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3D MODELS PRINTING PROCESS CALIBRATION AND MECHANICAL PROPERTIES OF RESIN INVESTIGATION

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Introduction

With the development of modern technology, three-dimensional graphics (3D) is increasingly making its way into various fields such as design, advertising, packaging, industry and even medicine (Fig. 1). The three-dimensional graphic elements can be not only modelled, but also adapted for the three-dimensional printing. 3D printing opens new opportunity for companies seeking to improve production efficiency and have big future (AMFG (2021) (Fig.2.) However, the quality of the print strongly depends on the used printing method, technological process and on the properties of the material such as elasticity, resistance to deformation, which is necessary to investigate.

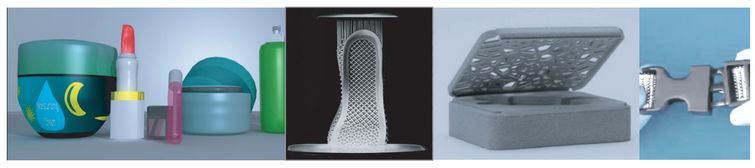


Fig 1. Examples of 3D models and products (Avid Product Development, n.d.; AmeraLabs, 2023)

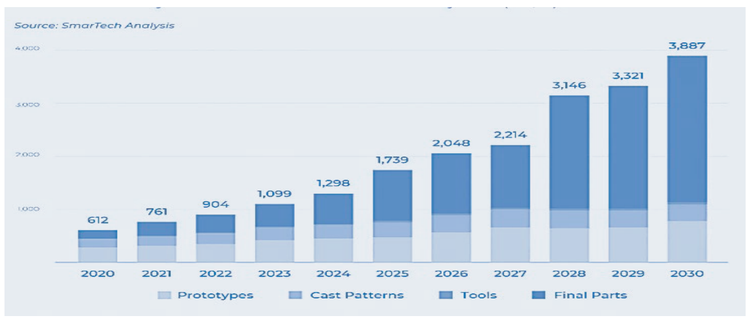


Fig. 2. Revenues from polymers 3D printing in the consumer goods industry in US million dollars. (AMFG, 2021)

The most widely used 3D printing technologies on the market are hot extrusion and resin VAT photopolymerization (Štaffová, Ondreáš, Svatík, Zbončák, Jančář, Lepcio, 2022). Using VAT photopolymerization it is possible to produce very high-quality products with good surface smoothness and detail integrity. However everyone resin is uncial, with its own material properties, which can influence parameters and quality of printed objects. Parameter accuracy becomes especially important to connect different individual parts of the product, so it is why before production goods with 3D printing it is necessary to make calibration process and correct parameters of 3D models.
Taking into account the areas of applicability of the resin, the main goal of this work was to make calibration process of 3D models printing and to investigate the strength properties of the TGM-7 resin.

Equipment and methods

During this work, using “Autodesk Fusion 360” program, the samples were modeled and prepared for printing using “CHITUBOX” program, according to the standard.
In this work, a new “Labsamera” acrylic resin TGM-7 was used for research. Table 1. shows the main chemical constituents of the resin.

Table 1. The main chemical constituents of the resin TGM-7

Name of chemical component	CAS Nr.	Concentration
4-(1-oxo-2-propenyl)-morpholine	5517-12-4	50-55%
(oktahidro-4,7-metano-1H-indenediil)bis(methylen)diacrylate	42594-17-2	6-9%
Diphenyl(2,4,6-trimetilbenzoil) phosphinoxide	75980-60-8	1-4%

The specimens were modelled using “Autodesk Fusion 360” software and prepared for printing using “CHITUBOX” program. All specimens were printed using a **Masked SLA printer** „Elegoo Mars 3 4K“ with 2.62 mW·cm^{-2} light intensity and a UV spectrum peak of 406.3 nm (the exposure was set at 1.8 s). Motor rotation deviation with respect to the Z axis was 1,25µm and woxel size 0,035 mm. After 3D printing, the samples were washed with isopropanol for 14 min in a wash and cure station „Anycubic Wash & Cure plus“, dried in the air for 30 min and then additionally polymerized (post-cured) in a standard UV chamber „Anycubic Wash & Cure 2.0“ (power 25 W) with UV light source of 405 nanometers wavelength.

Determining the strength properties, the tension measurement stand was chosen: the universal 10 kN power testing machine "Tinius Olsen" H10KT with a 500 N force measurement sensor. Tensile measurements were made according to the ISO 527-5A standard (tensile time 5 min, distance between grips 25 mm).

Results

In this work, models were created using 3D graphics software and tested after 3D printing. Newly developed by „AmeraLabs“ resin TGM-7 was used for the 3D printing. During the testing of the models, a calibration process of the equipment was carried out in order to obtain accurate and high-quality models with fewer inaccuracies or defects in the future. During the experiments, it was found that a more significant change in dimensions was observed in the lower part of the figures, which could have occurred due to the deposition of the polymer. The results were applied for 3D advertising robot model (Fig. 10).

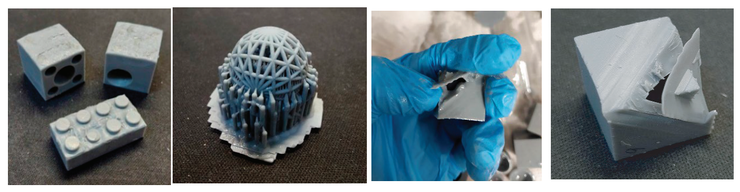


Fig. 4. 3D printing defects caused by the selection of the wrong supports and design solution

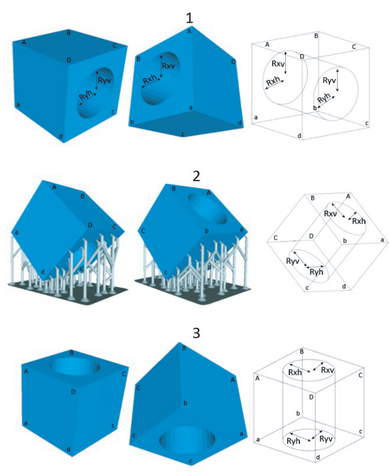


Fig 3. Marking angles and holes in calibration shapes

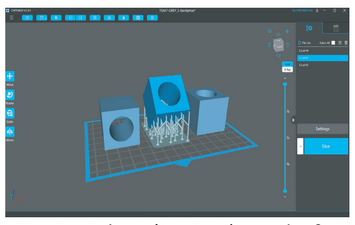
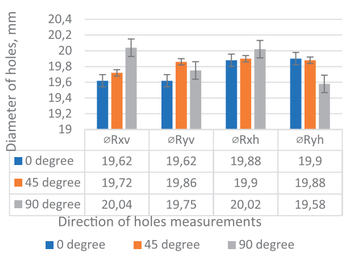
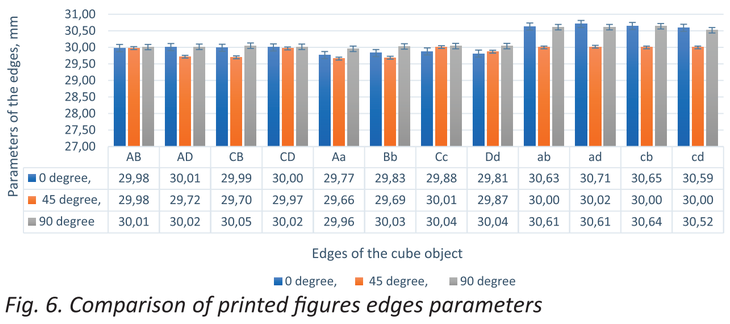


Fig 4. Cubes (1, 2, 3) ready for printing in CHITUBOX



	⌀Rxv	⌀Ryv	⌀Rxh	⌀Ryh
0 degree	19,62	19,62	19,88	19,9
45 degree	19,72	19,86	19,9	19,88
90 degree	20,04	19,75	20,02	19,58

Fig. 5. Comparison of holes diameter of printed cubes



	AB	AD	CB	CD	Aa	Bb	Cc	Dd	ab	ad	cb	cd
0 degree,	29,98	30,01	29,99	30,00	29,77	29,83	29,88	29,81	30,63	30,71	30,65	30,59
45 degree,	29,98	29,72	29,70	29,97	29,66	29,69	30,01	29,87	30,00	30,02	30,00	30,00
90 degree	30,01	30,02	30,05	30,02	29,96	30,03	30,04	30,04	30,61	30,61	30,64	30,52

Fig. 6. Comparison of printed figures edges parameters

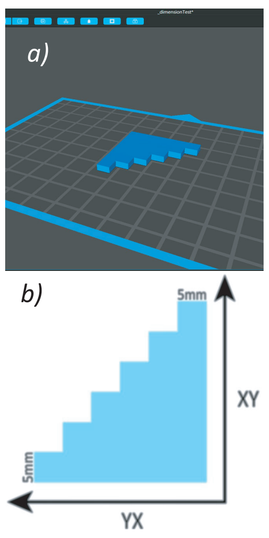


Fig. 7. Calibration detail "steps" in the CHITUBOX software environment (a) and step measurement diagram (b)

XY		
Nominal, mm	Measured, mm	Measured after Compensation, mm
5	4,94	4,94
10	9,99	9,98
15	15,01	15,02
20	20,02	20,00
25	25,03	25,00
30	30,02	29,99
YX		
Nominal, mm	Measured, mm	Measured after Compensation, mm
5	4,97	5,00
10	10,02	10,02
15	15,05	15,03
20	20,06	20,03
25	25,04	25,00
30	30,03	29,95

Results	Before Compensation		After Compensation	
	XY	YX	XY	YX
Scale, %	99,70	99,79	99,83	100,18
Compensation, mm	0,026	0,004	0,020	-0,018
Avg. Scale, %	99,74		100,006	
Avg. Compensation, mm	0,015		0,0012	

Fig. 8. Results of the dimensions of the calibration component 'steps' (test 1): (a) dimensions of the different axes, (b) overall average of results

During the work, the mechanical properties of the material were also determined, which are important for the many applications such as packaging, advertising items or other products subject to load.

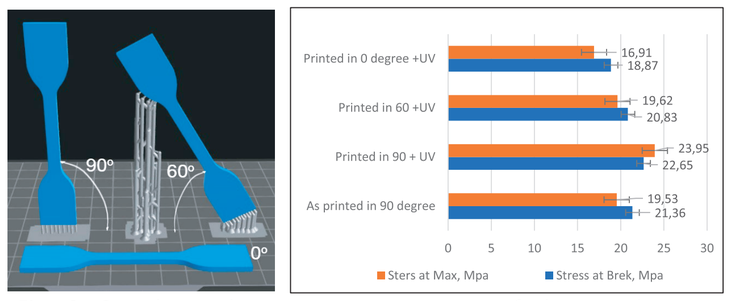


Fig. 9. Samples and stresses measurements of the samples at maximum and at break

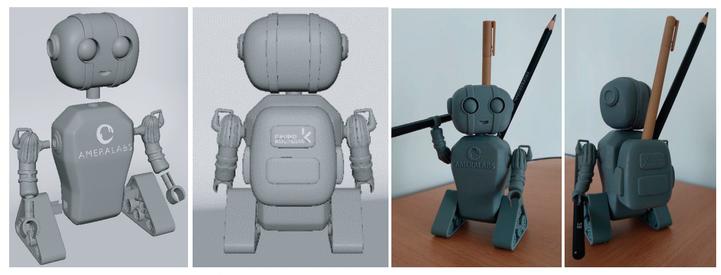


Fig 10. A 3D model of the advertising object and printed object

Discussion/Conclusions

1. During this work, calibration objects were created in the Autodesk Fusion 360 program and applied to the printing by rotating them at different angles of 0, 45 and 90 for the “Chitubox” program. The original “AmeraLabs” TGM-7 acrylic resin was used to 3D print the models.
2. After the test printing of objects of different shapes, such defects as surface dripping, "blooming" defect, surface irregularities due to the selection of improperly selected supports, tearing of objects due to the absence of vent holes in hollowed parts in the object were observed. It has been observed that filling the voids completely with material results in better product quality than trying to leave the voids unfilled with air gaps. This can make the product heavier, but with a small product it is worth sacrificing the amount of resin for the 3D printing for better final object quality.
3. After the initial visual quality assessment of the printed figures, measurements were made, and changes in shape were recorded. The real height of the cube-shaped figures decreased by an average of 110 µm. The width of the lower part was larger than the upper part by an average of 340 µm. Based on the results, the height of the objects was increased, and their width was reduced accordingly in the modelled samples. The difference in the dimensions may be caused by the inaccuracies of the 3D printing equipment and material shrinkage. Some of such inaccuracies can be overcome by adjusting the printing parameters, orientation, and adjusting the design of the model. When the sample was rotated at 45 degrees, a slight expansion of the lower planes was also observed, resulting in the external dimensions of the model being adjusted accordingly. Printing at this angle produced the most accurate dimensions of objects. After measuring the diameter of the holes, it was observed that the diameter of the holes when the specimen is in the vertical position is about 380 µm smaller in the vertical than in the horizontal position (a decrease of 110 µm), and when the specimen is at an angle or when the hole is in the vertical position, the lower part of the hole diameter is obtained higher than the upper one due to polymer deposition, shrinking and relaxation phenomena.
4. Measurements of step-shaped samples showed that the overall coefficient of compensation parts can serve to bring the dimensions of the product closer to ideals. However, compensation for XY and YX planes should be done separately to have even greater accuracy in small details. The position of the model on the base and the evenness of the light flux hitting the model can also affect the parameters of the object.
5. After performing mechanical measurements of the sample's stretching, it was found that the acrylic resin used for the work had plastic properties after printing, and the samples printed at an angle of 90 degrees and polymerized with UV light had a higher resistance to dynamic load.
6. In the course of this work, applying the results obtained from the conducted research, an original advertising robot model with certain functionality was modelled, prepared for the 3D printing and printed.