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Dimensional accuracy of camera casing models 3D printed on Mcor IRIS: A case study

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A B S T R A C T

The main objective of this research was to determine the deviations and evaluate the dimensional accuracy of 3D printed camera casing models compared to the original models in the STL format. The study sample consisted of the 3D printed camera casing models and the same models in the STL format. The STL format came from Mcor in a set of sample models shipped with the 3D printer. The models were 3D printed on Mcor IRIS and then scanned with ATOS 3D scanner. A comparison between the scanned and original STL models was made in the GOM Inspect software. The results indicate that the maximum deviation occurred on the scanned front camera cover and it is 0.82 mm in the direction z. The average deviation of scanned front camera cover is 0.0845 mm and the average deviation of scanned back camera cover is 0.0722 mm. The analysis of the results proves that the three-dimensional printed paper-based parts have the dimensions close to the original CAD models.

A R T I C L E   I N F O

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1. Introduction

One of the most important specifications of three-dimensional printing machines is the ability of a machine to print accurate parts in comparison to the designed models. The dimensional accuracy of a component part represents the degree of agreement between the manufactured dimension and its designed specification. According to current dimensioning and tolerating standards, the dimensional accuracy of a part is evaluated through its size and shape by changing the printing parameters [1]. The determination of dimensional accuracy is the topic of many researches, which is evident in the number of published papers [2-9]. The main material in this research used for printing parts is paper. Paper is subject to the influence of humidity. Furthermore, paper can absorb glue potentially causing the paper parts to shrink and change dimensions. The question is whether the paper based parts that absorb moisture and glue can have considerable dimensional accuracy compared to the original model. Therefore, determining the deviation between the paper based parts and the original STL model is the main objective of this research.

2. Method

The dimensional accuracy of 3D printed camera casing is evaluated in a few steps:

1. Printing of 3D models of camera casing,
2. Scanning of 3D models of camera casing,
3. Determination of deviation between the original STL and 3D printed models of camera casing.

The camera casing models are one of the samples shipped with the 3D printer. Model is delivered as an STL file and is considered as a reference model for further analysis. The 3D printer used in this research was model Mcor IRIS, product of Mcor Technology. It is a 360° high definition color paper-based printer, that uses standard A4 format paper (80 g/m^2) as building material [10]. The STL models were aligned and prepared in the printer software SliceIT, version 6.6.02. The aligned STL camera casing model in SliceIT is shown in Fig. 1. After that, the camera casing was 3D printed. The printed models were composed of 134 built layers. Time needed for printing was 5h 51' 35''. The 3D printed models of camera casing are shown in Fig. 2. Moreover, the printed models were measured with digital caliper Lux Profi model 572587, with the measurement range 1-150 mm and accuracy 0.01 mm. The measured dimensions on the front camera cover are shown at Fig. 3 i.e. on the back camera cover at Fig. 4.

After 3D printing, the camera casing models were stored inside the plastic bag in order to avoid the influence of humidity on dimensions. Furthermore, the models were kept inside the firm paper box to avoid any mechanical damage during transportation.

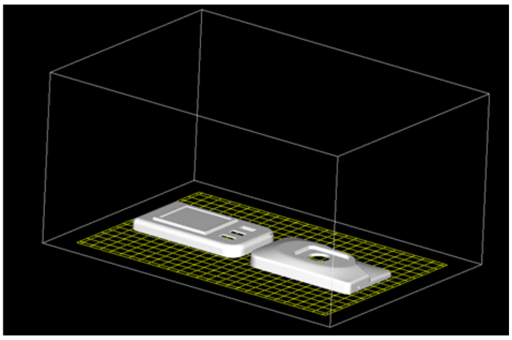

Fig. 1 STL models of camera casing aligned in Slice-IT

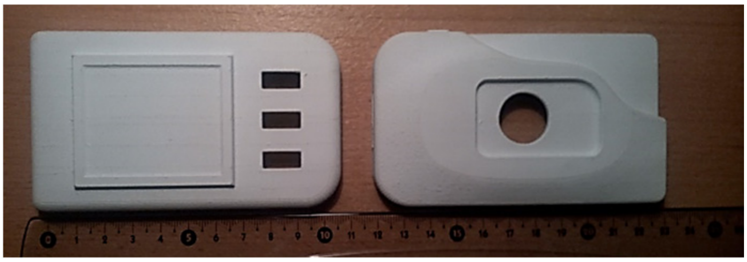

Fig. 2 3D printed models of camera casing

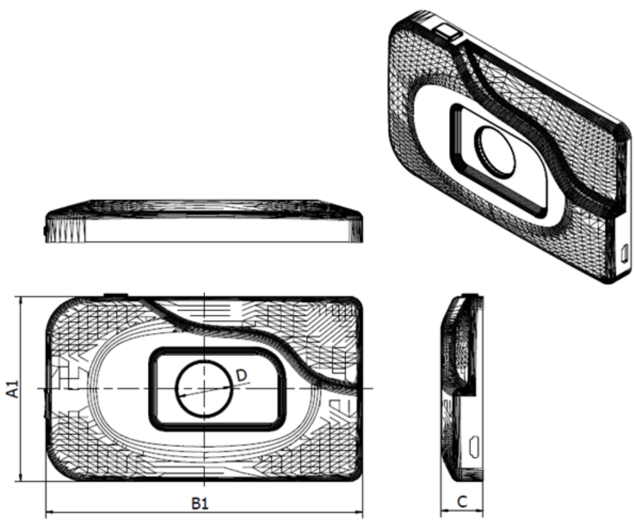

Fig. 3 Measured dimensions of original front cover

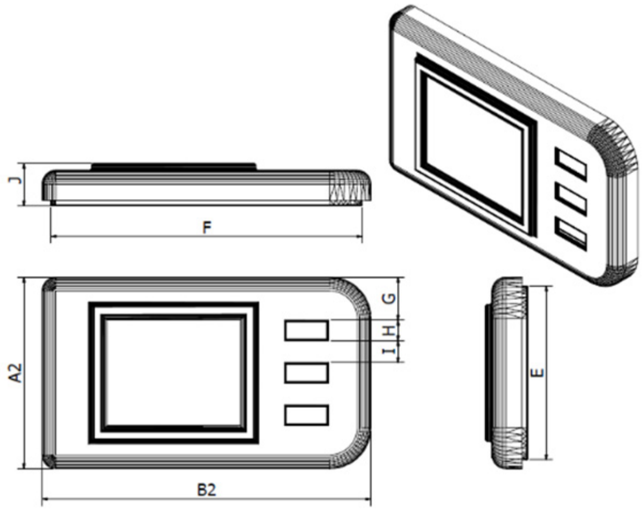

Fig. 4 Measured dimensions of original back camera cover

The printed models were scanned with 3D scanner ATOS Compact Scan 2M, product of GOM company, similar to those used in [11]. The parameters of ATOS Compact Scan 2M are as follows: Camera Pixels – 2 × 2 000 000, Measuring Area from 35 × 30 up to 1000 × 750 mm (model dimensions: 108 x 63 x 14.4), Point Spacing – 0.021-0.615 mm, Working Distance – 450-1200 mm [12]. The printed camera casing was scanned and two models were obtained, the first one for the front cover and the second for the back cover. For easier comparison, the original single STL file of camera casing was separated in two files, the original front cover and the original back cover. The camera casing was separated in Autodesk Meshmixer software, version 10.9.297 [13]. Details of original, scanned and printed front cover are shown side-by-side illustrating clearly visible deviations in Fig. 5.

Furthermore, the scanned parts and the original STL parts, the front and back covers were compared in GOM Inspect software, version 8.0 [14]. In GOM Inspect, the maximum, minimum and average deviations were obtained. The original STL and scanned camera casing aligned in GOM Inspect are presented in Fig. 6. The original STL model is marked with blue color and the scanned model is marked with grey color. Obtaining the dimensions of original camera case was conducted in Autodesk Inventor 2015 using add-in Mesh Enabler version 1.0.4. Using Mesh Enabler, the STL mesh model was changed to a solid model. Fig. 3 presents the measured dimensions of original front camera cover, while the measured dimensions of original back camera cover are shown in Fig. 4. The values are listed in Table 1.

Fig. 5 Detail of original (left), scanned (middle) and printed (right) front camera cover

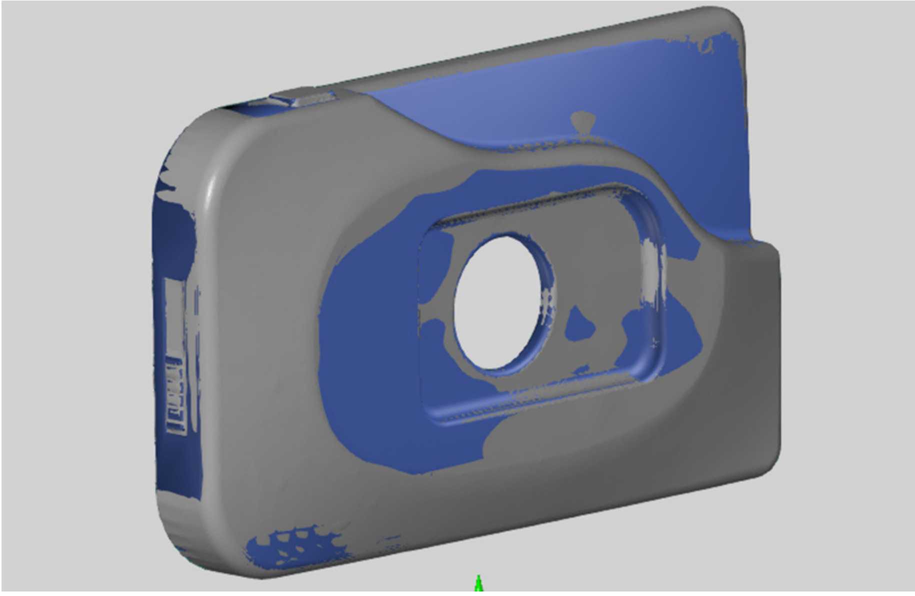

Fig. 6 Original STL (blue) and scanned front cover (grey) aligned in GOM Inspect

3. Results

The measurement results of the camera case are presented in Table 1. The nominal value of dimensions and common statistical calculated values are presented in table rows, grouped by measured dimensions. Calculated values are: arithmetic mean ($\bar{x}$); standard deviation (S); relative standard deviation (RSD); average error (Δx). The relative standard deviation adequately expresses the precision of a particular experiment combination regarding the measured dimensions. It is the absolute value of the coefficient of variation, usually expressed as a percentage and calculated by:

$$RSD = \frac{S}{\bar{x}} \cdot 100 \tag{1}$$

Table 1 Camera case measurements for controlled dimensions

	A1	B1	C	D	A2	B2	E	F	G	H	I	J
Nominal value	63	108	14.4	18	63	108	57.24	102.24	14.58	5.85	8.1	13.95
$\bar{x}$	63.1	108.06	14.46	17.94	62.98	108.05	57.22	102.24	14.49	5.94	8.11	13.58
S	0.045	0.107	0.108	0.133	0.031	0.031	0.041	0.046	0.058	0.018	0.029	0.017
RSD, %	0.072	0.099	0.747	0.742	0.049	0.028	0.071	0.045	0.397	0.302	0.354	0.126
Δx	0.10	0.06	0.06	0.06	0.02	0.05	0.02	0.00	0.09	0.09	0.01	0.37

If average error for every measured dimension on camera case are presented in a single chart, it can be noticed that the "J" dimension have significant average error compared to other dimensions (Fig. 7).

A comparison of the original STL file containing the front and back camera covers with the 3D scanned models produced on the 3D printer provided the resulting deviations for the analysis. The dimensions of original camera casing from the STL files are authoritative, considered as a reference geometry for the evaluation. The deviations with positive values mean that the scanned model is above the surface of original model and the negative deviation values are under the surface of original model. The colors on the 3D scanned model show the distribution of deviation starting with the green color for the deviations near the zero value. As deviations get more positive, the model colors are yellow, followed by red for the maximum positive value. As deviations get more negative, the colors of model are cyan, followed by blue for the maximum negative value.

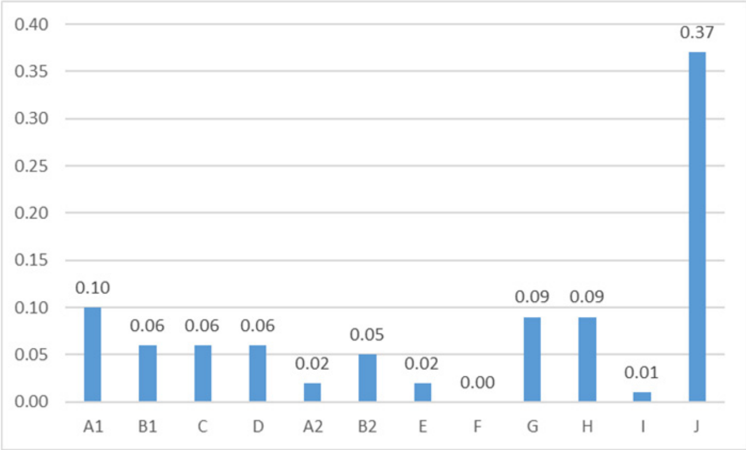

Fig. 7 Average error of camera casing

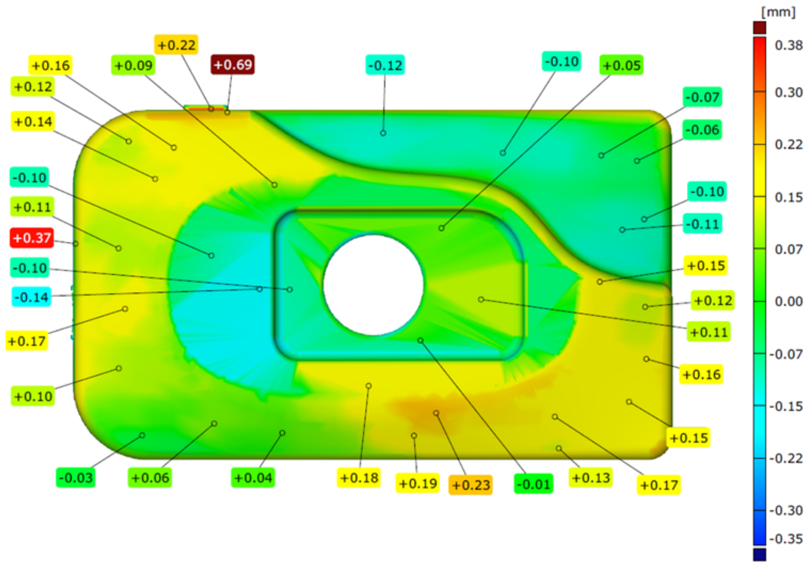

Fig. 8 Deviations of front camera cover – front view

In Fig. 8, the deviations of front camera cover from the front view are shown. The deviations are uniformed, only tenths of millimeters around zero. Maximum deviations occur on the top side of the front camera cover model: +0.69 mm. In order to investigate those deviations more closely, the top side view of the front camera cover is thoroughly examined, Fig. 9. The top side view reveals grey area on a groove for the camera switch.

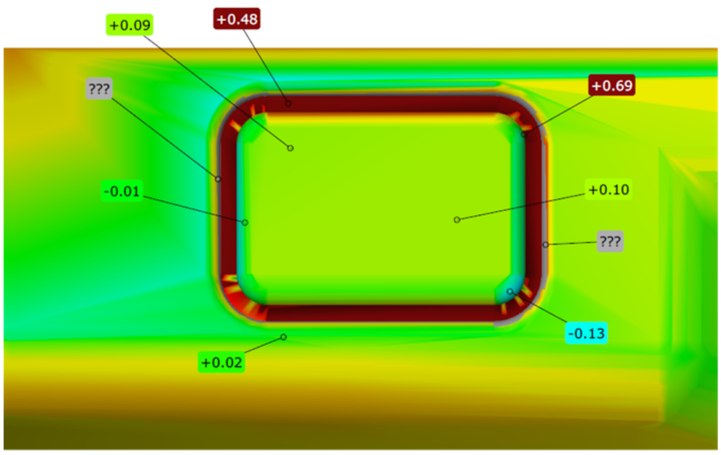

Fig. 9 Deviations of front camera cover – detail of top side view

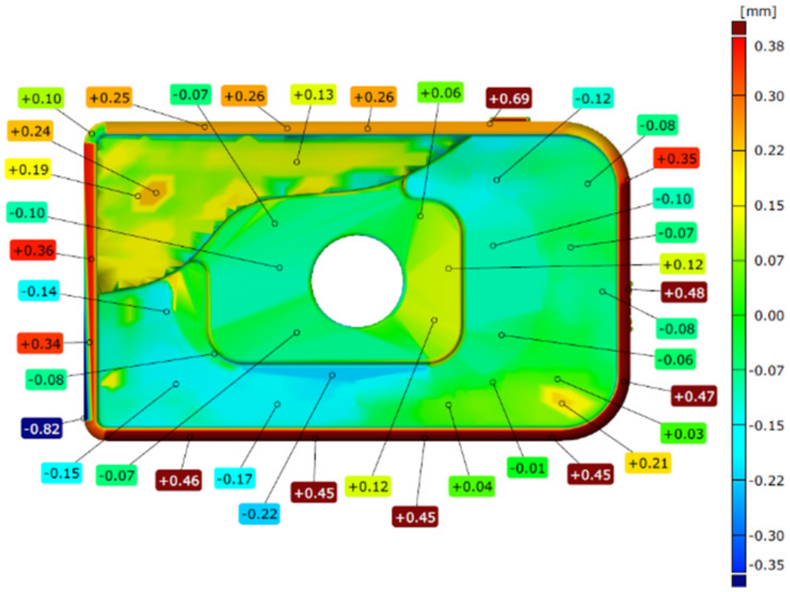

Fig. 10 Deviations of front camera cover – rear view

The deviations of front camera cover examined in the rear view (Fig. 10) reveal similar distribution. On the edge of positioning surface for the camera lens, the minimum value is -0.82 mm. These deviations must be additionally verified and further analyzed with the purpose of determining the probable causes.

Fig. 11 reveals that the deviations of back camera cover in the front view are uniformed. No significant deviations occur on a front side of the back camera cover model.

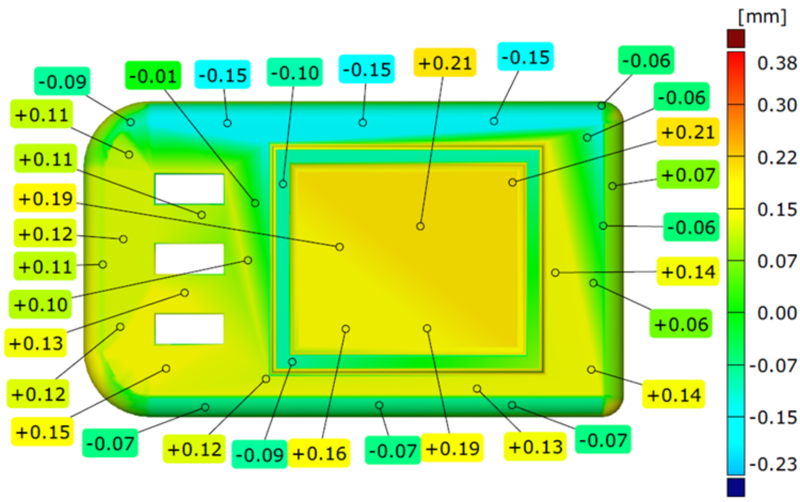

Fig. 11 Deviations of back camera cover – front view

The rear view of deviations of back camera cover presented in Figure 12 reveals maximum deviation alongside the fitting surface for joining the front and back camera cover. The maximum deviation of the fitting surface is +0.38 mm. The minimum deviation occur on the lower left edge of the bottom opening with value: –0.23 mm.

Finally, the overall average deviation of the scanned front camera cover is 0.0845 mm and the deviation of the scanned back camera cover is 0.0722 mm.

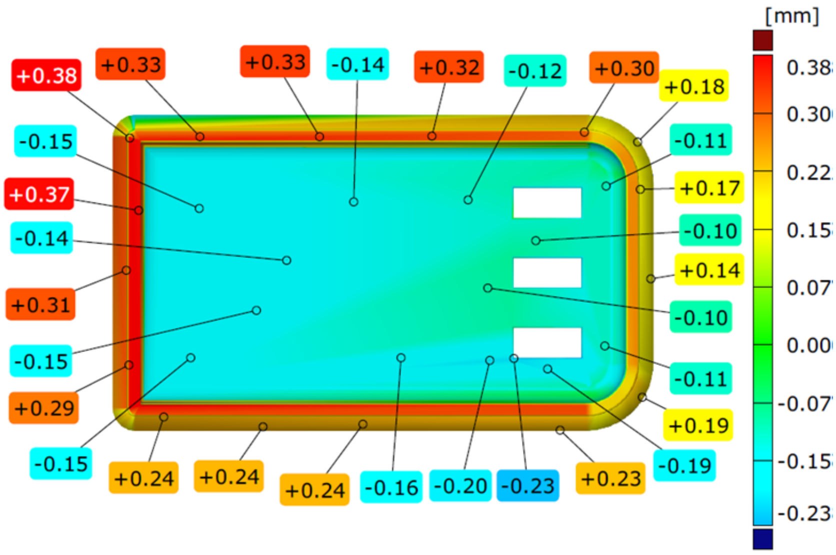

Fig. 12 Deviations of back camera cover – rear view

4. Analysis

A review of the deviations for the camera cover reveals that the maximum deviations occurred on the top side of the front case (Fig. 9). The minimum deviation occur in rear view of front case, at the edge of positioning surface for the camera lens (Fig. 10). However, no similar deviations appeared on other investigated surfaces.

In Fig. 13, the maximum deviation of the scanned camera casing model is shown. A detailed look at the critical section in GOM Inspect reveals the maximum deviation of +0.67 mm. Analysis of the average errors for measured values in Table 1, reveals the maximum value of 0.37 mm. Based on that, the upper deviation limit in GOM inspect is set to 1 mm so every deviation above 1 mm is colored grey i.e. ignored. Due to the light reflection, scanner software is interpolating surface in shape as shown at Fig. 14.

Detail section analysis of minimum deviation on front camera case (Fig. 10) did not reveal deviation of -0.82 mm (Fig. 15). Furthermore, analysis of this section show large sized triangles (Fig. 16) most probably generated during conversion of original CAD model to STL. The effect of large deviation can be compared with hang glider and pilot: if observer look at the side view, he will notice only small distance between pilot and glider's large kite. However, if observer looks from the top, he can clearly see large distance between tips of the kite and the pilot. In the same way, cross-section here does not reveal present big distance. The whole model of camera case verified the deviations only in the range of tenths of millimeters.

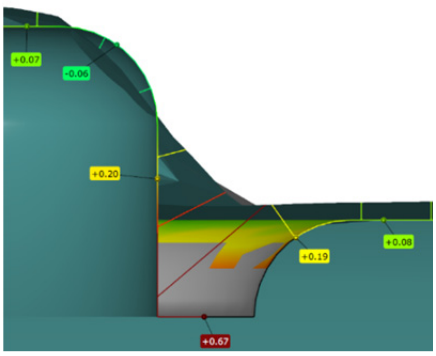

Fig. 13 Detail of section with maximum deviation of scanned camera casing model

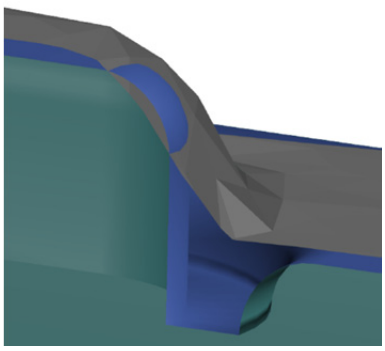

Fig. 14 Generated model (blue) and scanned model (grey)

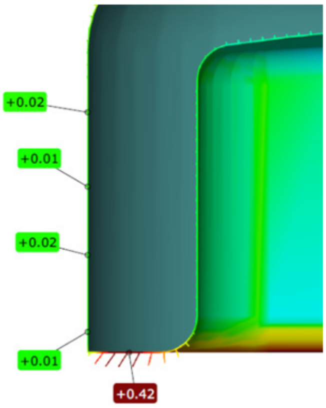

Fig. 15 Detail of section with minimum deviation of scanned camera casing model

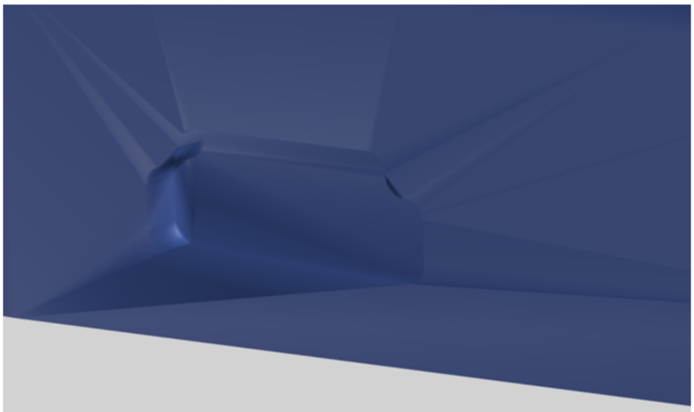

Fig. 16 Large size triangles on section with minimum deviation of scanned camera casing model

5. Conclusion

The results obtained in this research confirmed that the paper-based model has satisfactory accuracy, with the average deviation within only tenths of millimeters. Such low deviations confirm the accuracy of Mcor IRIS specified by manufacturer.

Selected long shell models enable special observation of accuracy in Z direction. Z direction in long thin models might be more affected by cutting force, humidity, gluing and post-processing. However, 3D scanning results did not reveal significant neither concave nor convex deviations in Z direction, thus confirming that glued papers successfully withstand 3D printing process and deliver sufficient rigidity.

Moreover, since we printed two parts, we were able to test mating and relative insertion of parts. It is additional verification of assembling capabilities for this particular technology, valuable to design engineers.

Paper changes due to absorbing of glue during the gluing process and removing of excess paper result in slight deviations in both positive and negative directions. High deviations that occurred in some sections of the camera casing were caused by the light noise and reflection during the 3D scanning process.

Since the accuracy of paper-based 3D printing is mainly constrained by the paper thickness and cutting methods, in order to improve the accuracy, researchers and manufacturers could devote some additional effort in this direction. The adjustable cutting angle of the knife might reduce the stair-look of sloped surface. The following experimental analysis of measured surface roughness similar to the conventional processes should verify the method [15]. However, the adjustable cutting angle will certainly result in a more complicated tool holder and controlling logic. It could furthermore increase time for 3D printing, so it should be very carefully balanced. The tests with thinner paper could also be considered to improve the accuracy, although it might require some greater changes of the actual 3D printer's components.

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