DIMENSIONAL MEASUREMENT OF AUTOMOTIVE BODY COMPONENTS BY 3D SCANNING

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Abstract:

This paper presents the application of non-contact 3D measurement in industry, with a particular focus on the nspection of an automotive cross member using the portable Creaform HandySCAN BLACK+™|Elite scanner. The paper covers the theoretical foundations and methods of non-contact measurement, a detailed description of the selected device, a comparison with alternative measurement systems, and its practical application on a real example. Special attention was given to the preparation of the object, the scanning process, and the data processing within the Creaform.OS software suite. The obtained results were compared with the CAD model of the cross member, and the generated measurement report enabled the detection of deviations and evaluation of the part's quality. The analysis demonstrated that non-contact 3D measurement significantly accelerates quality control processes, reduces the likelihood of measurement control error, and enables the digitalization of complex geometries with a high level of accuracy.

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1 Introduction

In today's industry, especially in the automotive manufacturing sector, increasing attention is being devoted to the quality of finished products, primarily due to market demands, competitiveness, and increasingly strict safety and regulatory standards. Engineers and manufacturers are faced with the need for precise and efficient quality control at all stages of the production process, which is particularly relevant for structural and safety-critical vehicle components. In this context, 3D contactless measurement represents an indispensable technology that enables rapid, precise, and inspection of the geometric features of complex parts. The manufacturing industry has increasingly prioritized optical metrology as a major research domain. Traditional measurement methods are progressively replaced by non-contact universal inspection technologies due to their efficiency [1]. The subject of research in this paper is the crossmember, that is, the transverse load-bearing element of an automobile body which is typically located in the lower part of the vehicle's chassis [2]. The crossmember has multiple functions — it contributes to the structural rigidity of the body, serves as a support for suspension and drivetrain components, and has a significant impact on the vehicle's passive safety during frontal and side collisions [3]. Since this component must meet high safety and structural requirements, ensuring its dimensional accuracy and geometric conformity with the designed CAD model is of utmost importance. This paper focuses on the application of 3D contactless measurement for the purpose of examining the dimensional accuracy of the manufactured crossmember. For this purpose, the HandySCAN BLACK+™|Elite was used — a highly precise handheld laser 3D scanner developed by the company Creaform. To manage the measurement process and process the collected data, the Creaform.OS software package was used. This software package integrates modules for data acquisition, point cloud processing, alignment with CAD models, and generating deviation reports (a dimensional accuracy report that also

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includes an option for calculating GD&T — "Geometric Dimensioning and Tolerancing," which is used in engineering to define the "perfect" geometry of a manufactured part and the allowable variations in its features). Creaform.OS enables the execution of analyses such as comparing the obtained scan with the nominal model, calculating surface deviations, tolerance inspection, and generating color maps, thus providing a comprehensive insight into the quality of the manufactured product.

2 Manufacturing process overview - transverse

The crossmember, or transverse beam, is among the most important load-bearing components in the construction of a vehicle body. Since this component directly affects the safety and structural integrity of the vehicle, the manufacturing process must meet exceptionally high standards — mechanical as well as dimensional and geometric. The manufacturing process of the beam typically begins with sheet metal forming. Depending on the production volume and available technology, the sheets are cut using laser cutting system or stamping tools. After cutting, the material is bent, shaped, or deep-drawn to obtain the final three-dimensional form [4], [5]. The next step is assembly, where the components of the crossmember are welded into a single piece. The most common method is resistance spot welding (RSW), which enables fast and strong welds as well as automated welding. Robotic systems have now become standard in these processes, providing repeatability, high productivity, and the ability to record process data in real time [6]. After welding, the part undergoes surface treatment. This step is essential as position of the crossmember is makes it constantly exposed to moisture, salt, and harsh environmental conditions (temperature changes due to heating and cooling), mechanical vibrations and stresses resulting from driving, impacts and suspension movement, as well as mechanical loads such as stones, sand, or mud striking the underside of the vehicle. Common surface protection methods include cathodic dip coating (CDC), electrostatic powder coating, or galvanizing, all aimed at providing long-lasting corrosion protection [7]. As shown, the production of crossmembers is technically demanding and highly structured — from material selection, forming, and welding to surface treatment and final inspection. Each process has its own specifications and requirements, ultimately aimed at producing a component that meets all safety, functional, and economic criteria of modern automotive manufacturing. The production of crossmembers in the automotive industry is not only technically demanding but also economically and environmentally optimized to ensure quality, cost-effectiveness, and sustainability. Fig. 1 shows the bottom and upper sides of the crossmember that will be examined in this paper.



Figure 1. Bottom and upper part of the crossmember

3 Product quality characteristics and dimensional requirements

Since the crossmember is a load-bearing component in the vehicle's underbody structure that withstands static and dynamic loads during driving, the key quality characteristics of such a part must be well defined and traceably controlled. Quality is not related only to mechanical properties, but also includes manufacturing accuracy, geometric precision, weld quality, resistance to environmental conditions, and overall compliance with technical documentation. Dimensional accuracy is the most important parameter that characterizes the functional performance of the part. As a component that connects to other sections of the chassis the crossmember must be manufactured within strictly controlled dimensional tolerances. Any deviation from the nominal size may lead to assembly difficulties, increased stress in the joints, reduced structural strength, and unwanted vibrations or noise during vehicle operation. In practice, for example, the position of mounting holes is often defined by a positional tolerance of ±0.1 mm, while length or width tolerances are not as strict, e.g., ±0.5 mm. Geometric tolerances are applied to ensure correct orientation and spatial relationships between surfaces, especially when multiple parts are assembled together. For instance, a parallelism specification between the top and bottom surfaces of the crossmember may be 0.2 mm over a length of 800 mm, which is

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important for uniform load distribution. These are not arbitrary specifications but are closely related to the functional purpose the part must fulfil. If, for example, the position of the mounting holes is inaccurate, it may cause unnecessary stress during installation, leading to premature component failure. Similarly, if surfaces are not sufficiently flat or properly aligned, vibrations, noise, or improper load transfer may occur. Ensuring all these quality specifications is made possible through advanced inspection and measurement methods, among which 3D contactless scanning is particularly prominent. That method is becoming an essential tool for manufacturers who need an accurate dimensional inspection, virtual image, analysis, and even physical prototype manufacturing. This technology uses advanced software for accurate measurement, storage, analysis, which helps increase the process's flexibility and reliability [8]. Within this research, that was done using HandySCAN BLACK+™|Elite scanner and Creaform.OS software.

4 3D scanning process

The physical principle of contactless measurement is the precise positioning of points in space relative to a reference point, with the specific technology varying depending on the type of scanner. In the case of laser scanning, a coherent beam of light is directed onto the surface of the object. Part of the light is reflected back to the sensor, and by measuring the time it takes for the light to travel to the object and back, the distance of each individual point is calculated. Alternatively, in structured light methods, a predefined pattern—such as a grid or a set of parallel lines—is projected onto the surface of the object, and cameras record how the pattern deforms according to the object's shape. The three-dimensional positions of points are calculated based on an analysis of the deformed pattern. Depending on the scanner type, hybrid systems combining laser and optical methods are commonly used in industry to optimally balance data acquisition speed, accuracy, and resilience to unfavorable measurement conditions [9]. One of the most significant advantages of contactless scanning compared to contact-based technologies such as coordinate measuring machines (CMMs) is the ability to collect large amounts of data in a short time. While contact methods rely on a probe touching the object at predefined points, thus reducing the number of measurement points and limiting overall geometric coverage, contactless scanning can capture millions of points per second. This generates a so-called point cloud, a digital representation of the real object with very high resolution. In addition to speed, another major advantage is the ability to measure complex geometries, including surfaces that would be impossible or at least very challenging to inspect using contact-based techniques. Contactless measurement also reduces the risk of damaging delicate or soft materials, as there is no contact with a probing tool, and thanks to portable solutions, it can be performed outside laboratory environments, such as directly on the production line or in the field [10]. Of course, the method has its limitations. Highly reflective, transparent, or very dark surfaces can make it difficult to detect the reflected signal, resulting in reduced measurement quality and accuracy. In such cases, the object's surface is usually prepared by applying a thin matte spray layer, which reduces reflection and enables uniform optical readings. In addition, accuracy can be affected by changes in lighting, environmental vibrations, and temperature fluctuations [10]. Object preparation is typically the first step in the contactless 3D scanning process. The surface is cleaned of dust, oil, and other contaminants that could interfere with light reflection. As a last resort, reference markers, small adhesive dots, are applied; the scanner uses them to aid in orientation and to align individual scans. The next step involves calibrating the device using a calibration plate to ensure that the scanner's optical components and sensors are set to factory accuracy. The measurement device selected for the purposes of this paper is the Creaform HandySCAN BLACK+™|Elite, a handheld contactless 3D scanner as it presents one of the most advanced technologies currently available for optical measurement and digitization of complex geometries. This system is designed to provide optimal accuracy, portability, and ease of use in industrial environments, and is therefore used across various industries, most commonly in the automotive and aerospace sectors. It is a system that combines advanced laser technology, high precision, and user-friendly software, enabling accurate measurements even in demanding production conditions. HandySCAN BLACK+|Elite (Figure 2) works on the principle of laser scanning, where multiple laser lines are projected onto the surface of the object and simultaneously recorded by high-resolution cameras. The computer system then calculates the three-dimensional shape of the object from the distortion of these lines, generating a so-called point cloud. Each point in the cloud has its own spatial coordinates, and a million such points form a digital geometry that completely describes scanned object. The main advantage of the technology is that it can record data at very high speeds without sacrificing the amount of detail. According to official technical requirements, the device can achieve measurement accuracy of up to 0.025 mm. In addition to

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accuracy, the device is also characterized by repeatability, i.e. the ability to provide stable results when scanning the same object repeatedly [11]. The instrument is used in conjunction with its own software package, Creaform.OS, which provides an integrated platform for scanning control and data processing. The software is designed for an intuitive workflow, allowing users to inspect acquired data in real time and immediately identify any coverage deficiencies. Creaform.OS also includes several additional modules, such as "Inspect" for dimensional inspection of the object and "Model" for creating CAD models and preparing scanned data. The scanner is also used in reverse engineering applications where a digital model of an existing part needs to be recreated for which documentation is missing or outdated. The 3D scanning market today is characterized by a wide variety of available technologies and devices, from handheld portable scanners to static high-precision systems. Each of them has both advantages and disadvantages, and the choice of the most suitable solution always depends on the intended use, the desired accuracy and operating conditions.



Figure 2. HandySCAN BLACK+|Elite

5 Scanning execution

Scanning plan step by step:

- Connecting the scanner to the computer and configure the operational software.
- System calibration and adjustment of parameters according to the specifics of the measurement.
- Preparation of the object for digitization.
- Performing the scan and removing unnecessary parts of the model within the Scan environment.
- Refining and processing of the scanned data in the Model module.
- Generating the measurement report by comparing it with the existing CAD model using the Inspect tool.

Calibration of the scanner is simple and quick, and it is recommended to perform it before each new use of the device. Calibration is especially important after moving the scanner, for example, during road transportation by car, when significant vibrations may occur, or in situations where the working temperature changes by more than ±5 °C. The calibration of the HandySCAN BLACK+™|Elite scanner is carried out using the appropriate calibration plate (Fig. 3). Before beginning the scanning process, a detailed visual inspection of the object must be carried out to ensure that there are no unwanted materials or residues on the surface (such as tape, adhesive, strings, etc.) that could affect scanning quality. If necessary, the surface is further cleaned with approved degreasing agents.

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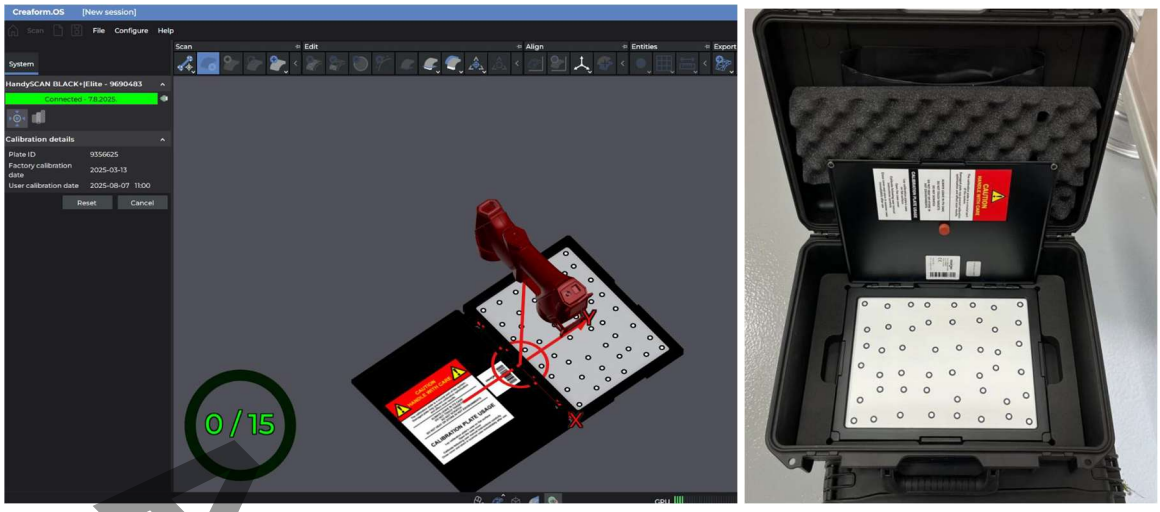


Figure 3. Calibration process

In cases where surfaces are problematic for scanning (e.g., shiny, reflective, or very dark), they may be treated with a matte spray. Reflective markers are placed on the object and, if needed, in its immediate surroundings. These markers are specially designed for Creaform scanners and cannot be substituted with alternatives. The software automatically detects and calculates the positions of the markers, so their use does not compromise the final measurement results. When placing the markers, certain rules must be followed: the distance between two markers must not exceed 10 cm, they should not be placed on transitions between different geometric shapes, and their arrangement in a straight line should be avoided [11]. Failing to follow these guidelines may create a virtual axis of rotation, which can cause errors during digitization. Once the object has been correctly prepared and marked, it is ready for scanning. Figure 4 shows prepared object, and scanned result. The scanner is connected to the computer using a combined cable that provides both power and data transfer via a USB 3.0 interface. The maximum permitted cable length is 16 m, which offers sufficient flexibility during operation. In situations where the user is far from the computer screen, it is recommended to use a tablet for screen mirroring.

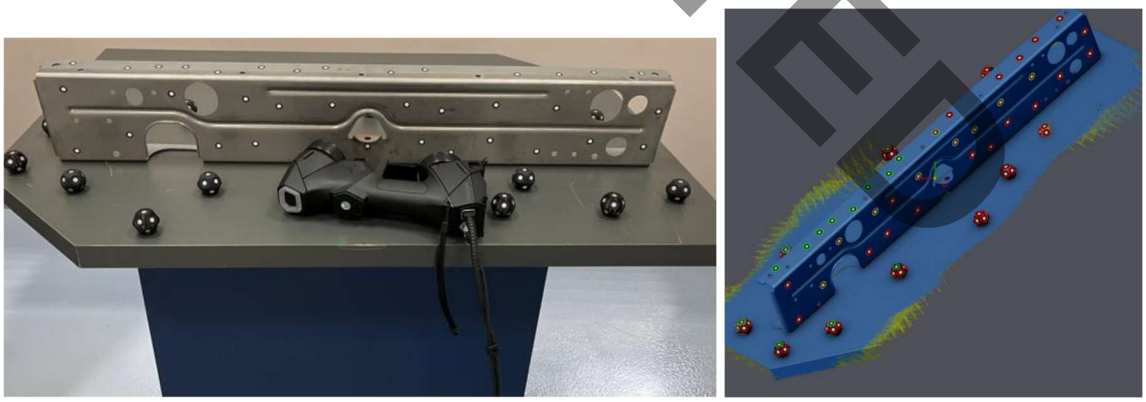


Figure 4. Prepared and marked object for scanning, and result

Before launching the “Inspect” module, the CAD model of the scanned object must be imported into the software. Based on this, the software automatically performs alignment using the “Best Fit” method and generates a deviation map relative to the CAD model (Fig. 5).

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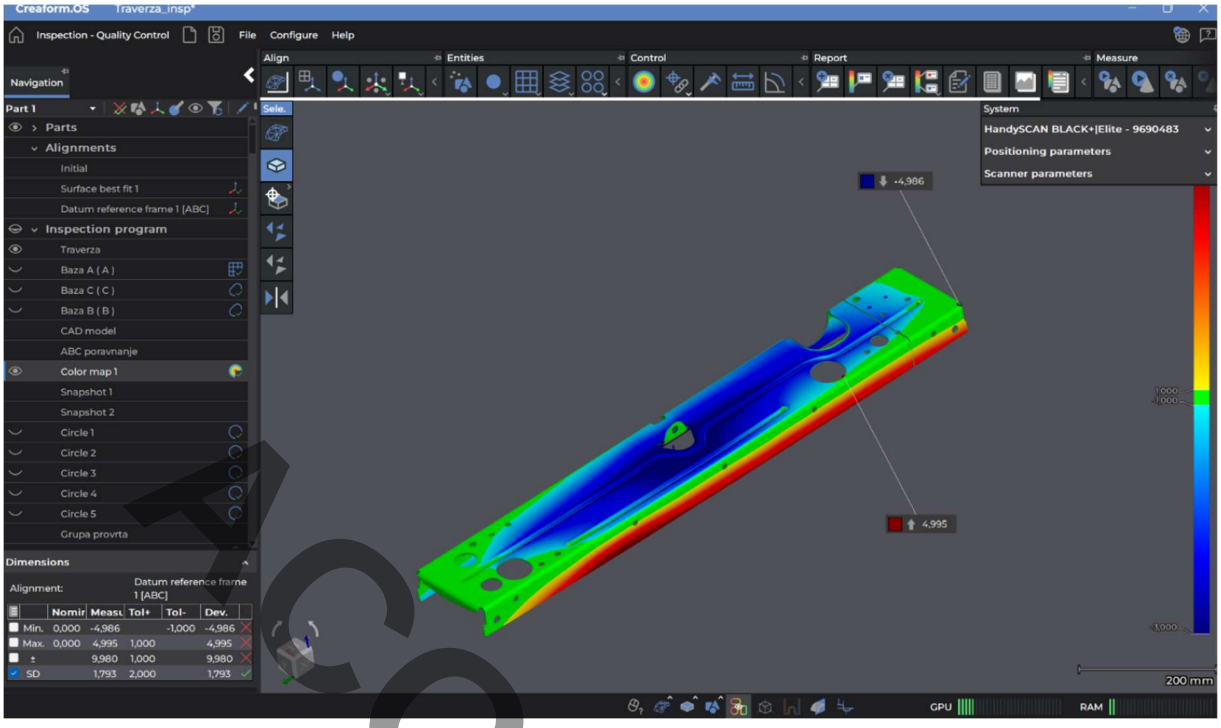


Figure 5. Colormap and Best Fit options in software

In the tables generated by the measurement report, it is possible to see the deviations relative to the measured value and the specified tolerance. An example extracted from the measurement report is shown in Fig. 6. For instance, in Fig. 6, one of CAD model the dimensions in the X direction has a nominal value of –78.650 mm, while the measured value is –78.685 mm, which represents a deviation of –0.035 mm. Since the tolerance range is ±1.0 mm, it is clear that this dimension is within the allowable limits. In addition to the tabular results, the measurement report also provides a color-coded visual representation, in a manner where each color represents a specific level of deviation. The second part of the report provides a detailed analysis of the holes on the crossmember. For each opening, the measured values were compared with the nominal dimensions of designed CAD model. Most of the measured values deviate from the CAD model by 0.1 mm to 0.5 mm, which is considered a very good result, as it remains within the specified tolerance range. Fig. 7 shows one group of holes.

Baza C (C)
Alignment: Surface best fit 1

Dimensions	Tolerance	Nominal	Measured	Deviations	Tendency	Out of tol.
X	±1,000	-78,650	-78,685	-0,035		
Y	±1,000	-240,000	-239,949	0,051		
Z	±1,000	60,000	60,017	0,017		
Length	±1,000	55,000	55,131	0,131		
Width	±1,000	49,000	49,055	0,055		

Figure 6. Part of measurement report - tabular results

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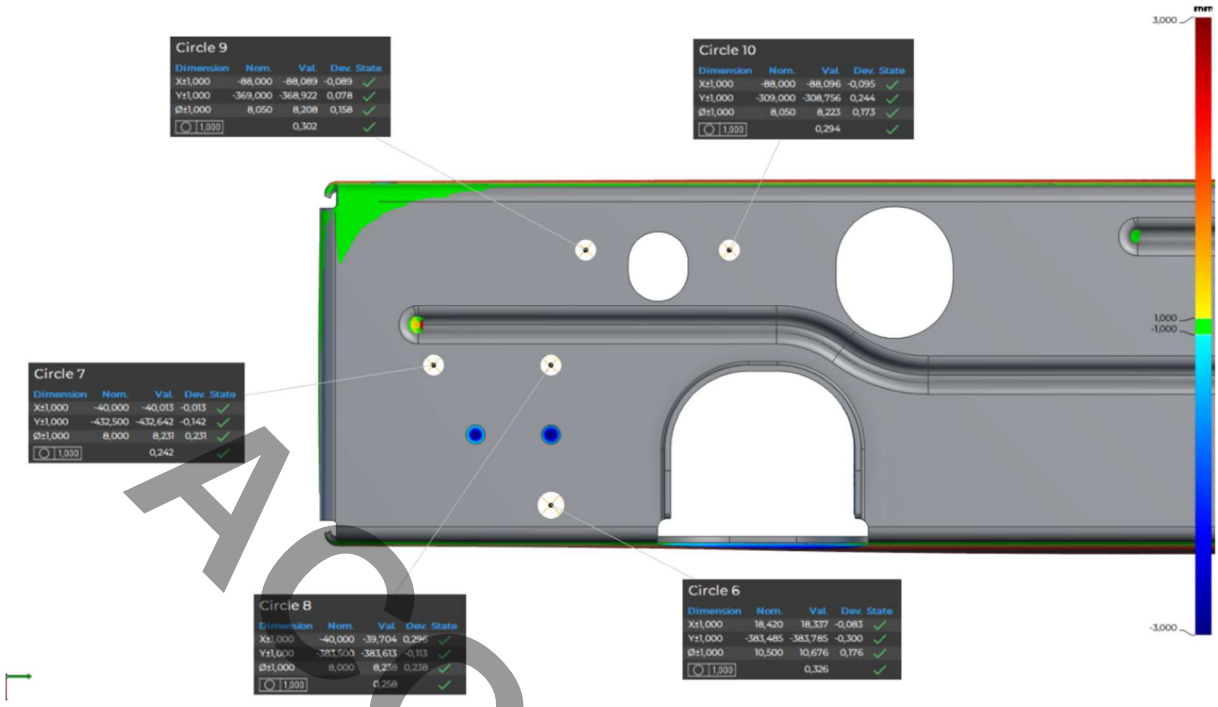


Figure 7. Part of measurement report - holes

It is necessary to highlight one exception — the hole marked as "Circle 11", for which a deviation of –2.617 mm was recorded in the Z-axis (Fig. 8 and Fig. 9). This means that the measured value was significantly lower than the nominal value and lies outside the prescribed limits.

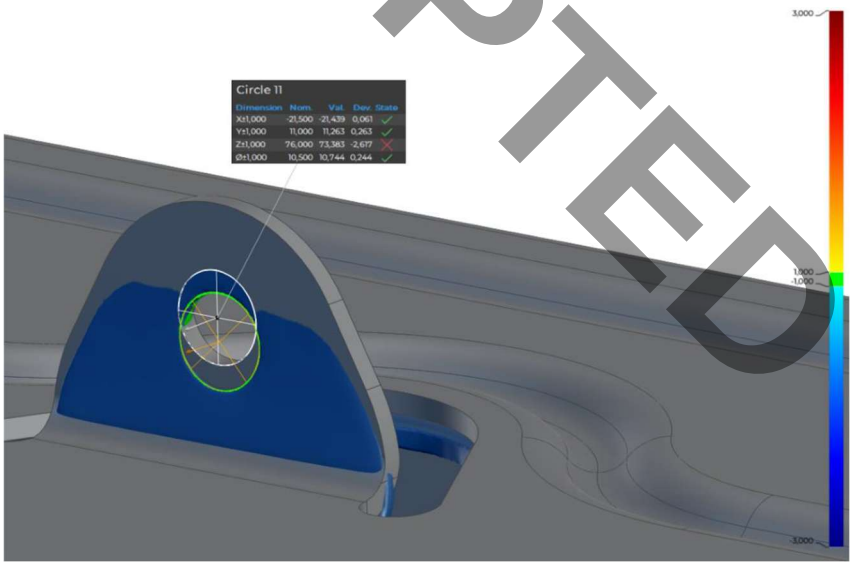


Figure 8. Part of measurement report - one hole

Circle 11
Alignment: Datum reference frame 1 [ABC]

Dimensions	Tolerance	Nominal	Measured	Deviations	Tendency	Out of tol.
X	±1,000	-21,500	-21,439	0,061		
Y	±1,000	11,000	11,263	0,263		
Z	±1,000	76,000	73,383	-2,617		-1,617
Ø	±1,000	10,500	10,744	0,244		

Figure 9. Part of measurement report- tabular result

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This result may indicate a manufacturing nonconformity. In any case, this is the only point on the scanned crossmember that shows a deviation outside the acceptable range, while all other holes met the requirements.

Such a finding in practice is important because it indicates the need for additional or eventual control correction in the production process. The third section of the report refers to the cross-section and length measurements, where the deviations are also very small. Fig. 10 shows that the measured value deviates by –0.744 mm from the nominal value, which lies within the permitted tolerance of ±1 mm.

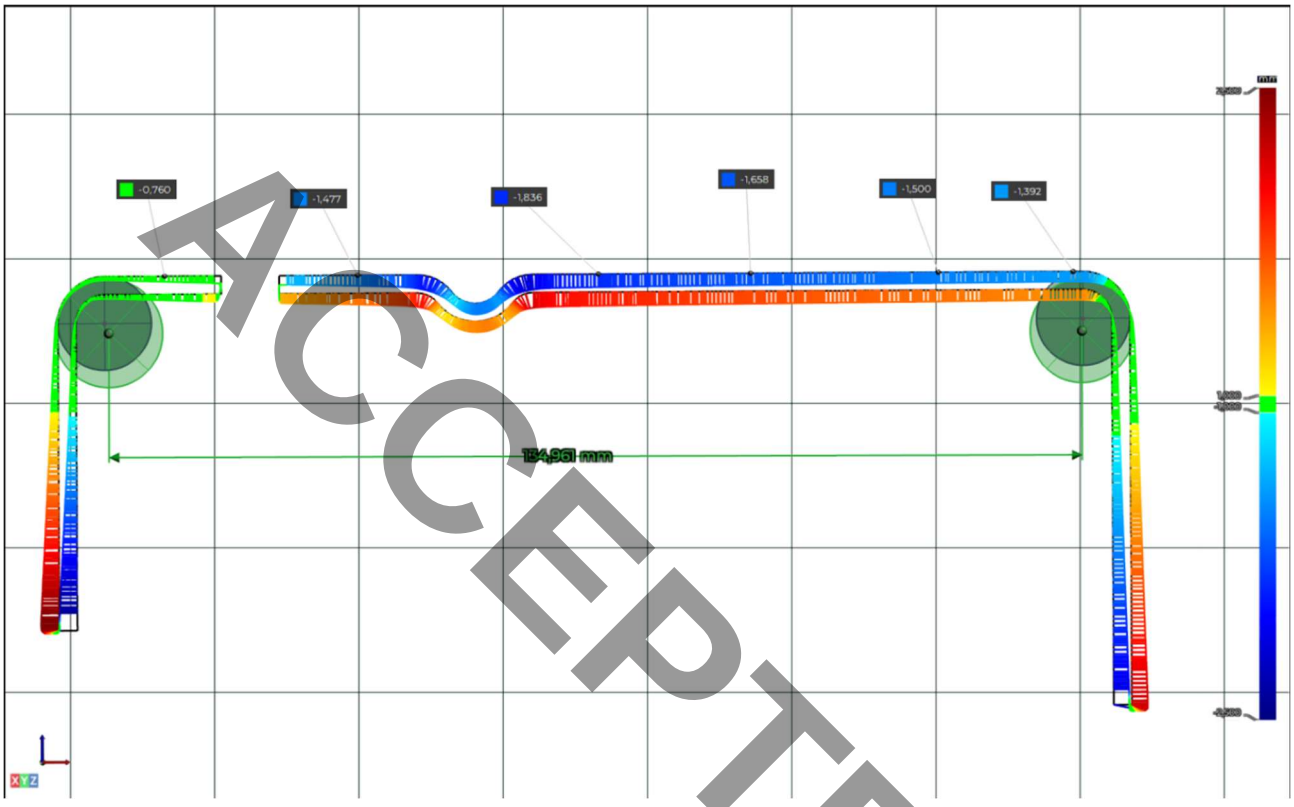


Figure 10. Part of measurement report- cross-section

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6 Conclusion

This paper has described the application of non-contact 3D measurement in industry, specifically the use of the portable Creaform HandySCAN BLACK+™|Elite scanner for measuring the dimensions of an automotive crossmember. The paper provided the theoretical background of optical 3D measurement, the development of the technology, a comparison with conventional measurement methods, and an example of scanner application in a real industrial case. The conducted research showed that non-contact measurement offers numerous advantages over traditional contact methods. First, it enables very fast and accurate data acquisition, producing a three-dimensional representation of complex geometries in a short period of time that faithfully replicates the original object. In addition, the measurement process is highly flexible because it can be performed directly in the workshop, without the need to move parts to a laboratory. This simplicity and mobility make portable scanners extremely suitable for industrial applications where speed and efficiency are key factors. The experimental phase of the study, in which the automotive crossmember was scanned and compared with the CAD model, served to confirm the practical value of this method. The measurement report provided a clear overview of deviations, showing that some local discrepancies were within the allowable limits, while others revealed potential production non-conformities. This demonstrated that the method is more than a tool for documenting geometry; it is also an instrument for quality control and reliable decision-making within the production process. A particularly important part of the measurement report are the visual representations in the form of color-map analyses. These show the distribution of deviations across the entire surface of the scanned object relative to the CAD model. Green indicates areas where the measured values fall

within the allowed tolerances, while red and blue indicate positive and negative deviations, respectively. For the scanned crossmember, most of the surface appears in green, confirming that dimensions of manufactured item correspond to the dimensions of nominal model CAD model in majority. Deviations are concentrated only in a small number of local areas, which is visible in the visual representations and confirmed by the numerical data in the tables. All key parameters fall within the allowed tolerances, except for one hole that shows a more significant deviation. Despite its high level of development, non-contact measurement still presents certain limitations. Transparent surfaces require additional preparation, and environmental conditions such as lighting or vibrations can affect the quality of the results. However, with proper object preparation (e.g., applying a matte spray) and correct use of the scanner, these drawbacks can be effectively minimized. In conclusion, it can be stated that non-contact 3D measurement is a technology that plays a significant role in modern industrial processes. As demonstrated in this work, the method significantly reduces the time required for inspection compared to classical methods, while simultaneously providing greater accuracy and consistency of results. In the future, further development and refinement of optical 3D technologies can be expected, enabling even faster and more precise inspection of complex products in real production conditions. Grounded in the outcomes of this research, it is reasonable to assume that these technologies will become a standard in industry, particularly in sectors such as the automotive industry.

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