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Issue Article

SOI: 1.1/TAS DOI: 10.15863/TAS

International Scientific Journal

Theoretical & Applied Science

p-ISSN: 2308-4944 (print) **e-ISSN:** 2409-0085 (online)

Year: 2026 **Issue:** 02 **Volume:** 154

Received: 26.02.2026
Accepted/Published: 28.02.2026

https://T-Science.org

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QUALITY OF ELECTRONIC MODELS OBTAINED BY 3D SCANNING OF HOUSING PARTS

Abstract: *This article presents an analysis of the results of 3D scanning of metallic and plastic housing parts of various configurations. Electronic models of housing parts were demonstrated after laser 3D scanning with an accuracy of 0.5 mm using the "Creality CR-Scan Raptor Pro" scanner. Artifacts were identified in general views of the point cloud and analyzed in more detail in electronic models of the parts after merging. Scanning small elements on housing parts, such as blind holes, is associated with inaccuracies in their formation on electronic models.*

Key words: *3D scanning, housing, cover, model of the part, artifact, element.*

Language: *English*

Citation: Chemezov, D., et al. (2026). Quality of electronic models obtained by 3D scanning of housing parts. *ISJ Theoretical & Applied Science, 02 (154),* 67-74.

Soi: https://s-o-i.org/1.1/TAS-02-154-11 ***Doi***: crossref https://dx.doi.org/10.15863/TAS.2026.02.154.11

Scopus ASCC: *2209.*

1. Introduction

3D scanning is a non-contact process of collecting data about the shape, size, and texture of a physical object to create an electronic model of it. The technology enables the transformation of real-world objects into point clouds, which are then processed in specialized software packages to produce polygonal meshes or CAD models.

3D scanning features high accuracy, fast data processing, and detailed surface imaging, enabling the creation of accurate electronic models for applications such as reverse engineering, quality control, and product design. Challenges in obtaining electronic models include working with reflective or transparent surfaces that can distort scan results, producing complex geometric shapes with high detail, and managing large data sets that require significant computing power. Additionally, ensuring proper alignment, calibration, and minimizing noise and errors during scanning are critical to creating reliable electronic models.

The issue of optimizing the quality of 3D scanning of parts of various configurations has been deeply analyzed in the scientific literature. For example, in [1] the authors discuss the use of 3D scanning and reverse engineering methods to improve quality control in the manufacturing of quick response products. The paper highlights the benefits of integrating 3D scanning into the manufacturing process to improve product quality, reduce errors, and shorten inspection times, ultimately leading to greater efficiency and reliability of manufacturing processes. The article by Kus, Unver and Taylor [2] presents a comparative analysis of 3D scanning technologies used in engineering, product design, transportation and fashion design education. The study evaluates the effectiveness, benefits and limitations of different scanning methods across disciplines, highlighting their potential to transform educational practice and design workflows. The article by Fabian and Kupec [3] discusses the application of 3D parametric models in the design process of automotive components and highlights how these models improve design flexibility, accuracy and efficiency. The study [4] is devoted to the application of optical 3D scanning technology in the automotive industry, highlighting the process of its implementation, advantages and potential for improving production processes, quality control and design. Ameen, Al-Ahmari and Mian [5] assessed the performance of portable scanners in the automotive industry. The authors analyzed their accuracy, usability, and potential benefits for tasks such as vehicle inspection, quality control, and maintenance. The article by Lazarević et al. [6] presents the use of 3D scanning technology for optical inspection of cutting parts. The authors highlight the benefits of detailed surface analysis and rapid data collection to improve inspection procedures and ensure higher standards in the production of cutting tools and parts. In the article [7] the authors analyze the practical and technical aspects associated with 3D scanning of stone artifacts using micro-computed tomography and laser scanners aimed at simplifying geometric morphometric analysis. In the paper by Asicioglu et al. [8], a new 3D scanning-based image processing method is presented to accurately measure the sequence of intersecting lines. This method uses advanced 3D visualization to improve the accuracy and reliability of linear measurements in complex intersecting structures, addressing challenges faced by traditional 2D methods. A new method for rapid identification of individual aluminum cast and wrought alloys using a 3D scanning laser-induced fracture spectroscopy system was demonstrated in [9]. Little, Patterson, Moyle and Bec [10] explore the use of 3D scanning technology to preserve and display cultural heritage artefacts digitally, turning them into interactive experiences.

Based on the conducted a priori analysis of scientific sources, it can be noted that there are gaps in the research on the comparison of the quality of electronic models of housing parts obtained by 3D scanning of physical housing parts made of different materials. Thus, the quality analysis of two CAD models of vehicle components after 3D laser scanning was carried out. The novelty of the study is the presentation of the quality of the geometry of various elements of the models of housing parts obtained by 3D scanning of physical parts made of metal alloy and plastic.

2. Materials and methods

2.1. Description of housing parts

Two housing parts, cast from different materials, were subjected to 3D scanning. General views of the parts are shown in the Figures 1 and 2.

The Figure 1 shows the housing of an internal combustion engine made of aluminum alloy. The part has a complex shape with many holes, protrusions and internal cavities. The part shows several blind holes, one of which contains a ball bearing. Inside the semicircular part of the housing there are cast stiffeners and fasteners. There are two through cylindrical holes in recesses of the housing. On the left you can see a cylindrical part with a threaded connection and several holes around the perimeter, intended for fastening or connecting to other parts. On the right, the housing has an open, semi-circular shape with an uneven edge, where there are also holes. On the left side of the part, a protruding element with a square hole is visible. The large surface area of the part has a rough texture typical of casting. Machined surfaces are designed to ensure precise connection of the housing with the mating parts. The housing surfaces are engraved with the manufacturer's logo. To qualitatively assess the dimensions of the housing, some elements of the part were measured with an electronic caliper with an accuracy of 0.01 mm, and numbers from 1 to 11 were applied with a marker near these elements:

- position No. 1 is hole with a diameter of 61.9 mm;
- position No. 2 is hole with a diameter of 35.51 mm;
- position No. 3 is oval hole of 44.65 mm long and 23.23 mm wide;
- position No. 4 is hole with a diameter of 25.81 mm;
- position No. 5 is hole with a diameter of 51.71 mm;
- position No. 6 is hole with a diameter of 27.91 mm;
- position No. 7 is hole with a diameter of 19.87 mm;
- position No. 8 is hole with a diameter of 15.88 mm;
- position No. 9 is hole with a diameter of 61.05 mm;
- position No. 10 is hole with a diameter of 20.04 mm;
- position No. 11 is hole with a diameter of 68.78 mm.

Figure 1. Views of internal combustion engine housing made of aluminum alloy by casting.

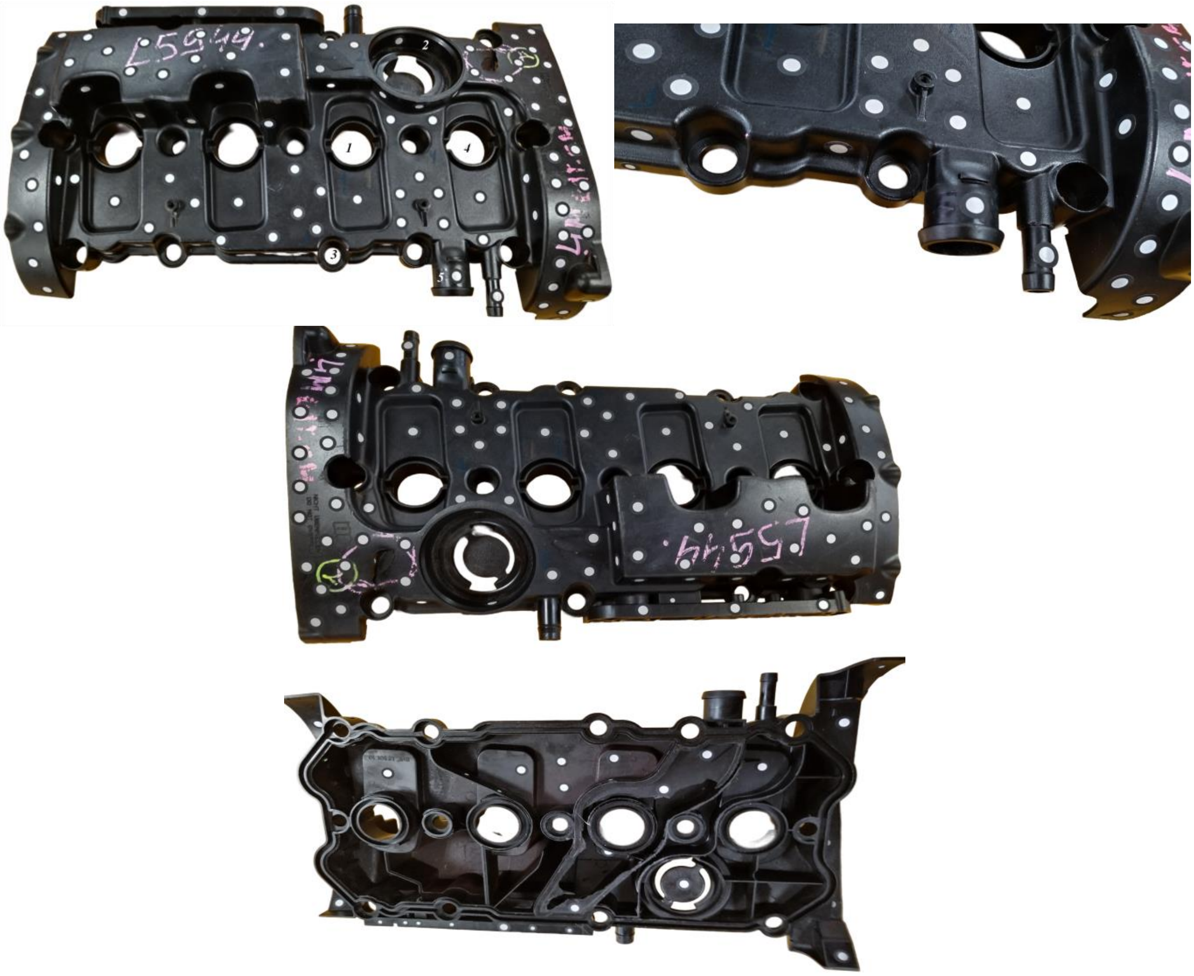

Figure 2. Views of plastic valve covers for car internal combustion engine.

The Figure 2 shows a black plastic valve cover for a car's internal combustion engine. The part has a complex shape with many holes of different diameters intended for spark plugs, coils or other components. A sealing contour is visible around the perimeter of the part, ensuring tightness. To the right of the center, there is a large round hole on the cover. Below it is four smaller round holes, which are also visible along the entire length of the cover. The bottom of the cover has various small cylindrical parts and holes protruding from it. On the top side of the part there are two cylindrical protrusions, and along the edges there are fastening elements. A small plastic pipe is visible at the top, which can be used for ventilation or connecting hoses. There are also small plastic tubes or fittings that can be used to connect to the crankcase ventilation system or other engine systems. The cover surfaces are engraved with the manufacturer's logo and the product's serial number. As in the case of the housing, several elements of the cover were measured with a similar measuring tool and numbers from 1 to 5 were applied with a marker near these elements:

- position No. 1 is hole with a diameter of 31.28 mm;
- position No. 2 is hole with a diameter of 65.75 mm;
- position No. 3 is hole with a diameter of 19.65 mm;
- position No. 4 is hole with a diameter of 18.14 mm;
- position No. 5 is hole with a diameter of 21.56 mm.

2.2. Preparing for 3D scanning of parts

Round markers of different sizes were glued to both parts. Markers serve as physical reference points for the scanner in hard-to-reach areas of parts, ensuring precise positioning and data alignment. The total number of markers glued to the aluminum alloy internal combustion engine housing was 166 pieces, and for the plastic valve cover of the car's internal combustion engine was 149 pieces.

The 3D scanning process was carried out using a "Creality CR-Scan Raptor Pro" handheld 3D scanner. The accuracy of 3D scanning of parts is adopted as 0.5 mm, since the products are large-sized. Data processing during and after 3D scanning was performed using the "Creality Scan 4" software package.

3. Results and discussion

The statistical data of the 3D scanning process of the aluminum alloy internal combustion engine housing and the plastic valve cover of the car's internal combustion engine include 19,688 and 33,286 frames, 1,357,859 and 849,992 points, respectively.

The Figure 3 shows point clouds of scanned housing parts. Each point cloud is shown in blue and orange. The main part of the point cloud is colored blue, which indicates good quality of the 3D scan (compliance with the nominal dimensions of the physical housing part). Artifacts (unwanted distortions, defects or extraneous data in the electronic model that do not correspond to the real object) are highlighted in orange areas. It was noted that the point cloud after scanning the internal combustion engine housing made of aluminum alloy has fewer artifacts and almost all of them were identified in small diameter blind holes. For the point cloud of a plastic valve cover of the car's internal combustion engine, the distortions are more defined in the pockets on the back of the part and near the bosses on the top of the part.

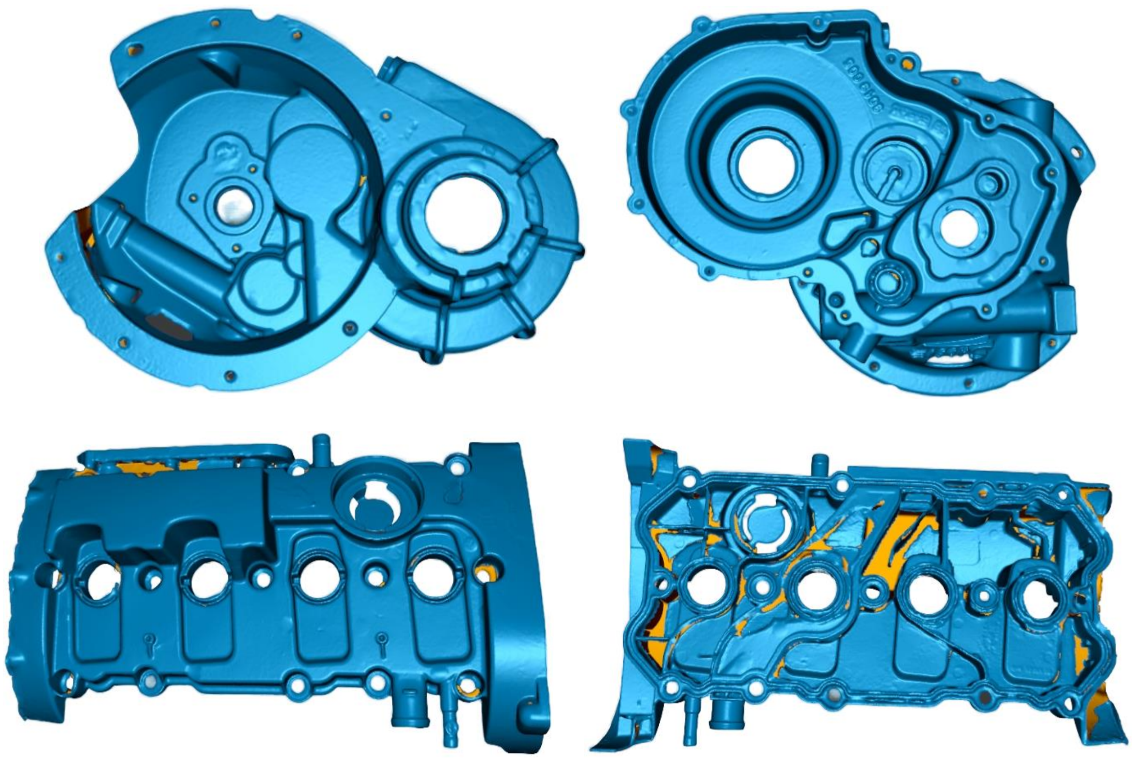

Figure 3. Point cloud views of electronic models of the aluminum alloy internal combustion engine housing (top) and the plastic valve cover of the car's internal combustion engine (bottom) after 3D scanning.

The next stage of obtaining an electronic model is post-processing, which included primary processing (cleaning, noise filtering and alignment), creation of a polygonal mesh, i.e. connecting points together to form triangles. The mesh is generated on the models and empty areas are filled. The solid model is obtained in STL format by converting a polygonal mesh. The Figures 4 and 5 show the results of creating solid-state electronic models of parts with a grid triangle count of 3,614,854 pieces for the internal combustion engine housing made of aluminum alloy, and 2,138,321 pieces for the plastic valve cover of the car's internal combustion engine. The results in the figures are presented as general views of the housing and cover models with detail views of artifacts, enlarged several times to display the distortions in detail.

For the internal combustion engine housing model, a number of holes and pipe were considered. Deviations of holes from the nominal dimensions in diameter and depth are noted. The cause of these defects is “geometric shadow”. The build-up in the pipe hole appeared as a result of “reflection” (glare), since the part has a metallic sheen.

For the plastic cover model, connecting and fastening elements on various surfaces were considered. The geometry of pipes, fittings and shallow cylindrical recesses was obtained satisfactorily. On the lateral surface of the boss, the boundaries of the elements merge. On the lower part of the cover model, in the pocket, the geometry of elements is significantly distorted. The shaped geometric element on the side was not fully scanned, the boundaries are blurred.

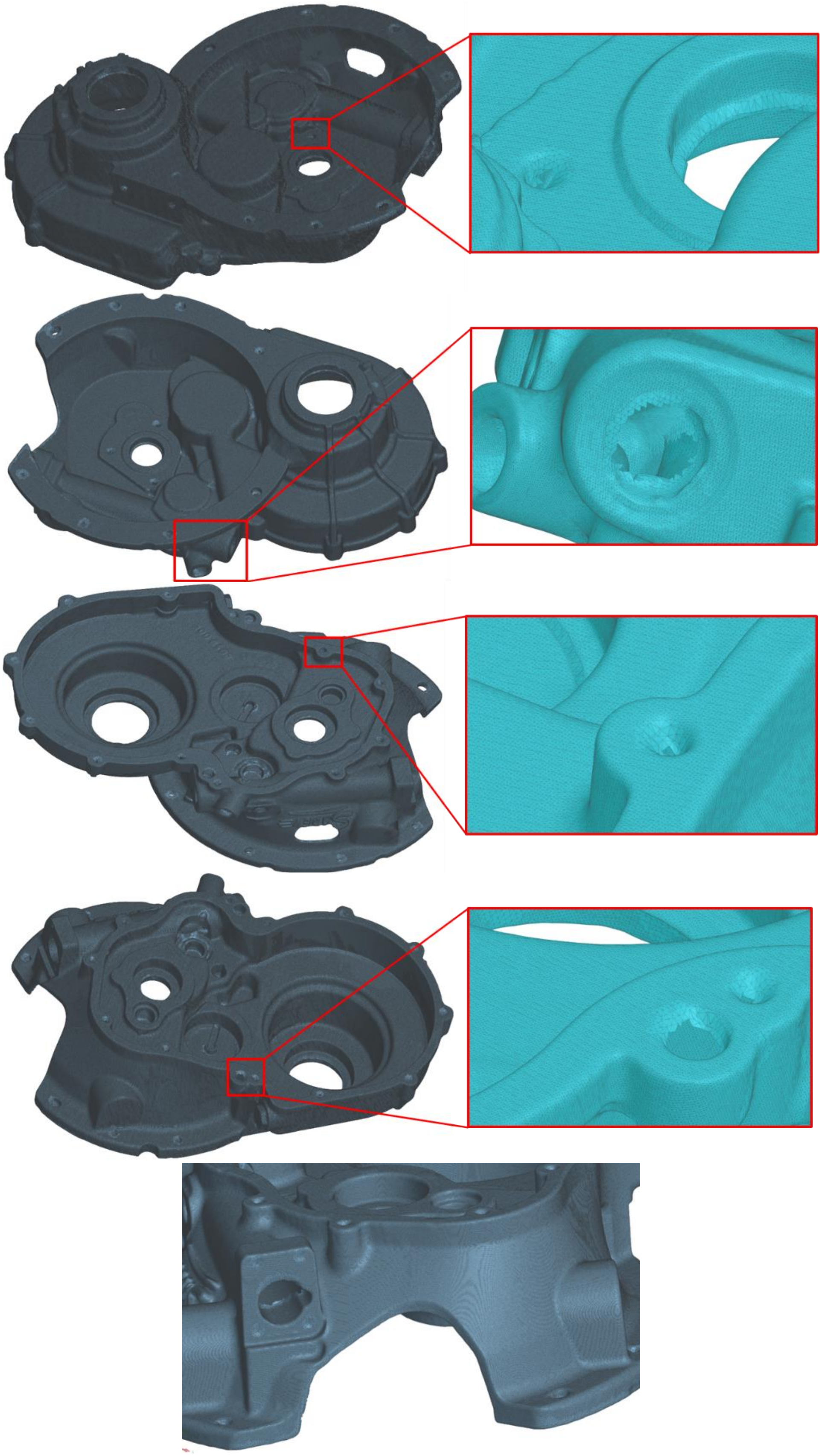

Figure 4. Views of the electronic model of the internal combustion engine housing made of aluminum alloy after merging.

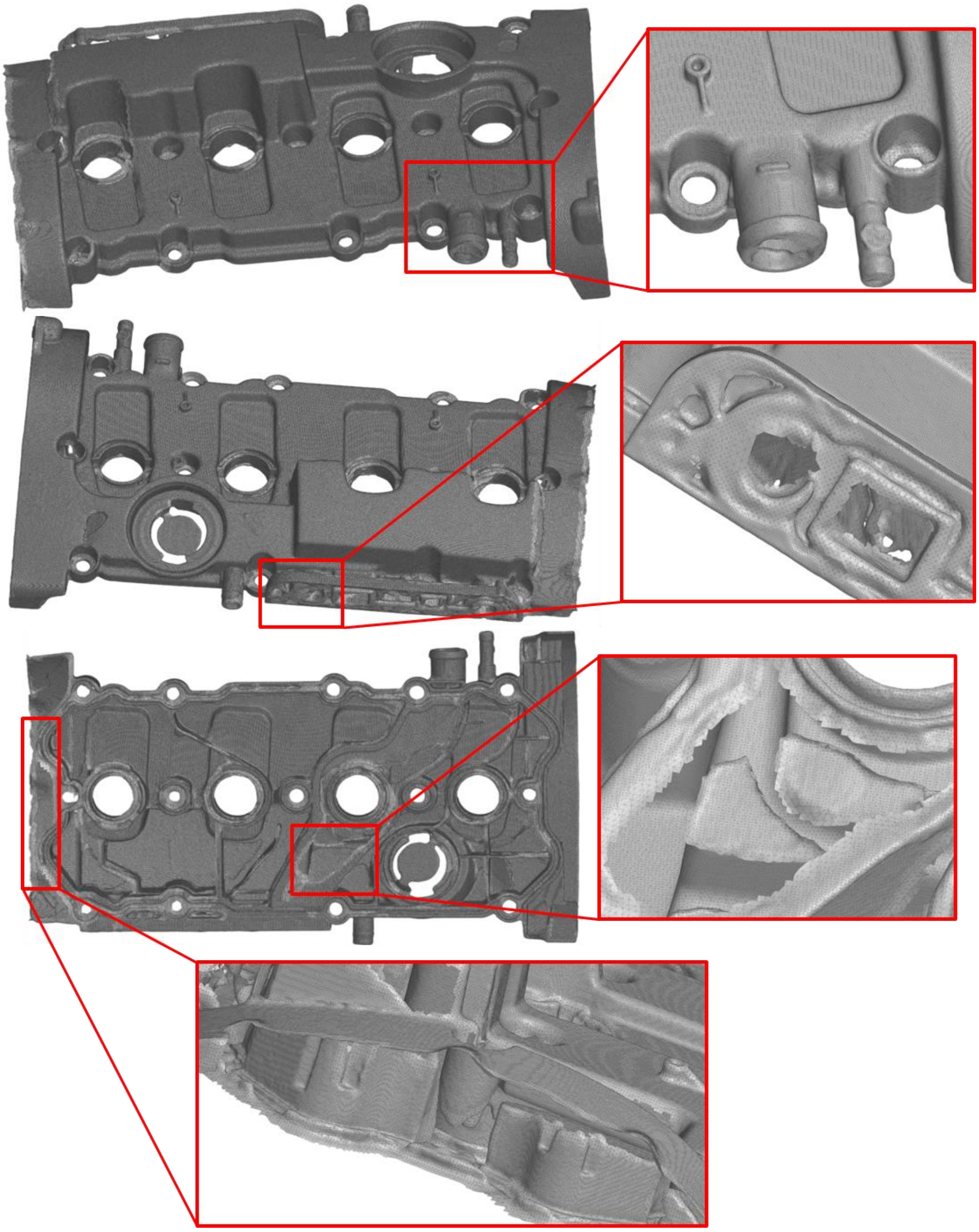

Figure 5. Views of the electronic model of the plastic valve cover of car's internal combustion engine after merging.

Comparing the quality of the generated electronic models of parts, it can be concluded that metal parts are more optimal in the 3D scanning process for obtaining high-quality CAD model geometry than matte plastic parts.

4. Conclusion

The labor intensity of creating large-scale, complex models of parts is reduced through the implementation of 3D scanning technologies. This is especially important for functionally significant components of vehicles.

The study's results revealed problems with 3D scanning of matte plastic parts, including a large number of artifacts in hard-to-reach areas. The electronic model of the aluminum housing was obtained with fewer artifacts (mainly in small diameter blind holes).

To improve the quality of the electronic model geometry, it is recommended to create more point clouds during 3D scanning and increase the number of markers on the scanned physical part.

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