# C3TS report 2 – Development of the 20µm layer thickness for AlSi10Mg (Surface quality)

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This report describes the development of the 20 µm layer thickness for aluminum (AlSi10Mg). Tests have been done to improve surface quality for parts made of aluminum. Some parts have very small features and good surface quality is important. 20 µm layer thickness is the smallest that can be used with powder which have particle sizes of 20-65 µm. This study focus on improving border and up skin parameters.

## Things that affects to the surface quality

Things that affects to the surface quality are:

- Powder particle sizes
- Layer thickness
- Scanning parameters for border, down skin and up skin
    - Laser power
    - Scanning speed
    - Energy density
    - Focus (laser spot size)

Most of the aluminum jobs were done with 30 and 50 µm layer thicknesses before parameter development for the 20 µm layer thickness. Bigger layer thicknesses are good when surface quality is not the determining issue. Powder particles can melt partly when borders is scanned. This will cause bigger surface roughness. Laser power and scanning speed affects to the energy density which influence on quality of the melt pool. In table 1 is showed scanning parameters for 30 µm and 50 µm layer thicknesses. Parameters in table 1 are standard parameters (SLM Solutions). P means laser power [W], S means scanning speed [mm/s], $h_d$ means hatch distance [mm] and Ed is energy density [J/mm$^3$ or J/mm$^2$]. Energy density calculation equations is showed in the page 2 (equations 1 and 2).

**Table 1.** Parameters for Aluminum (50 µm) and AISI 316 L (30 µm)

| Parameter type | Aluminum, 50µm | | | | Aluminum, 30 µm | | | |
|---|---|---|---|---|---|---|---|---|
| | P | S | $h_d$ | Ed | P | S | $h_d$ | Ed |
| Border | 350 | 600 | - | 12 | 300 | 730 | - | 13.7 |
| Up skin | 350 | 850 | 0.15 | 54.9 | 350 | 830 | 0.13 | 108 |
| Volume hatch | 650 | 2100 | 0.17 | 36.4 | 350 | 1650 | 0.13 | 54.4 |

Down skin parameters does not affect to the surface quality in this case because there are no down skin areas. In fig.1 is showed different parameter types in one layer (picture taken from slice viewer software).

Red means that it is border, yellow is fill contour and brown volume hatch. Border is the outer frame which affects most on the surface quality. Fill contour mounts the volume hatch. Up skin is the top layer on the part.

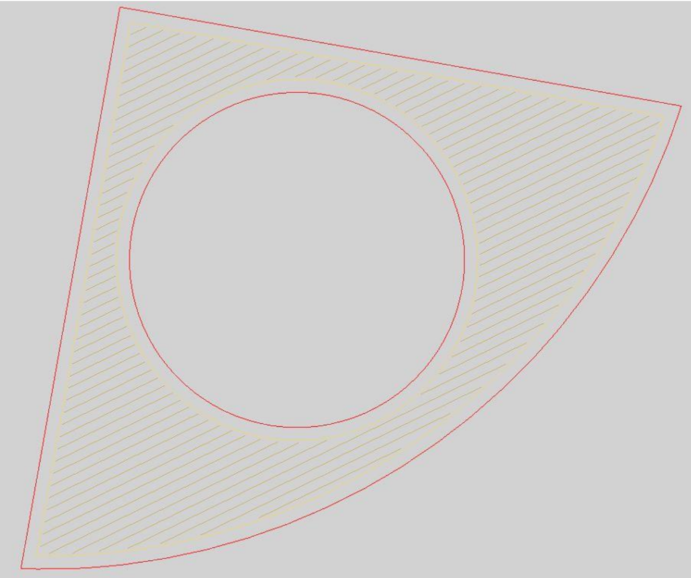


**Fig 1.** Parameter types

## Development of the 20 µm layer thickness

### Methods

Development of the 20 µm layer thickness includes several test runs. First tests was done for cubic parts. Dimensions of the cubic are 10x10x10 [mm]. Tests have been created by material development module in magics software. Benefits of this module is that different parameters can be tested in one run. But only one kind of part can be tested at once. In this module a matrix is created and every part have different parameters.

In this study is tested different laser powers and scanning speeds. In first test reference parameters are the same than 30 µm layer thickness. Best parameters were chosen in first test and selected as reference parameters in the next test. In fig.2 is showed parameters of cubic test for 5x5 matrix which is created in material development module. Parameters for the borders in the second test was:

- Laser power 260 – 340 W
- Scanning speed 670 – 790 mm/s
- Energy density 16.5 – 25.4 J/mm$^2$

Parameters for up skin was:

- Laser power 113 – 153 W
- Scanning speed 970 – 1090 mm/s
- Energy density 5.8 – 7.0 J/mm$^2$

Energy densities is calculated for borders with simple equation:

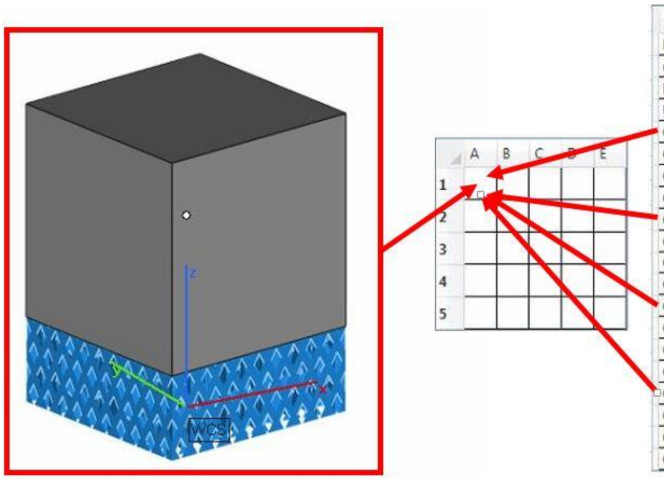
$$Ed = P/(S*lt) \quad [J/mm^2] \qquad (1)$$

,where P is laser power, S is scanning speed and lt is layer thickness.

Energy densities for volume hatch is calculated with equation:

$$Ed = P/(S*lt*hd)\ [J/mm^3] \tag{2}$$

,where abbreviations are same than equation 1 except hd is hatch distance.




| Name | Matrix element | Path to parameter | Parameter settings |
|---|---|---|---|
| Border_Speed_670-790 | C1 - C5 | /Scanning/Borders/Speed | 670 - 790 mm/s |
| up skin speed 970-1090 | C1 - C5 | /Scanning/Up Skin/Speed | 970 - 1090 mm/s |
| BorderPower 260-340W | A3 - E3 | /Scanning/Borders/Power | 260 - 340 watt |
| Up skin power 113-153W | A3 - E3 | /Scanning/Up Skin/Power | 113 - 153 watt |
| Copy of Border_Speed_670-790 (1) | A1 - A5 | /Scanning/Borders/Speed | 670 - 790 mm/s |
| Copy of Border_Speed_670-790 (2) | B1 - B5 | /Scanning/Borders/Speed | 670 - 790 mm/s |
| Copy of Border_Speed_670-790 (3) | D1 - D5 | /Scanning/Borders/Speed | 670 - 790 mm/s |
| Copy of Border_Speed_670-790 (4) | E1 - E5 | /Scanning/Borders/Speed | 670 - 790 mm/s |
| Copy of up skin speed 970-1090 (1) | A1 - A5 | /Scanning/Up Skin/Speed | 970 - 1090 mm/s |
| Copy of up skin speed 970-1090 (2) | B1 - B5 | /Scanning/Up Skin/Speed | 970 - 1090 mm/s |
| Copy of up skin speed 970-1090 (3) | D1 - D5 | /Scanning/Up Skin/Speed | 970 - 1090 mm/s |
| Copy of up skin speed 970-1090 (4) | E1 - E5 | /Scanning/Up Skin/Speed | 970 - 1090 mm/s |
| Copy of BorderPower 260-340W (1) | A1 - E1 | /Scanning/Borders/Power | 260 - 340 watt |
| Copy of BorderPower 260-340W (2) | A2 - E2 | /Scanning/Borders/Power | 260 - 340 watt |
| Copy of BorderPower 260-340W (3) | A4 - E4 | /Scanning/Borders/Power | 260 - 340 watt |
| Copy of BorderPower 260-340W (4) | A5 - E5 | /Scanning/Borders/Power | 260 - 340 watt |
| Copy of Up skin power 113-153W (1) | A1 - E1 | /Scanning/Up Skin/Power | 113 - 153 watt |
| Copy of Up skin power 113-153W (2) | A2 - E2 | /Scanning/Up Skin/Power | 113 - 153 watt |
| Copy of Up skin power 113-153W (3) | A4 - E4 | /Scanning/Up Skin/Power | 113 - 153 watt |
| Copy of Up skin power 113-153W (4) | A5 - E5 | /Scanning/Up Skin/Power | 113 - 153 watt |

**Fig 2.** Parameters in second test

Surface roughness of the borders were measured with microscope in both directions (Along the layers and across). 5x5 [mm] area were pictured and Ra values were calculated as well as average value of the lines. Up skin were not measured. One issue were observed for the up skin because borders were higher than hatching area. This is due to shrinking effect after cooling.

After these parameter tests were done and best solution had been found, these was tested for really small part which were orientated 45 ˚ angle. Part included shape sizes like 0.3 – 0.5 mm. This part had few demands which was good surface quality and really accurate shapes.

## Results

Results indicated that Ra 3.2 is possible to gain according to the measurements. This value is for vertical walls. Value will change if part is angled. Best surface quality were gain with parameters of (Border):

- Laser power 360 W
- Scanning speed 670 mm/s
- Energy density 26.9 J/mm$^2$

Issue with higher border on the up skin were fixed with small chamfers which equalized up skin surface. Glass ball blasting is not necessary needed if parts are orientated vertically and 20 µm layer thickness is in use.

When testing further these parameters for a little part which was orientated 45 ˚ angle, it was seen that energy density area of 16 – 24 J/mm² made the best surface quality and the most accurate features.

## Conclusions and future work

This study showed that:

- 20 µm layer thickness is possible to use with aluminum even particle sizes of the powder are 20 – 65 µm
- Printing time will rise but surface roughness is improved

  - This study showed that Ra 3.2 is possible to gain
  - Ra values were measured by microscope which means that there can be some errors
  - Still visual inspection did correspond measured results
- Best parameters for borders were when parts were orientated vertically
  - Laser power 360 W
  - Scanning speed 670 mm/s
  - Energy density 26.9 J/mm$^2$
- Best energy density values were 16 – 24 J/mm² when parts orientated 45 °
  - Most accurate features were gain
- Up skin were examined visually
  - Best parameters so far were
    - Laser power 133 W
    - Scanning speed 1030 mm/s
    - Hatch distance 0.13 mm
    - Calculated energy density 49.7 J/mm$^3$
- Small chamfers will equalize surface borders when border rise higher than volume hatch on the up skin
- Future work will include
  - Mechanical tests
    - Hardness
    - Tensile strength
    - (Fatigue strength)
  - Things that affects to mechanical strength are for example
    - Volume hatch distance
    - Laser power and scanning speed for volume hatch
  - Development of 90 µm layer thickness
    - Is it possible to use
    - Which are the best parameters
    - Reduction of printing time