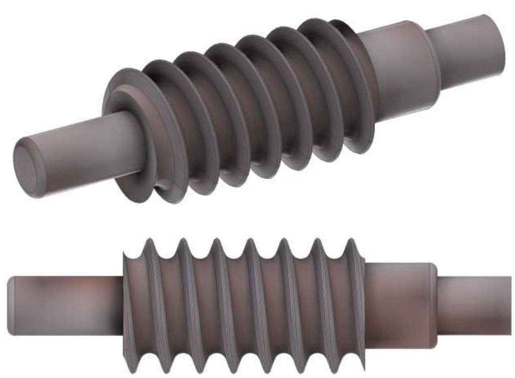

Fig. 10. Virtual model of the worm shaft from the construction of the seat adjustment mechanism of an Audi car [5].

The steps for modeling the worm shaft from the construction of the seat adjustment mechanism of a Mercedes car are the same as the modeling of the part previously presented, the dimensions being taken from Figure 11.

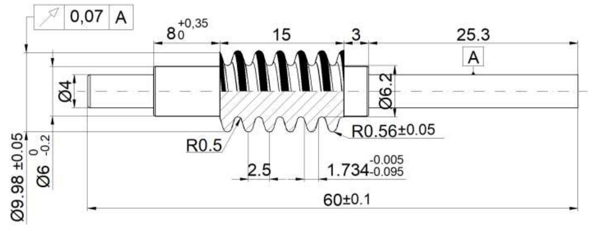

Fig. 11. The dimensions of the worm shaft from the construction of the seat adjustment mechanism of a Mercedes car.

Therefore, two points will be constructed in the *XYZ* space: a point having coordinates *0*, *0*, *0* (*Point 1*) and another point having coordinates *0*, *7*, *0* (*Point 2*).

Afterwards, in the *YZ* reference plane, a line will be built, using the *Line* command, having as a reference point the *Point 1*, previously built and the length of 15 mm (representing the length of the active part of the worm shaft from the construction of the seat adjustment mechanism of a Mercedes car). The helical flank of the worm shaft will be built, using the *Helix* command, starting with *Point 2* previously built, the pitch being 2.5 mm, according to Figure 11.

On the *XY* plane, a sketch is made on which the profile will be built that materializes the gap between the flanks of the worm shaft from the construction of the seat adjustment mechanism of a Mercedes car, having the dimensions shown in Figure 12.

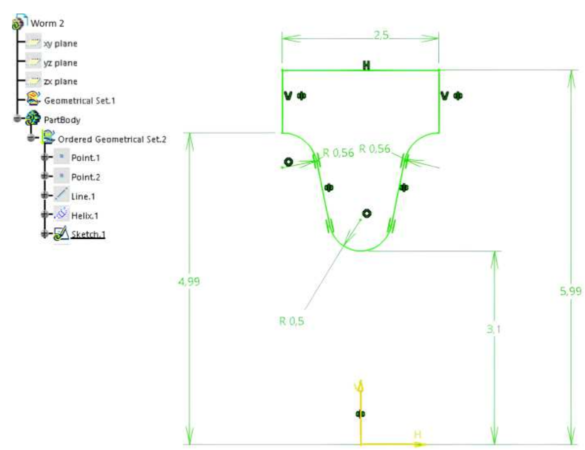

Fig. 12. 2D creation of the profile that materializes the gap between the flanks of the worm shaft from the construction of the seat adjustment mechanism of a Mercedes car.

Thus, it is possible to model the counter-form of the helical flank of the worm shaft from the construction of the seat adjustment mechanism of a Mercedes car with the help of the *Volume Swept* control, the characteristics of the control being shown in Figure 13.

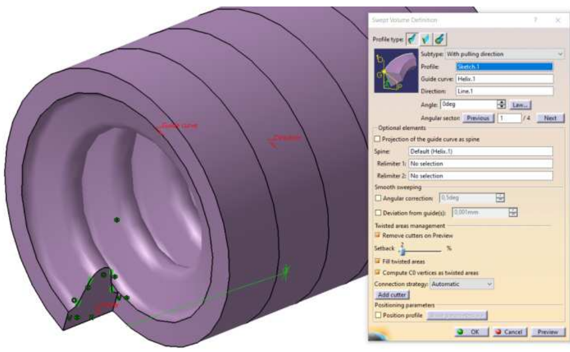

Fig. 13. 3D modeling of the helical area of the worm shaft from the construction of the seat adjustment mechanism of a Mercedes car.

By creating a circle with a diameter of Ø9.98 mm on the *YZ* plane and using the *Volume Extrude* command, the leg area of the worm shaft from the construction of the seat adjustment mechanism of a Mercedes car can be constructed, Figure 14.

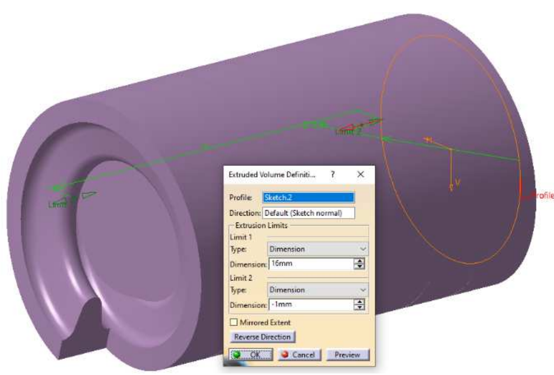

Fig. 14. 3D modeling of the leg area of the worm shaft from the construction of the seat adjustment mechanism of a Mercedes car.

Using the *Remove* command, the areas corresponding to the gaps of the active part of the worm shaft can be removed, Figure 15.

Finally, the other components that make up the part will be built using *Circle* and *Volume Extrude* commands, as well as the *Edge Fillet* command.

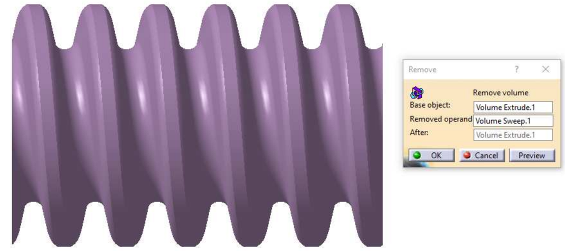

Fig. 15. 3D modeling of the helical profile of the worm shaft from the construction of the seat adjustment mechanism of a Mercedes car.

Figure 16 shows the virtual model of the worm shaft from the construction of the seat adjustment mechanism of a Mercedes car made in the CATIA software program.

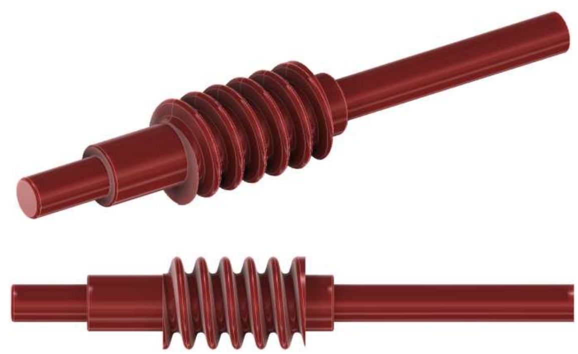

Fig. 16. The virtual model of the worm shaft from the construction of the seat adjustment mechanism of a Mercedes car [5].

3. THE SCANNING PROCESS OF THE WORM SHAFTS

The scanning process of the two worm shafts was carried out using a device called Atos Core, Figure 17 [16], [17].

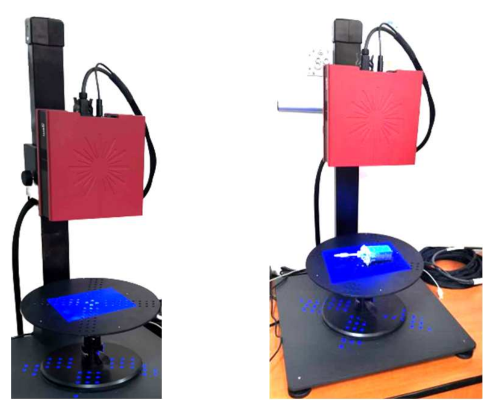

Fig. 17. Atos Core scanning device [16].

This scanning equipment, with extensive applications in areas such as rapid prototyping and reverse engineering, has proven to be essential in obtaining an accurate and detailed representation of the complex geometry of the two parts.

Atos Core uses 3D optical scanning technology to capture in detail the shape, the dimensions and the structure of the worm shafts.

This advanced technology allows obtaining an accurate digital model, faithfully reproducing every contour and feature of the two components.

The images obtained from the scanning technique are processed using the GOM Scan software.

It stands out as highly accessible and intuitive software that plays a significant role in transforming raw data from the scanning device into detailed and accurate three-dimensional digital models.

With a user-friendly interface, GOM Scan offers engineers and designers a simple experience in manipulating and interpreting the data obtained in the scanning process.

The advanced functionalities of this software allow efficient manipulation and correlation of 3D data, as well as making fine adjustments to ensure an exact correspondence with the original geometry of the worm shafts [16].

Thus, by using the *Scan* IIII command from the *Acquisition* -> *Measurement* module, Figure 18, the actual scanning process is performed.

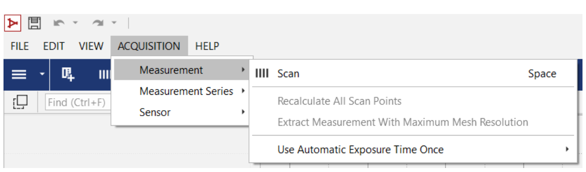

Fig. 18. The *Scan* command.

During scanning, the software projects different line patterns on the surface of the object. The software immediately displays the captured surface data in the 3D view.

It is possible to take measurements both with and without reference markers, however, it is recommended to use reference markers in the scanning process.

These reference markers are placed both on the components to be scanned and on the table surface of the scanning equipment before the actual scanning process begins.

By using the reference markers, the correct alignment of the scanned data is ensured, minimizing possible errors or deviations in the measurements.

Thus, a stable and precise frame of reference is created, which contributes to obtaining reliable results corresponding to the strict standards in the field of 3D measurements.

At the same time, in order to ensure the highest possible accuracy in the scanning process, it is essential to use an anti-reflective spray on the components to be scanned.

The purpose of this spray is to transform the glossy surfaces of the parts into matte surfaces, as glossy surfaces can lead to reduced scan quality.

This aspect is essential in scanning items with glossy or reflective surfaces, where there is a risk of distortion or loss of information due to uncontrolled reflections.

The transformation of the surfaces into matte ones contributes to the uniformity of the intensity of the reflected light, thus facilitating the process of capturing details and contours.

Therefore, Figure 19 show the application of the reference markers and the anti-reflective spray on the two worm shafts.

(a) (b)

Fig. 19. Applying the reference markers to the parts (a); Applying the anti-reflective spray to the parts (b).

Figures 20 and 21 show sequences following the scanning process of the two worm shafts.

Finally, 64 scans resulted for the worm shaft from the construction of the seat adjustment mechanism of an Audi car, Figure 22, and 52 scans for the one of a Mercedes car, Figure 23.

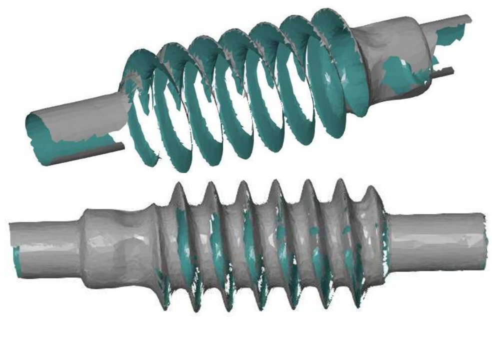

Fig. 20 Sequences following the scanning process of the worm shaft from the construction of the seat adjustment mechanism of an Audi car.

Fig. 21. Sequences following the scanning process of the worm shaft from the construction of the seat adjustment mechanism of a Mercedes car.

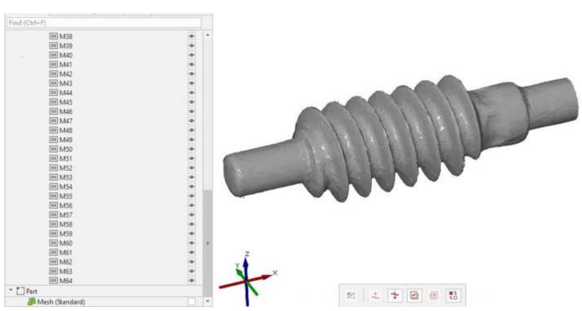

Fig. 22. The number of scans for the worm shaft from the construction of the seat adjustment mechanism of an Audi car.

Fig. 23. The number of scans for the worm shaft from the construction of the seat adjustment mechanism of a Mercedes car.

Thus, after the polygonalization process, Figures 24 and 25 show the final model of the two worm shafts.

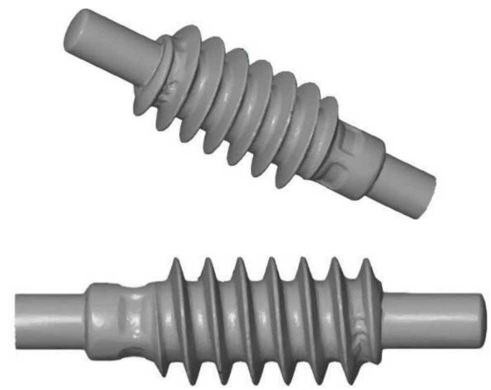

Fig. 24. The scanned model of the worm shaft from the construction of the seat adjustment mechanism of an Audi car.

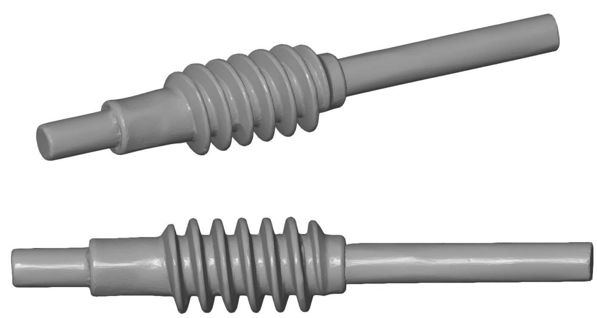

Fig. 25. The scanned model of the worm shaft from the construction of the seat adjustment mechanism of a Mercedes car.

The polygonalization process involves aligning and correlating all the data obtained by scanning the part, resulting in a complete and detailed numerical model.

4. COMPARISON BETWEEN THE CAD MODEL AND THE SCANNED MODEL OF THE WORM SHAFTS

The comparison between the CAD model and the scanned model of the worm shafts was done using the GOM Inspect software.

A first step is to import the two models in the inspection program the models having different orientations in relation to the reference system prescribed in the program, Figure 26 and Figure 27.

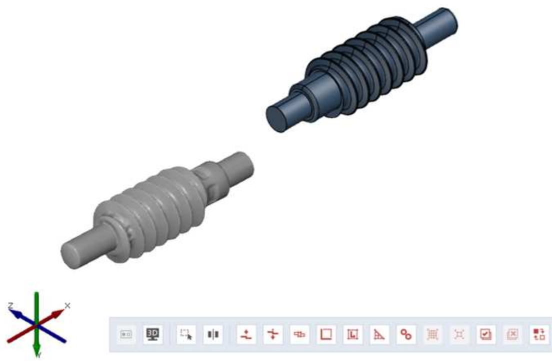

Fig. 26. Importing the scanned model and CAD model of the worm shaft from the construction of the seat adjustment mechanism of an Audi car.

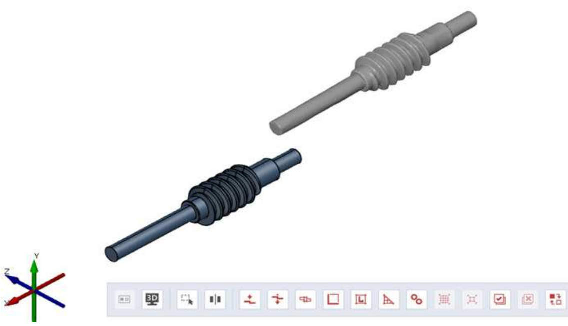

Fig. 27. Importing the scanned model and CAD model of the worm shaft from the construction of the seat adjustment mechanism of a Mercedes car.

In order to overlap the two models in a single reference system, the *Operations -> Alignment -> Initial Alignment -> Prealignment* menu is accessed and the models shown in Figure 28 and Figure 29 are obtained.

The comparison of the two models begins and, in this case, it is necessary to access the menu *Inspection -> CAD Comparison -> Surface Comparison on CAD*, from *GOM Inspect* software.

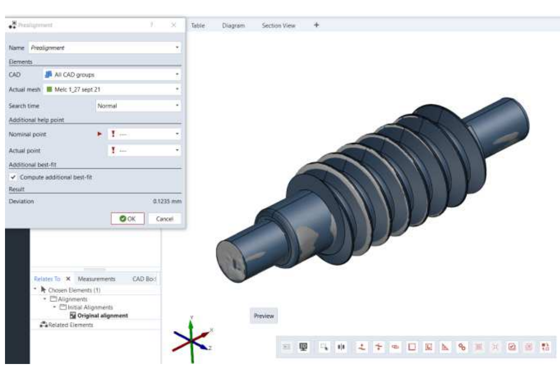

Fig. 28. The overlap of the two models of the worm shaft from the construction of the seat adjustment mechanism of an Audi car.

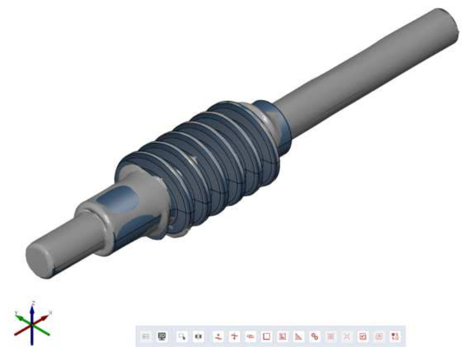

Fig. 29. Overlap of the two models of the worm shaft from the construction of the seat adjustment mechanism of a Mercedes car.

The inspection process, aimed at analyzing the imperfections present on the two worm shafts, according to the two models, is facilitated by means of a deviation map, Figure 30 and Figure 31.

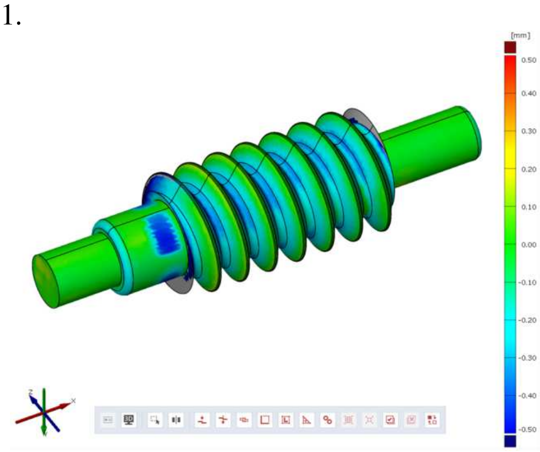

Fig. 30. Map of deviations in the case of the worm shaft from the construction of the seat adjustment mechanism of an Audi car.

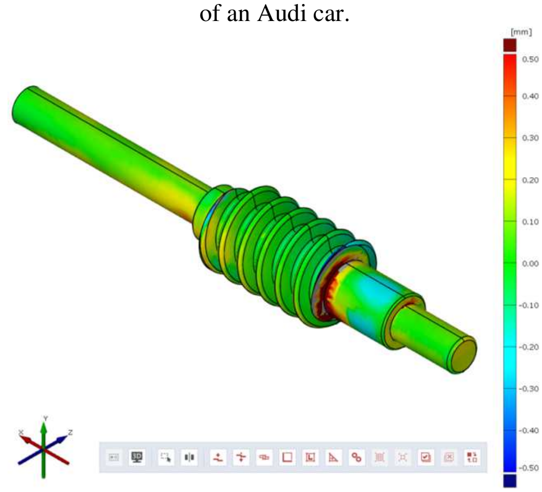

Fig. 31. Map of deviations in the case of the worm shaft from the construction of the seat adjustment mechanism of a Mercedes car.

This map is an essential tool in assessing the accuracy and geometric conformity of components, providing clear and concise information on possible deviations.

This is based on numerical values that represent deviations at the micrometer level, providing a detailed insight into the accuracy of each point or segment on the surface of the worm shafts.

In this analysis, specific limits were chosen for the maximum and minimum accepted deviations. Thus, the upper limit value of the deviations, represented in the bar, was set to *0.5 mm* and, similarly, the lower limit value was set to *-0.5 mm*.

Through the deviation map and these established limits, the inspection process becomes an effective tool in identifying and quantifying discrepancies between the digital model and the physical object.

These areas may be the result of specific conditions of the scanning process or of the structure of the inspected objects, such as hard-to-reach surfaces or areas with reflections, which may affect the quality of the collected data.

In the final step, labels are generated in order to display the numerical values associated with the deviations, using the *Deviation Label* command in the *Inspection* module, Figure 32 and Figure 33. These labels are an effective way of presenting the details of the identified deviations, providing precise and easy-to-understand information about the dimensional variations of the analyzed components.

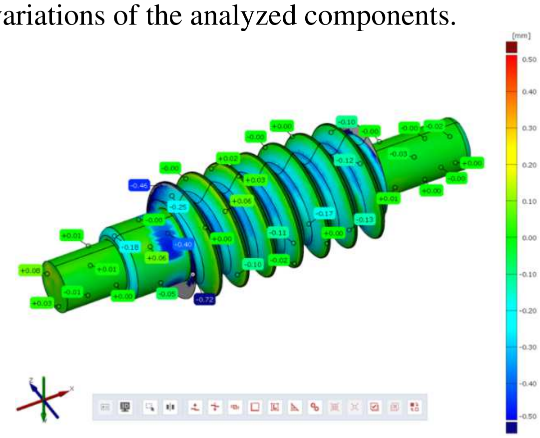

Fig. 32. Deviations in the case of the worm shaft from the construction of the seat adjustment mechanism of an Audi car.

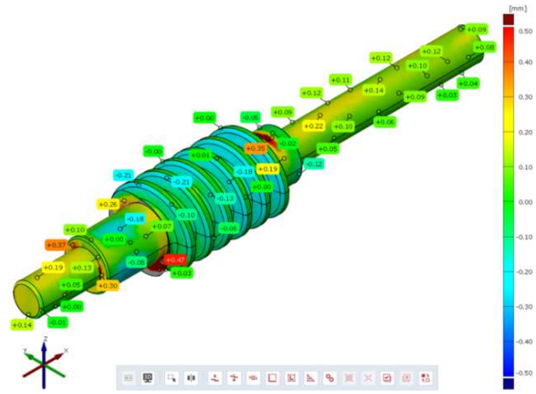

Fig. 33. Dimensional deviations in the case of the worm shaft from the construction of the seat adjustment mechanism of a Mercedes car.

5. THE INSPECTION PROCESS OF THE WORM SHAFTS

The *GOM Inspect* software can also be used to determine the dimensional characteristics of parts scanned with the *Atos Core* equipment and implicitly, with the *GOM Scan* program.

Thus, in order to determine the dimensions of the worm shafts, it is necessary to build the contour of the two parts, using the *Single Section* command, Figures 34÷37.

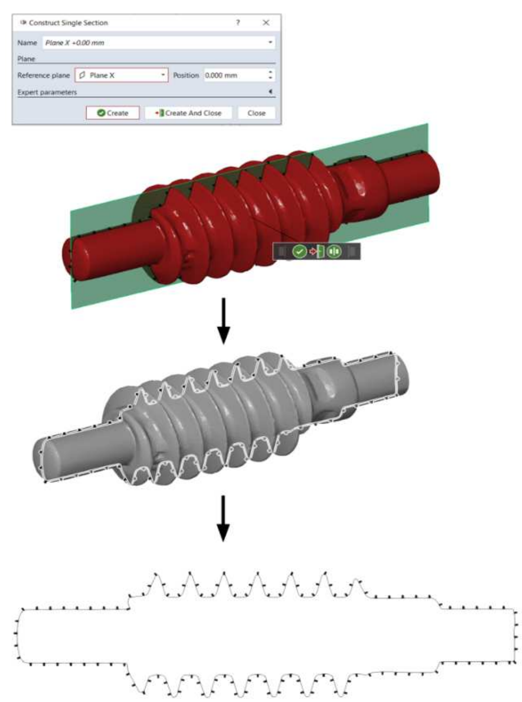

Fig. 34. The contour of the longitudinal section of the worm shaft from the construction of the seat adjustment mechanism of an Audi car.

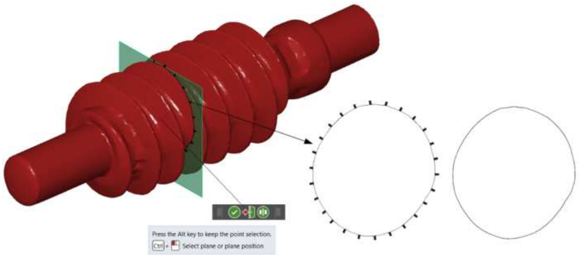

Fig. 35. The contour of the cross section of the worm shaft from the construction of the seat adjustment mechanism of an Audi car.

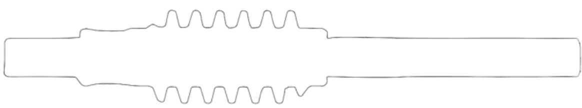

Fig. 36. The contour of the longitudinal section of the worm shaft from the construction of the seat adjustment mechanism of a Mercedes car.

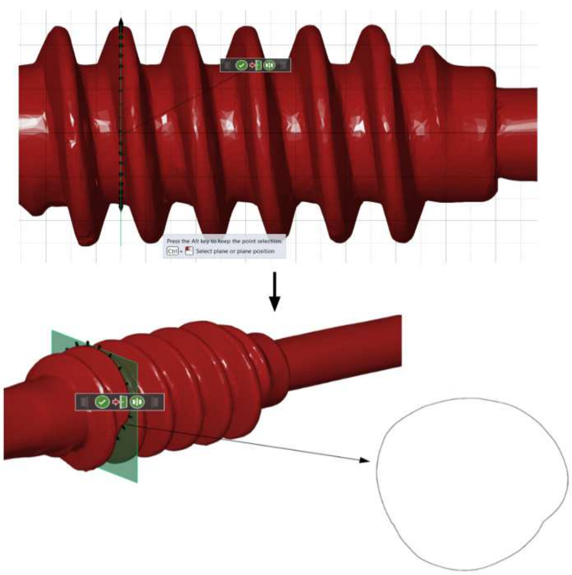

Fig. 37. The contour of the cross section of the worm shaft from the construction of the seat adjustment mechanism of a Mercedes car.

Thus, with the help of the two contours, the dimensions of the two worm shafts can be determined.

For example, in order to determine the maximum length of the two parts, two points are built at the ends of the parts (*Point* ● command), and with the help of the *2-Point Distance* •–• command, dimensional values can be accurately determined, according to the scanned parts, Figures 38 and 39.

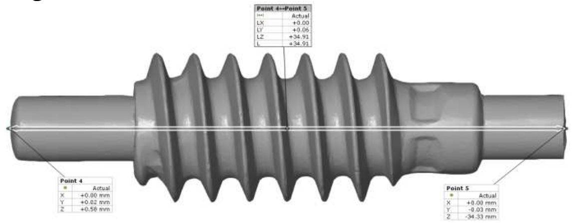

Fig. 38. The maximum value of the worm shaft from the construction of the seat adjustment mechanism of an Audi car.

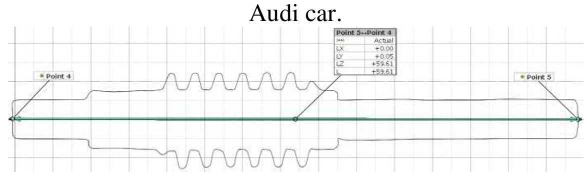

Fig. 39. The maximum value of the worm shaft from the construction of the seat adjustment mechanism of a Mercedes car.

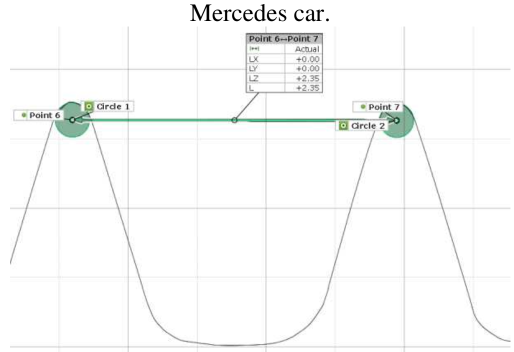

Fig. 40. The pitch value of the worm shaft from the construction of the seat adjustment mechanism of an Audi car.

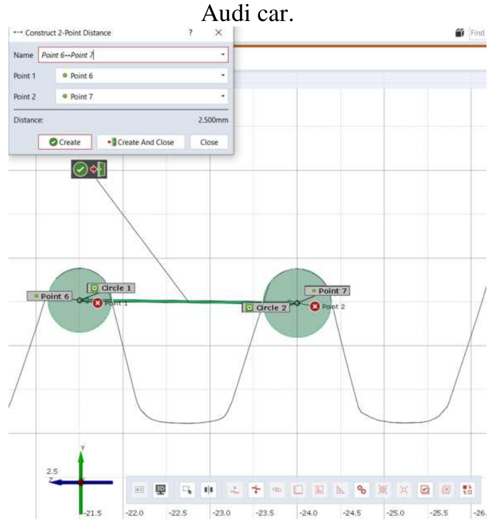

Fig. 41. The pitch value of the worm shaft from the construction of the seat adjustment mechanism of a Mercedes car.

In order to determine the pitch of the thread, two circles are built on the peaks of the teeth, using the *Fitting Circle* command from the *Construct -> Circle* module, subsequently constructing two points placed in the center of the respective circles, using the *Point* command, following the actual measurement of the pitch, using *2-Point Distance* command, Figures 40 and 41.

In order to determine the maximum diameter of the two shafts, several points are constructed that pass through the peaks of the teeth and two lines are drawn that pass through all these points, subsequently measuring the distance between the lines, by means of the *Projected Point Distance* command, Figures 42 and 43.

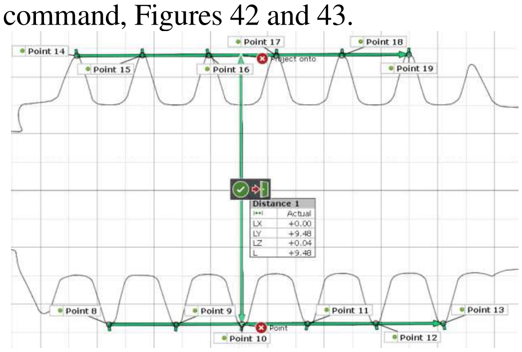

Fig. 42. The maximum diameter of the worm shaft from the construction of the seat adjustment mechanism of an Audi car.

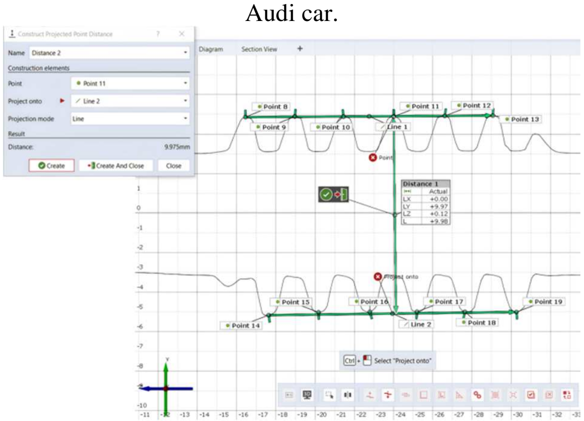

Fig. 43. The maximum diameter of the worm shaft from the construction of the seat adjustment mechanism of a Mercedes car.

6. CONCLUSIONS

The worm-type parts existing in the construction of micromotors in the automotive industry represent relatively complex working bodies, whose profiles include different shapes, such as circle arcs, straight segments, helical curves and non-analytical curves, obtaining the constructive shape of the worms being quite difficult.

Thus, the paper highlights, through the working methods used, several essential aspects:

- the successful use of *CATIA* graphical design software in the three-dimensional modeling of the worms from the structure of two seat adjustment micromotors from an Audi or Mercedes car, when there is adequate technical documentation;

- the use of reverse engineering, scanning and 3D laser measurement techniques is much more efficient compared to analysis by means of coordinate measuring machines;

- the substantial reduction of measurement time by using systems based on 3D optical scanners is equivalent to the reduction of design, manufacturing, assembly and production time;

- the possibility of comparing theoretical models with those obtained in a few seconds through an impressive number of measurement point clouds and calculated by a dedicated software;

- obtaining micron-level dimensional accuracy by using 3D measurement systems, even in areas that are difficult to reach from an optical point of view;

- identification of manufacturing problems, based on the possibility to compare both the theoretical and the real geometry of the obtained surfaces.

7. ACKNOWLEDGEMENT

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Modelarea grafică a arborilor melcați din cadrul unor micromotoare din industria automotive

Sistemele grafice reprezintă instrumente fundamentale în diverse domenii, fiind folosite pentru a crea modele tridimensionale complexe și reprezentări bidimensionale ale componentelor fizice. Ele sunt esențiale pe tot parcursul procesului de proiectare, de la faza conceptuală și aranjarea detaliată a pieselor, până la analizele de rezistență pentru a defini modul de fabricare a acestora. Un exemplu specific este reprezentat de micromotoare, care sunt componente esențiale în anumite mecanisme din structura autovehiculelor. Lucrarea prezintă modelarea grafică a arborilor melcați din ansamblul micromotoarelor din structura unor mecanisme cu rol în reglarea scaunelor unor vehicule din industria automotive. Astfel, lucrarea oferă o perspectivă asupra procesului de proiectare și fabricație, evidențiind importanța sistemelor de reprezentare grafică și a ingineriei inverse în dezvoltarea și realizarea componentelor complexe din industria auto.

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