

ANALYSIS OF 3D PRINTED NOTCHED SPECIMENS

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Key words: 3D metal printing, three-point bending test, CMT, FEM analysis, notched specimen, WAAM

Abstract: The base material of 3D printing is basically metal powder but in some researches wire form can also be applied. In this article the three-point bending test of specimens prepared with 3D printing is presented. These specimens were made with 2 different notches. The results of the tests were compared with the specimens which were crafted from a plate. The comparison shows there is no significant deviation between the results of the printed and the cut specimens. The effect of the notch was simulated by FEM. The results of the three-point bending test were compared with those of the FEM.

1 INTRODUCTION

In Our research we have used a CMT Welding machine the torch of which was fixed by a 3D printer, the wire was AlMg4,5Mn0,7. We made closed loops with the same parameters see Table 1., three-point bending test specimens were crafted from these closed loops. Bending tests are performed on such specimens which brake due to tension that is lower than those experienced during the tensile test. This tension is lower than those in the peripheral thread. Specimens with 2 different notches were used for the tests. The results of the 3D printed specimens were compared with the specimens which were crafted from a plate with the same quality.

Table 1. Manufacturing parameters

t / s	v / mm/s	l / mm
4	65	260

1.1 Manufacturing of specimens

The specimens were crafted from the 3D printed pieces and the sheet from the fiber direction, with 2 different notches. The surfaces of the 3D printed specimens and the plates were milled to ensure the even thickness. Notches were designed before the experiment with 0,25 and 1 mm radius and 0,5 mm deep. The drawings of the specimens are shown in Figure 1., Figure 2.. The notches of the specimens were made with plane cut, the plane cut tools were made by hand and their accuracy was checked with a measuring template. Zeiss Primotech KMAT microscopy was used for checking the dimensions of the notches. The results of the measurements showed that the notch of 0,25mm radius is 0,4mm, and the notch of 1mm radius is 0,7mm. Henceforth the marking will be R0,25 for the smaller radius and R1 for the bigger radius. The results of the microscopy measures are shown in Figure 3.

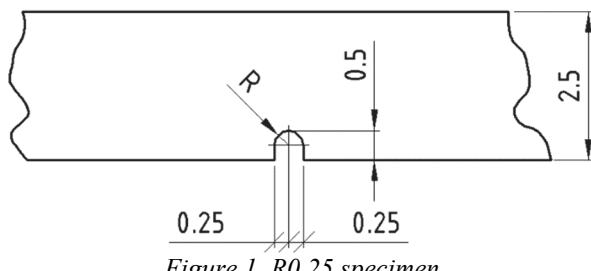


Figure 1. R0,25 specimen

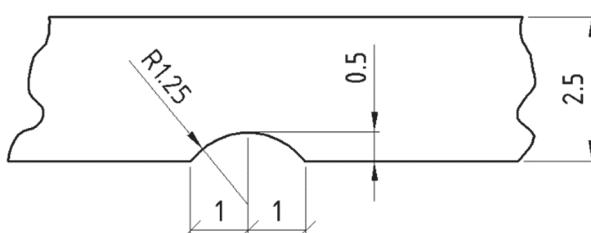


Figure 2. R1 specimen

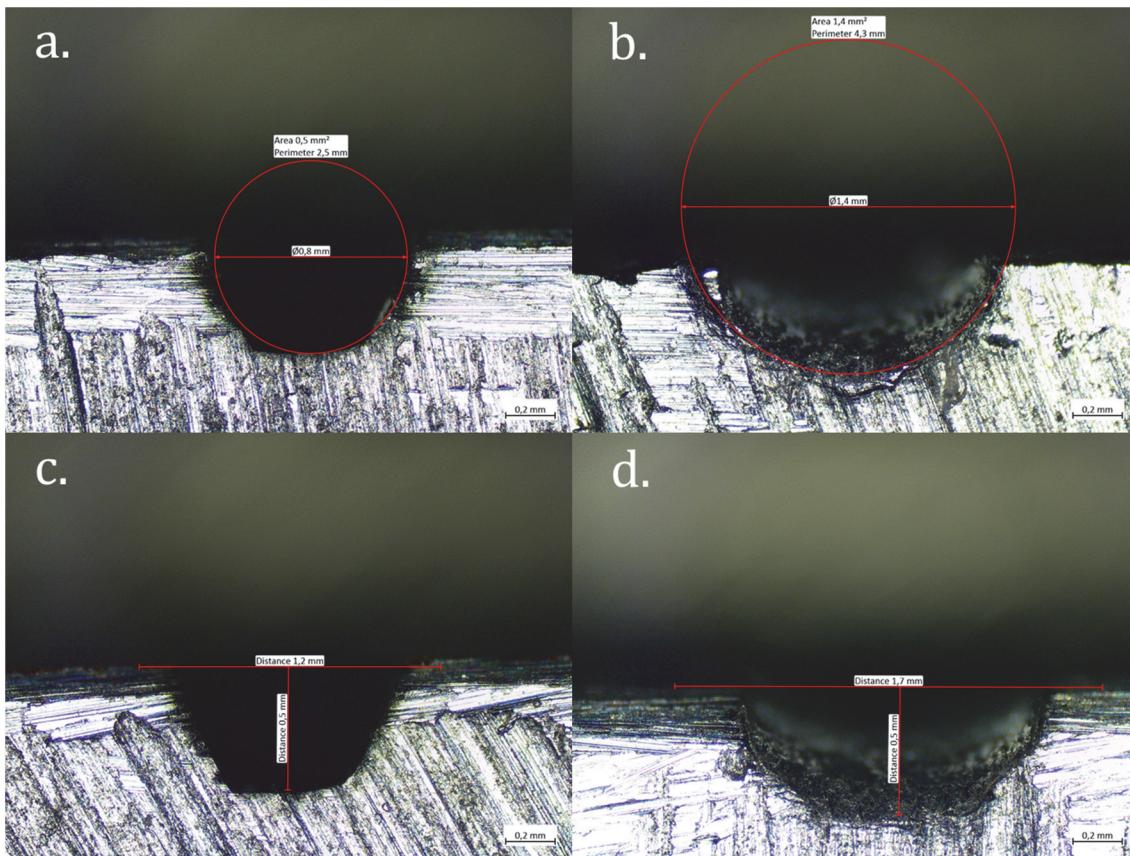


Figure 3. Specimens dimensions measured with microscope(a. R0,25 diam., b. R1 diam., c. R0,25 depth, d. R1 depth)

2 POINT BENDING TEST

During the 3 point bending test strength attributes can be determined. The test is used for brittle materials. Aluminium is not a brittle material therefore we examined the extent to which the notches change the flexural strength. The layout of the 3 point bending test is shown in Figure 4. The test was performed according to ISO 7438 standard. Tests were made by Zwick and Roell bending machine. The dimensions of the notches were measured with ZEISS Primotech KMAT microscopy. During the tests the loaded specimens were bent up to 90° bending or up to breaking point. The results of the tests were shown Table 2. and Table 3. Table 2. and Table 3. contains σ_{max} MPa.

$$\sigma_{max} = \frac{3FL}{2bh^2} \quad (1)$$

Where:

F - applied force N

L - support span mm

b - width of beam mm (all of the specimens are 20mm)

h - thickness of beam mm

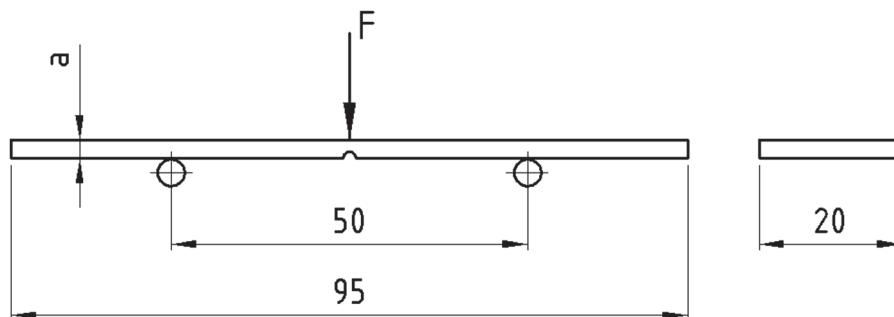


Figure 4. Layout of the bending test

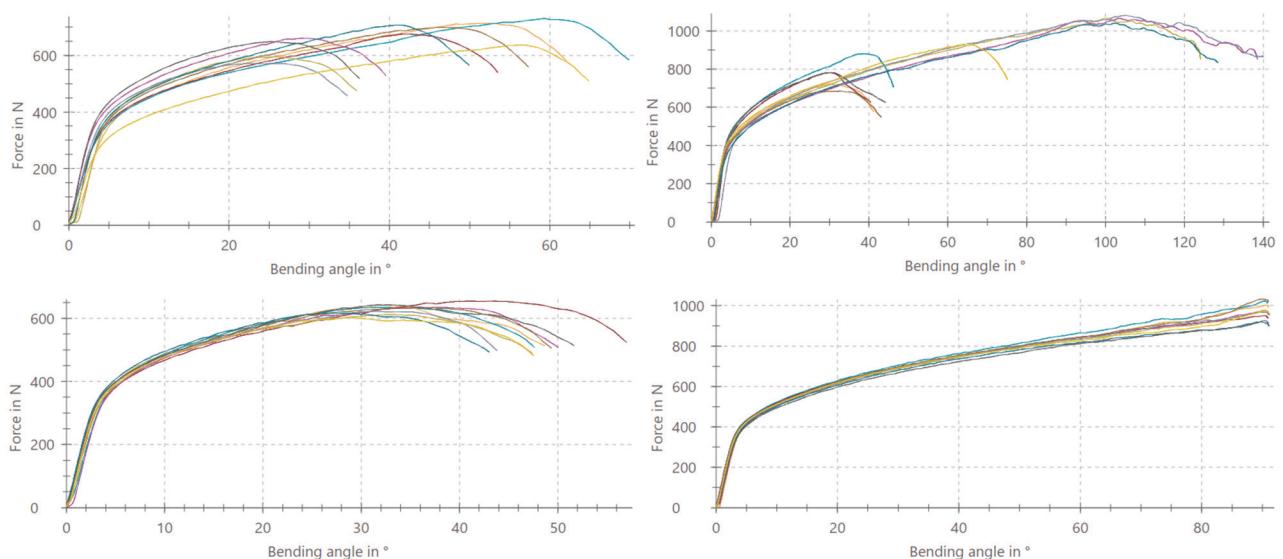


Figure 5. Force and bending angle diagram

Table 2. 3D printed specimens results

R0,25					R1				
F_{\max} / N	$\alpha / ^\circ$	a / mm	h / mm	σ_{bh} / MPa	F_{\max} / N	$\alpha / ^\circ$	a / mm	h / mm	σ_{bh} / MPa
714	50,79	2,5	2	671,05	723	50,9	2,73	2,23	545,2
731	52,05	2,58	2,08	630,46	880	51,59	2,78	2,28	634,81
676	50,21	2,78	2,28	487,65	781	50,81	2,8	2,3	553,64
594	50,72	2,7	2,2	459,54	1070	50,97	2,53	2,03	968,85
661	50,48	2,78	2,28	475,88	1070	50,55	2,5	2	999,63
699	51,97	2,56	2,06	616,15	684	52,08	2,74	2,24	518,46
572	50,73	2,57	2,07	499,85	1080	51,04	2,59	2,09	921,19
707	50,79	2,78	2,28	509,76	1040	52,29	2,71	2,21	794,93
649	51,23	2,82	2,32	449,92	781	50,26	2,84	2,34	531,68
637	51,84	2,43	1,93	639,37	932	50,51	2,63	2,13	766,9

Table 3. Sheet specimens results

R0,25					R1				
F_{\max} / N	$\alpha / ^\circ$	a / mm	h / mm	σ_{bh} / MPa	F_{\max} / N	$\alpha / ^\circ$	a / mm	h / mm	σ_{bh} / MPa
641	48,67	2,55	2,05	571,69	1000	90,99	2,47	1,97	962,9
635	47,67	2,58	2,08	547,66	1020	90,81	2,5	2	953,87
654	57,00	2,5	2	610,07	950	90,86	2,48	1,98	907,8
612	47,42	2,55	2,05	545,83	977	90,92	2,49	1,99	926,56
635	50,07	2,46	1,96	616,78	968	91,11	2,48	1,98	923,62
633	49,35	2,48	1,98	602,77	1030	90,98	2,49	1,99	972,44
622	43,81	2,52	2,02	571,92	968	90,97	2,5	2	905,69
617	43,04	2,57	2,07	539,71	919	91,07	2,45	1,95	907,22
643	51,65	2,52	2,02	588,58	926	90,87	2,46	1,96	904,37
602	47,57	2,51	2,01	557,38	974	91,04	2,46	1,96	954,59

Table 4 shows the statistical results of the 3D printed specimens crafted from a sheet. The table contains the means, standard deviations, minimum and maximum values of the stresses. The statistics were generated by IBM SPSS Statistics 26 software. Table 4 shows that the 3D printed specimens which are made with R1 radius have higher stress, minimum and maximum stress values. Figure 5 shown force and bending angle diagram, left side up is R0,25 3D printed, left side down R0,25 sheet. Right side up R1 3D printed, right side down R0,25 sheet.

Table 4. Sheet and 3D printed specimens statistical results

	R0,25 AM	R0,25 Sheet	R1 AM	R1 Sheet
Mean	543,96	575,24	723,53	931,91
Standard deviation	84,88	28,10	191,44	26,53
Minimum value	449,92	539,71	518,46	904,37
Maximum value	671,05	616,78	999,63	972,44

2.1 FEM analysis

In the first part of the study the effect of the notches were examined in the linear range. Around the notches there is an increase in the stress. Geometric discontinuities cause on object to experience a localised increase in stress. Examined

models. Stress concentration factor[1]. There is no big difference in deformation because the smallest cross section is the same. A non-linear examination was performed. The type of the FEM: PLANE2d. Material attribute: elasticity modulus: E: 70GPa, Yield stress: 200MPa, Tangent modulus: 7000Mpa. Models and results. The applied FEM mesh shown in Figure 6. Deformation and Mises Stress shown in Figure 7., and Figure 8.

The nominal stress:

$$\sigma_{nom} = \frac{Fl}{4W} = 142,4 \text{ MPa} \quad (2)$$

Stress concentration factor in model A (R1):

$$K_t = \frac{\sigma_{MAX}}{\sigma_{nom}} = 1,25 \quad (3)$$

Stress concentration factor in model B (R0,25):

$$K_t = \frac{\sigma_{MAX}}{\sigma_{nom}} = 1,4 \quad (4)$$

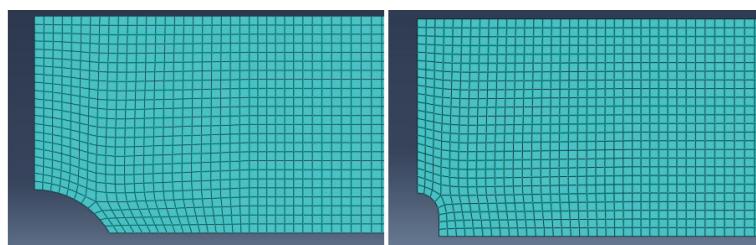


Figure 6. Applied FEM mesh

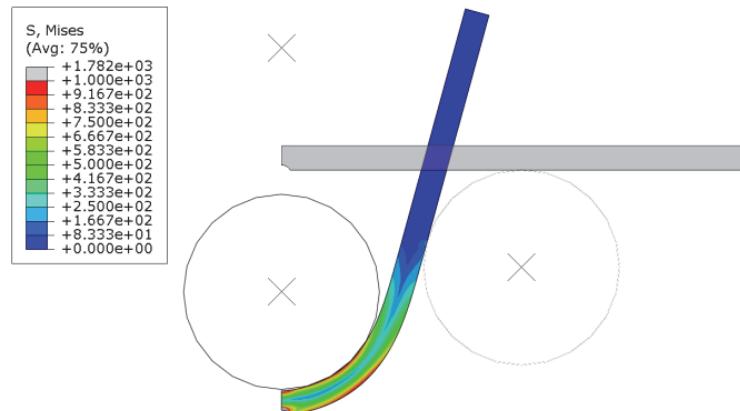


Figure 7. Deformation and Von-Mises stress in notch R1

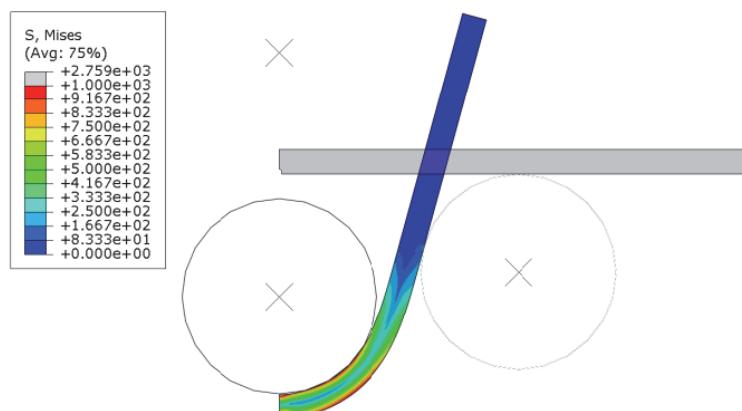


Figure 8. Deformation and Von-Mises stress in notch R0,25

3 CONCLUSION

There is a significant difference between the measured and the FEM results. The FEM analysis assumes homogeneous, isotropic material. Further studies show that the modulus of elasticity is less different from the applied

geometry E=70GPa. The value of the tensile strength is a half of the applied one. In case of model A (R1) we get bigger forces for the angle 45⁰ thanks to the better geometry. The difference is caused by the fact that the material is not homogeneous and isotropic. There is also some difference between the results of the tests with specimens with the same setting parameters. 3D printed specimens have less strength and the setting parameters play an important role.

ACKNOWLEDGEMENT

Special thanks for Assoc. Prof. Attila Kossa who made FEM calculation and the colleagues of the Medical Simulation Education Center who helped the measurements

4 REFERENCES

- [1] Larour, P., Hackl, B., Leemann, F., Benedyk, K., (2012). Bending angle calculation in the instrumented three-point bending test. *Lightweighting: Possibilities & Challenges, Volume: C/25/12.*