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ANALYSING THE MODEL-SUPPORT CONNECTION BY TORSION TEST FOR SELECTIVE LASER MELTING PROCESS

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Abstract *3D printing of metal parts was investigated in this research work, which connecting to the supporting of model. The connection between the support and the model is important form the viewpoint of the mechanical fixturing, the heat conduction, the removability of the support and the success of printing. In this research work, some support and tooth parameters such as the top length, the hatch distance, and base length, tooth height were investigated to create a model-support connection strength map. This knowledge makes it possible to select the most appropriate connection type between the support and the model by the requirements specified in different cases. The strength of the support-model connection was characterized by the shearing properties using the torsion test. The results are illustrated and compared by different support parameters and materials. The 316L stainless steel and Ti6Al4V alloy were investigated.*

Keywords *additive, SLM process, metal, 316L, Ti6Al4V, support, model, connection*

1 INTRODUCTION

The Selective Laser Melting (SLM) process is spreading in the industry, but this is intensively researched to clarify the challenges and opportunities (M. K., Thompson et al., 2016, B., Ahuja, et al., 2017). In the case of the SLM process of metals, the models must be connected to a building platform during the printing. This connection is created by different types of support structures with various parameters. Setting the parameters will significantly affect the properties of the printed models and the ability of the support to dispose of its tasks properly. In order to clarify the correlations, different materials, support types and test methods (tensile, peeling test) are investigated by the researchers (J.P., Järvinen et al.,2014, P., N., J., Lindecke et al.,2018, M., Leary et al., 2019). Knowing the connection strength of the support also important in case of simulation process too, because of the validation of simulation models (P., N., J., Lindecke et al.,2018). Choosing the right support type and the parameter is essential not just for the technical but economic viewpoint too. Therefore, minimizing the support quantity is a strong ambition (A., Hussein et al., 2013).

The presented research aim was to determine the influence of specific tooth parameters of the applied support structure on the connection shearing strength between the support and the model in the case of

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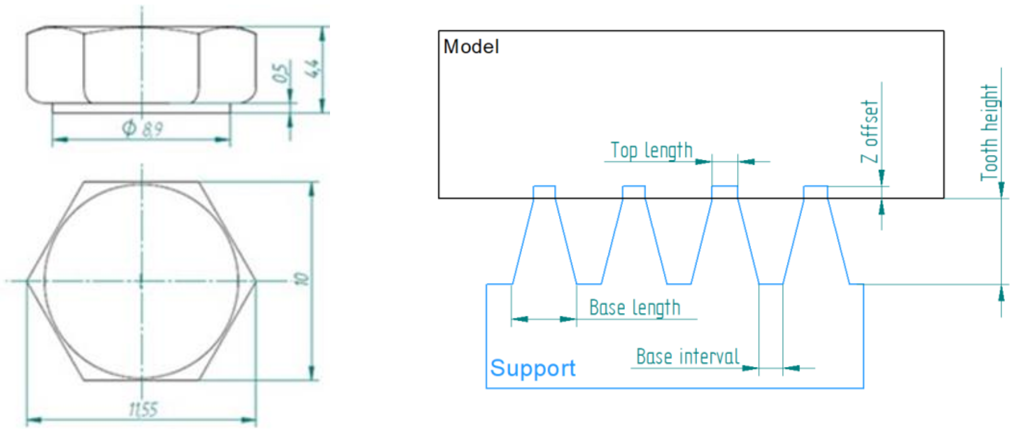
Ti6Al4V materials. Based on the results, the effect of the tooth can be properly planned later in the printing process.

2 EXPERIMENTS

The applied EOS M100 is a laser additive manufacturing machine working with a fiber laser with a nominal power of 200 W. The unit has a cylindrical working space of ø 100 x 95 mm. A 100 mm diameter disc shape platform is used. The platform thickness is 15 mm. The applied material was the EOS Ti6Al4V powder, and the default EOS technology was applied for 20 micrometers building layer thickness. The printed model was an M6 screw head, and the main parameters are illustrated in Fig.1a. The designed specimens were placed on a platform with a specific distribution taking into account the direction of the coater and the suction position using Magics software. We have designed various supports between the screw heads and the building platform. The support height was 4 mm, and the block support was applied in every case. The interpretation of some tooth parameters is shown in Fig 1a. The parameters of the support are illustrated in Fig 1b. The aim was to determine the change of the torques when using the block type support, changing the top length (TL), base length (BL), toot height (TH) and hatch distance (HD) parameters. The changed parameters are illustrated in Table 1. The Z offset value was 0 in all cases. A Kistler type 9273 torque measuring cell was used for torque measurement, which allows continuous measurement of torque values, but the maximal torque values were evaluated and illustrated in the diagrams.



a) geometry of printed model b) parameters of support teeth

Fig. 1 The geometries of model and support teeth

Tab. 1 The tooth parameters that were changing during the tests

Elements	***Applied values***
Hatch distance, HD (mm)	*0.2 /0.4 / 0.6 / 0.8 / 1.0*
Top length, TL (mm)	*0.1 / 0.15 / 0.2 / 0.3 / 0.4 / 0.6*
Tooth height, TH (mm)	*0.2 / 0.4 / 0.6 / 0.8 / 1.0*
Base length, BL (mm)	*0.4 / 0.5 / 0.6 / 0.7 / 0.8 / 0.9 / 1.0*

3 RESULTS AND DISCUSSION

Fig. 2a shows a platform obtained after printing where the models are fixed to the build platform with support. Fig. 2b shows the samples after the torsion test where the models are detached.

a) before the torsion test   b) after the torsion test

Fig. 2 Printed samples

3.1 Effects of hatch distance (HD) and top length (TL) on model-support connection

Fig. 3. shows the measured maximum torques depending on the hatch distance values in the case of different top lengths. It can be seen from the diagrams that increasing the value of the hatch distance from 0.2 mm to 1 mm decreases the measured maximum torque in a monotonic way. The rate of reduction is between 70 and 90 %. It can be observed that the decrease is more intense at smaller hatch distance values, and then the decrease slows down in the range of larger hatch distance values. This phenomenon changes in the same way for all top length values. Observing the effect of top length, it can be seen that higher top length values provide higher maximum torque, which larger connecting surfaces can explain. With these two support parameters, the maximum connection torque can be varied by order of magnitude between 5 and 100 Nm.

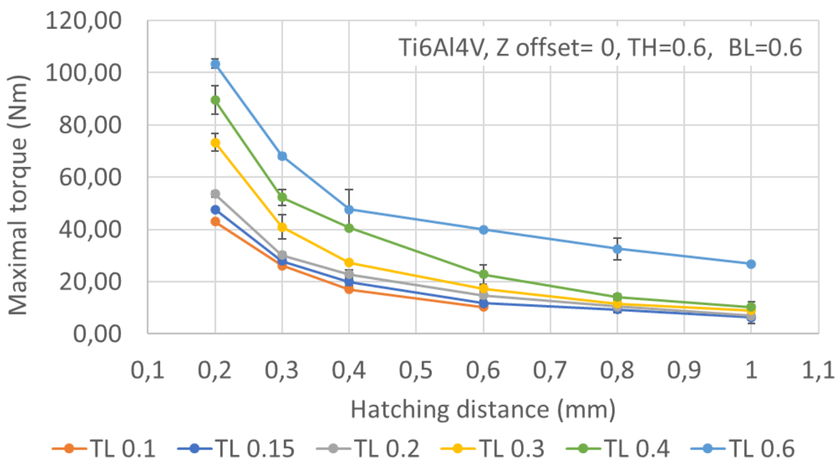


Fig. 3 Effect of hatch distance and top length on maximal torque

3.2 Effects of base length (BL) on model-support connection

In Fig. 4, the effect of the base length parameter is illustrated. As it can be seen by changing the base length from 0.4 mm to 1 mm, the maximal torque essentially does not change. The small differences shown in the diagrams are more due to the measurement uncertainty, which is also shown by the larger standard deviations. It means that the base length of the tooth does not affect the strength of the connection.

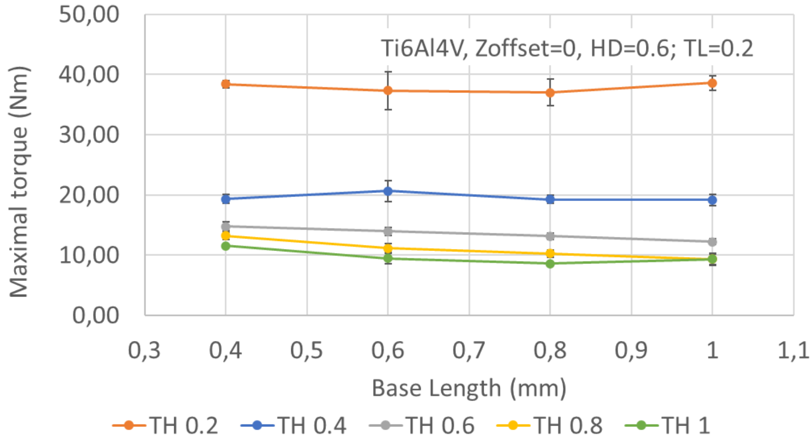


Fig. 4 Effect of base length on maximal torque

3.3 Effects of tooth height (TH) on model-support connection

In Fig. 5, the effect of tooth height can be seen on the maximal torque. Changing the tooth height from 0.2 mm to 1 mm, the measured torque decrease monotonously. In this range, the rate of reduction reaches 25%. It can also be observed in this diagram that the base length does not affect the measured torque. Since the top length value was not changed in this case, so there is no difference in the size of the connecting surface. The decrease can be explained by the lower teeth and the higher stiffness of the tooth.

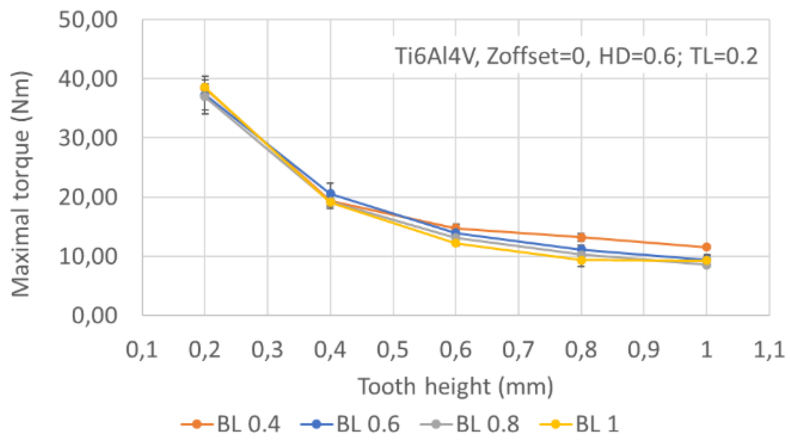


Fig. 5 Effect of tooth height on maximal torque

4 CONCLUSIONS

Investigating the model-support connection in case of 316L steel and Ti6Al4V titan alloy with different support parameters, we can conclude the follows:

• An alternative test method has been developed to qualify and characterise the strength of the model-support connection. The developed method is suitable to create a support-model connectivity strength map and to help select the main support parameters depending on the required connectivity strength and the removability of support in the case of 316L and Ti6Al4V materials.

The tooth design parameters affect the strength of the connection. The top length and tooth height significantly influence the strength of the connection,

• The torque required for detachment depends not only on the size of the associated surfaces but also on the tooth's shape. Although the base length affects the tooth's shape, it does not affect the measured torque,

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