Multidiszciplináris Tudományok, 14. kötet, 2. szám (2024) pp. 40–46. **https://doi.org/10.35925/j.multi.2024.2.4**

RESEARCH OF THE ACCURACY OF 3D PRINTED PLASTIC GEARS

Imre Marada
PhD Student, University of Miskolc, Institute of Machine and Product Design
3515 Miskolc-Egyetemváros, e-mail: machmi@uni-miskolc.hu

János Bihari
associate professor, University of Miskolc, Institute of Machine and Product Design
3515 Miskolc-Egyetemváros, e-mail: janos.bihari@uni-miskolc.hu

Abstract
The best-known additive manufacturing process is 3D printing, which is increasingly used to manufacture various machine components. In this article, we investigate the accuracy of plastic gears made by 3D printing. The aim of the research was to study gears manufactured using 3D printing technology with m >0.6 mm module, to determine how the resulting gears differ from the initial geometry and how the manufacturing method affects the parameters of the gears.

Keywords: *gear, plastic, 3D printing*

1. Introduction

Injection moulding is the most common production method for plastic gears. However, this is only economical for large production volumes, as it requires the design and manufacture of expensive tooling. (VDI, 1981), (VDI 2736, 2014), (JIS B 1759, 2019)

In recent years, FDM 3D printers have become common manufacturing tools in industry, and more and more plastic parts are being produced using this method. This is because 3D printing is an economical process for both individual and mass production, as unlike injection moulding, it does not require the design and manufacture of tooling. However, the question arises whether this method is accurate enough to produce plastic gears. (Bihari et al., 2023)

2. The printing method

In this article we produced the gears with 3D printing based on the FDM process. FDM (Fused Deposition Modeling) is the most widely used 3D printing technology available on the market. Printers using this technology require a filament of material to be loaded into the machine, and then the machine melts the filament and deposits it layer by layer onto a build plate following a predetermined path. The layers then cool and adhere to each other, creating a three-dimensional part. FDM printers typically use thermoplastic polymers and operate with one or two extruders. The most commonly used materials are ABS, ASA and PLA. (Marada et al., 2022)

An Ultimaker S5 printer was used for this purpose. TPLA was used as the material, which is a tougher variant of the most commonly used PLA material. The printer was equipped with a nozzle with a diameter of 0.4 mm during the production of the parts. For printing, the settings recommended by the manufacturer of the printer and the material were used.

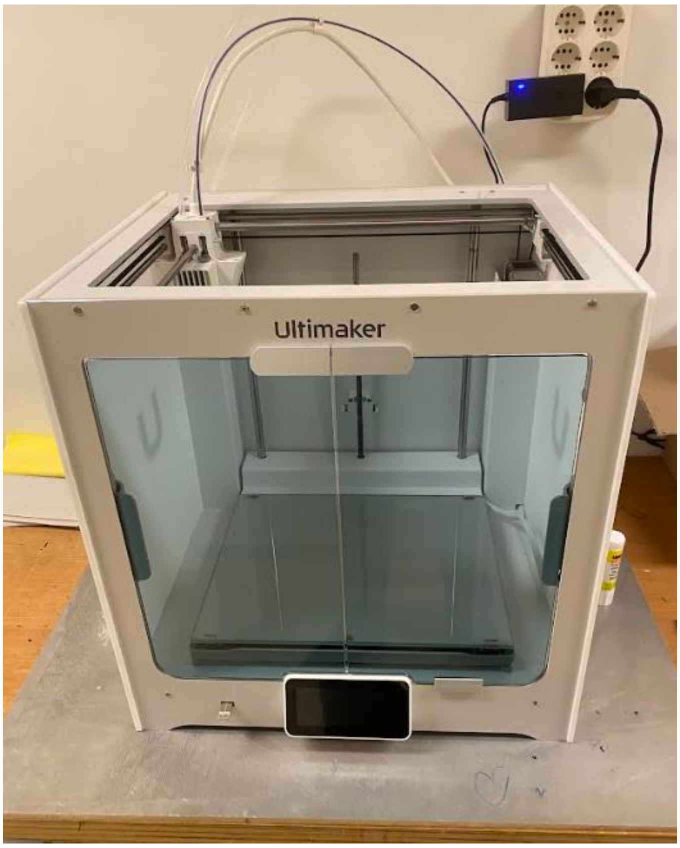

Figure 1. *Ultimaker S5*

3. The geometry of the gears

The gear geometries were generated using KISSsoft software. This software generates a real involute profile, not a polygonal approximation of the tooth profile. The gear models were generated with 0.8, 1, 1.5 and 2 mm modules. From each module, gears with z = 20 and 30 teeth were generated.

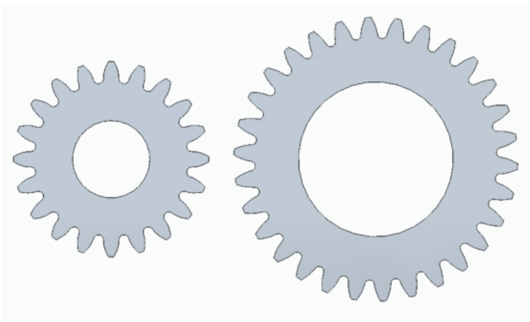

Figure 2. *The 3D model of the m = 0.8 gears (left: z = 20, right: z = 30)*

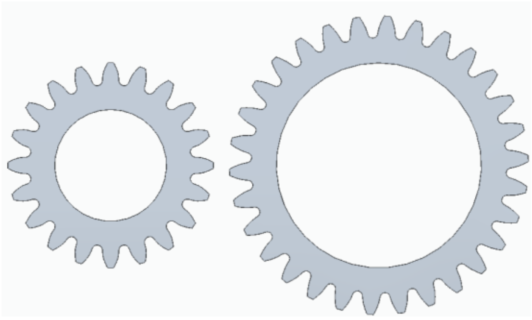

Figure 3. *The 3D model of the m = 1 gears (left: z = 20, right: z = 30)*

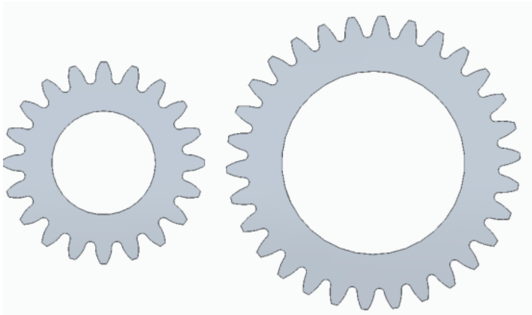

Figure 4. *The 3D model of the m = 1.5 gears (left: z = 20, right: z = 30)*

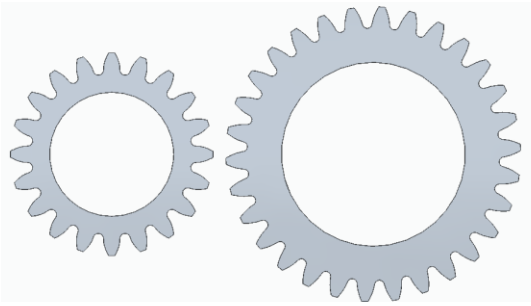

Figure 5. *The 3D model of the m = 2 gears (left: z = 20, right: z = 30)*

Figure 6. *The 3D printed gears*

4. The measurements

The measurements in this research were made using an optical microscope. In the tests, we first looked at the similarity of the teeth to the initial geometry. In addition, we created measurement templates for each gear to help us measure the different tooth sizes. The parameters that we measured were the tooth thickness, the pitch, the tooth height and the addendum.

4.1. The tooth shape

As the microscopic images show, the shape of the teeth of the gears closely resembles the initial geometry. An easily noticeable difference is that the ends of the teeth are slightly rounded. However, this roundness decreases as the size of the teeth increases.

It can also be seen that an increase in module is not only associated with a decrease in roundness, but the larger this standard size, the more similar the geometry of the printed teeth is to the geometry of the generated teeth.

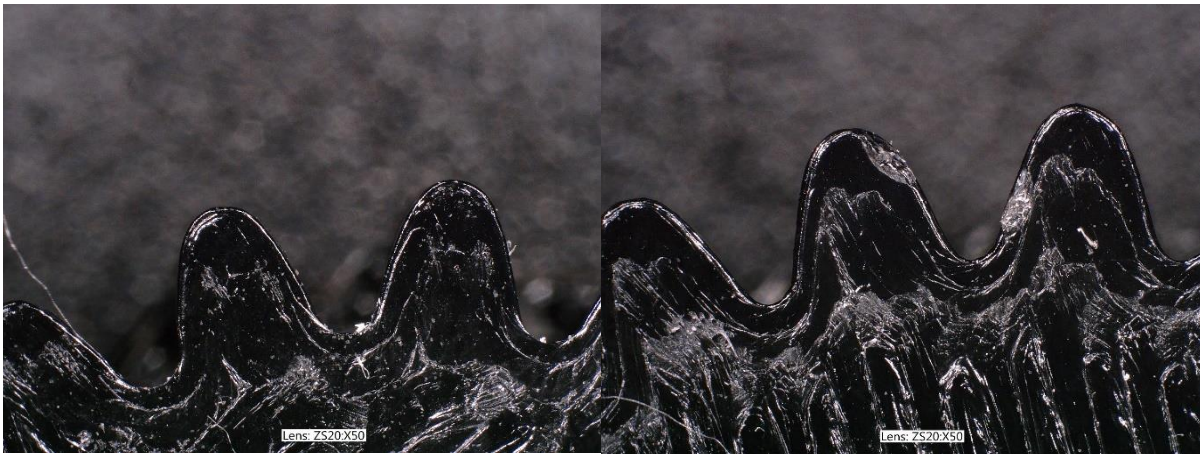

Figure 7. *The tooth shape for m = 0.8 gears (left: z = 20, right: z = 30)*

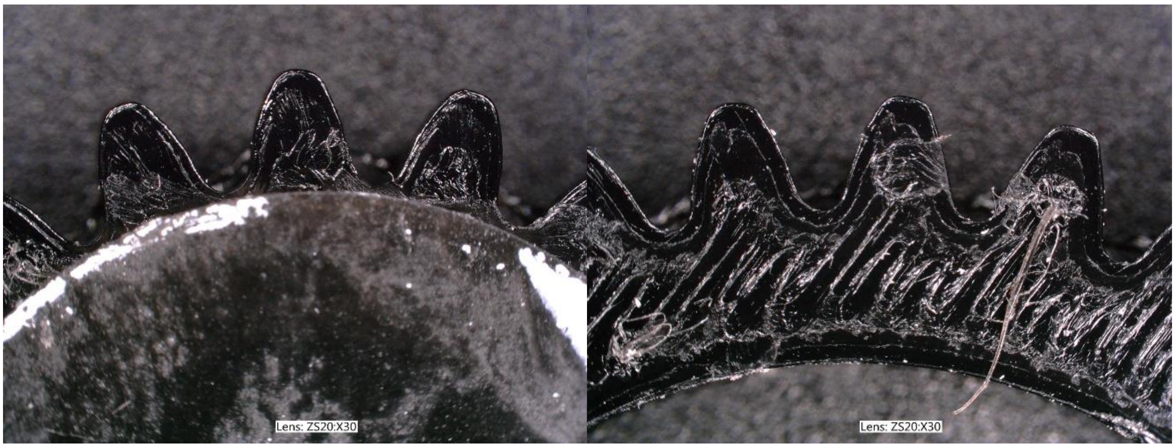

Figure 8. *The tooth shape for m = 1 gears (left: z = 20, right: z = 30)*

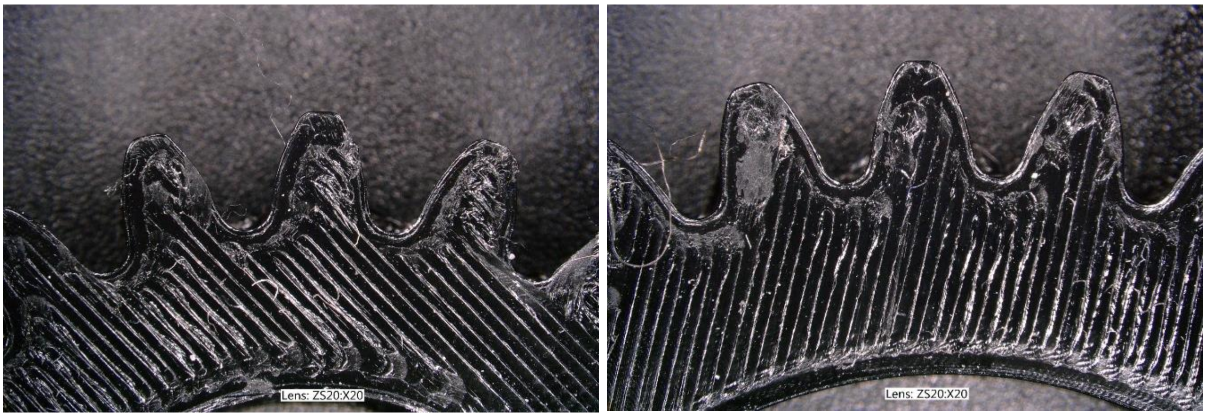

Figure 9. *The tooth shape for m = 1,. gears (left: z = 20, right: z = 30)*

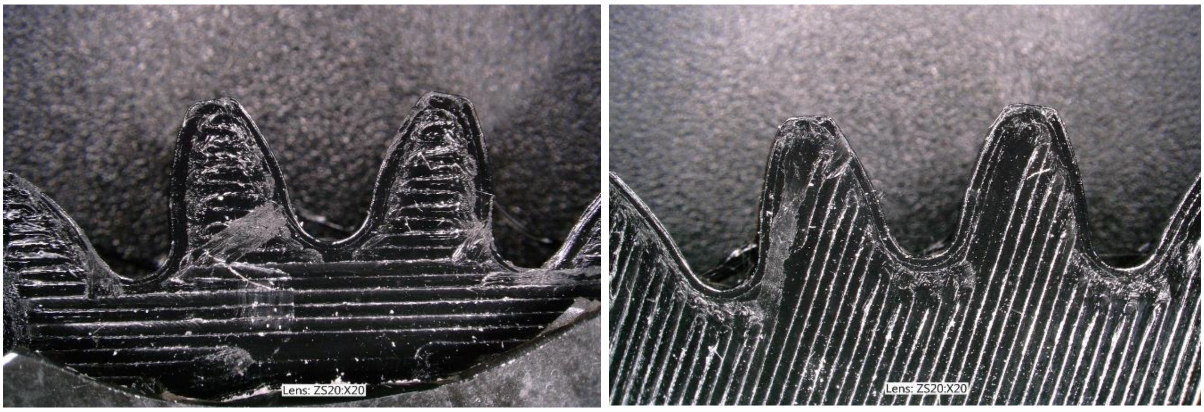

Figure 10 *The tooth shape for m = 2 gears (left: z = 20, right: z = 30)*

4.2. The parameters of the teeth

Table 1. *The nominal values measured on the 3D model of the initial geometry*

Gear	**Tooth thickness [μm]**	**Pitch [μm]**	**Tooth height [μm]**	**Addendum [μm]**
m = 0.8, z = 20	1186.576	2502.866	1797.5	797.5
m = 0.8, z = 30	1187.415	2508.725	1797.5	797.5
m = 1, z = 20	1500.505	3128.689	2247.5	997.5
m = 1, z = 30	1501.339	3135.843	2247.5	997.5
m = 1.5, z = 20	2285.127	4692.888	3372.5	1497.5
m = 1.5, z = 30	2286.354	4703.781	3372.5	1497.5
m = 2, z = 20	3069.74	6257.181	4497.5	1997.5
m = 2, z = 30	3050.465	6271.722	4497.5	1997.5

Table 1 shows the values measured on the 3D model of the initial geometry. *Table 2* summarises the maximum, minimum and average values of the measured results. The measurements were performed on 10-10 randomly selected teeth.

Table 2. *The measured results on the 3D printed gears*

Gear	Value	Tooth thickness [μm]	Pitch [μm]	Tooth height [μm]	Addendum [μm]
m = 0.8, z = 20	maximum	1348.55	2492.94	1893.4	860.9
	average	1325.01	2479.935	1820.2	821.321
	minimum	1303.31	2461.41	1728.79	779.34
m = 0.8, z = 30	maximum	1441.47	2487.58	1860.16	860.8
	average	1417.677	2479.144	1828.332	840.636
	minimum	1379.62	2462.22	1803.21	816.26
m = 1, z = 20	maximum	1653.36	3131.55	2306.89	1031.79
	average	1602.057	3108.72	2272.9	975.295
	minimum	1528.27	3083.02	2219.07	923.74
m = 1, z = 30	maximum	1665.72	3108.9	2305.31	1028.94
	average	1622.298	3093.756	2273.332	1006.901
	minimum	1583.41	3082.68	2231.76	986.2
m = 1.5, z = 20	maximum	2449.44	4702.67	3446.71	1585.64
	average	2403.5	4679.584	3350.232	1521.213
	minimum	2355.62	4638.28	3264.47	1444.64
m = 1.5, z = 30	maximum	2502.48	4677.95	3388.36	1690.43
	average	2473.506	4656.354	3343.462	1656.523
	minimum	2443.38	4639.28	3268.25	1615.33
m = 2, z = 20	maximum	3230.7	6289.14	4490.98	2064.64
	average	3195.518	6246.694	4466.876	2036.141
	minimum	3149.82	6216.73	4452.45	2008.72
m = 2, z = 30	maximum	3230.86	6260.32	4616.11	2118.13
	average	3219.122	6240.116	4533.69	2110.577
	minimum	3207.75	6215.18	4453.05	2097.21

The tables show that in all cases, the tooth thickness is 0.1–0.2 mm greater than the original value. It can also be seen, however, that the largest deviation in the pitch is no greater than 60 μm. This means that, although the thickness of the teeth deviates significantly from the nominal size, their repetition is close to the standard value. The maximum deviation in tooth height and addendum is also similar to that in tooth thickness, in the order of 0.1–0.2 mm. In this case, however, the differences are not always the same.

5. Summary

In this article, we investigated the accuracy of 3D printed gears using the FDM process. For the tests, gears with 0.8, 1, 1.5 and 2 mm modules were produced and their parameters were compared with the initial geometry. The parameters we investigated were tooth shape, tooth thickness, pitch, tooth height and addendum. It can be seen that there are significant differences in both tooth thickness and tooth height compared to the initial geometry. However, the proportion of these deviations from the initial tooth size decreases with the increase of the module. Furthermore, it can be observed that the shape of the teeth is similar to the initial geometry and the value of the pitch does not deviate much from the nominal value. It can be concluded that if a modification factor is found to change the tooth thickness and tooth height, a tooth of similar size to the original parameters can be obtained. Which could be the subject of a future research.

Acknowledgements

A Kulturális és Innovációs Minisztérium ÚNKP-23-3-II kódszámú Új Nemzeti Kiválóság Programjának a Nemzeti Kutatási, Fejlesztési és Innovációs Alapból finanszírozott szakmai támogatásával készült.
Supported by the ÚNKP-23-3-II New National Excellence Program of the Ministry for Culture and Innovation from the source of the National Research, Development and Innovation Fund.

Literature

[1] Marada I., Bihari J. (2022): A kisméretű műanyag fogaskerekek FDM és SLA elven történő 3D nyomtatása során szerzett tapasztalatok. *GÉP*, 73, 3–4, pp. 60–65., 6 p.

[2] VDI 2736 (2014): *Thermoplastische Zahnräder*. BeuthVerlag, Berlin.

[3] JIS B 1759 (2019) (JGMA/JSA): *Estimation of tooth bending strength of cylindrical plastic gears*. Japanese Standards Association, Tokyo.

[4] VDI (1981): *Zahnräder aus thermoplastischen Kunststoffe*. VDI Verlag, Düsseldorf.

[5] Bihari J., Marada I. (2023): Testing Bolted Connections in Plastic Parts Made by FDM Printing. *GÉP*, 74, 2–3, pp. 26–29., 4 p.