Available online at www.sciencedirect.com

ScienceDirect

Procedia Manufacturing 36 (2019) 95–100

Procedia MANUFACTURING

www.elsevier.com/locate/procedia

17th Nordic Laser Material Processing Conference (NOLAMP17), 27 – 29 August 2019

Disk Laser Assisted Surface Heat Treatments Of AlSi10Mg Parts Produced By Selective Laser Melting (SLM)

Timo Rautio*, Jarmo Mäkikangas, Aappo Mustakangas, Kari Mäntyjärvi

Kerttu Saalasti Institute, University of Oulu, Nivala 85500, Finland

---

Abstract

Metal parts produced with the Selective Laser Melting (SLM) method have a great variety of uses today and because of this the requirements on the surface quality differ between applications. The surface treatments of the printed metal pieces, like other finishing phases, are often still manually worked on and thus are very time-consuming processes. This study focuses on the SLM printed AlSi10Mg aluminium specimen's surface laser heat treatment with disk laser equipment (wavelength of 1030nm). The goal of this study was to achieve the desired effect on the aluminium's surface quality with robotized laser heat treatment equipment. This was to show that the used finishing treatment method could be automated or robotized. The study showed that with the correct laser parameters, it is possible to generate desired effects and features on to the AlSi10Mg aluminium piece's surface with a robotized process.

Peer-review under responsibility of the scientific committee of the 17th Nordic Laser Material Processing Conference.

Keywords: Additive Manufacturing (AM); Selective Laser Melting (SLM); AlSi10Mg; laser forming

---

1. Introduction

Surface quality can have a huge impact on performance of parts. Fatigue resistance and chemical resistance are some qualities that can be directly affected trough surface quality [1]. Surface quality of metals can be improved in many ways. Mechanical, chemical and heat-treatments are all used in different ways to create suitable surface quality to final parts. This paper focuses on laser heat treatment. SLM (selective laser melting) manufactured cubes are examined and their surface improved with robot-controlled disk laser. Cubes are made of AlSi10Mg. By using robot, the surface treatment of AM manufactured parts can be automated saving time in otherwise time-consuming operation.

---

* Corresponding author. Tel.: +358 50 562 4668.
E-mail address: timo.rautio@oulu.fi

2351-9789
Peer-review under responsibility of the scientific committee of the 17th Nordic Laser Material Processing Conference.
10.1016/j.promfg.2019.08.014

Laser can also be more efficient solution when working on complex geometries where tooling can be difficult or even impossible.

Additive manufacturing usually uses layer by layer manufacturing. This means most 3D-printed objects have layer lines on surface. The surface quality of 3D-printed parts can be affected through different print parameters. Layer height has a big impact on surface quality of parts, and it also effects the build time significantly. Different slope angles on part also print differently. In SLM printing steep slopes cause laser to melt more of the underlying powder into the part being printed. Steeper angles cause worse print quality and printed parts are usually designed so that the surface angles going over 45 degrees are minimized or supported to build platform. Most surfaces facing towards print bed tend to be rougher quality than the surfaces facing upwards. Surfaces with supports must be machined to achieve good surface quality. Surfaces facing directly upwards can be remelted while being printed improving surface quality significantly. Different scanning parameters can also be used when borders are scanned and can have a big impact on surface quality and strength of the part. [2],[3]

Using laser for surface treatment requires consideration of key parameters. Laser intensity can be determined through laser power, scanning speed and beam size. Different parameters and shield gas used are determined by material being treated and desired outcome.[4] Laser can be used to melt thin surface layer to smoothen the surface or to create dimples or patterns making it rougher surface [5],[6]. Laser treatment on the surface can also have effect on the endurance of the part. A thin surface layer can be heat treated on surface while leaving rest of the part untreated. If the laser surface treatment does not penetrate far enough, fatigue resistance of the part can remain the same as starting points for cracks remain on surface [7].

AlSi10Mg is aluminium alloy often used in SLM and diecasting. It is lightweight, has good heat conduction and corrosion resistance. SLM produced AlSi10Mg parts have been reported to be as strong or even stronger than casted parts. Parts produced in SLM show anisotropy and are weaker in build direction and AlSi10Mg is no different. [8]

2. Improving the surface quality

2.1. Manufacturing the test specimen

The study for improving the surface quality was started by designing and manufacturing the suitable test specimen. A simple cube with dimensions of 25 mm x 25 mm x 25 mm was chosen as the shape and AlSi10Mg was used to print the test specimen. Cubes can be easily generated on the platform with the build processor without a separate CAD tool and when printed with two opposite corners aligned vertically, the need for support structures is very minimal. This reduces the time needed for post-processing of the pieces after printing and the parts are easily removable from the platform. To save the powder, the cubes were made hollow with a wall thickness of 3 mm which is suitable for the treatments made for the surface. Used orientation on the platform and the shape of the specimen results in different surface qualities on each surface of the cube caused by the qualities of the used manufacturing method. A SLM 280 printer with a 400 W laser and a layer thickness of 30 µm was used for printing.

The placement and the orientation of the test specimen on the printing platform is presented in Figure 1. Several cubes were printed for statistics and they were all printed in the same orientation. Gas flow in the printing chamber was on the negative x direction in this case and the powder was spread on both directions on y axis. The build chamber door is located at the front of the picture.

A more detailed view of the specimen orientation on the platform is presented in Figure 2 from both front and back view of the build chamber. The support structure was used on the three edges pointing down and are shown in blue color. As the material in this study was aluminium the supports could be kept light and easily removable. The red cylinders in the figures present points where the platform is secured to the build chamber. To be able to later identify the original orientation of the specimen, the cubes were printed with dots on each side located at the corners as shown in the figure. Corners were printed with holes to get the powder out of the hollow core after the printing.

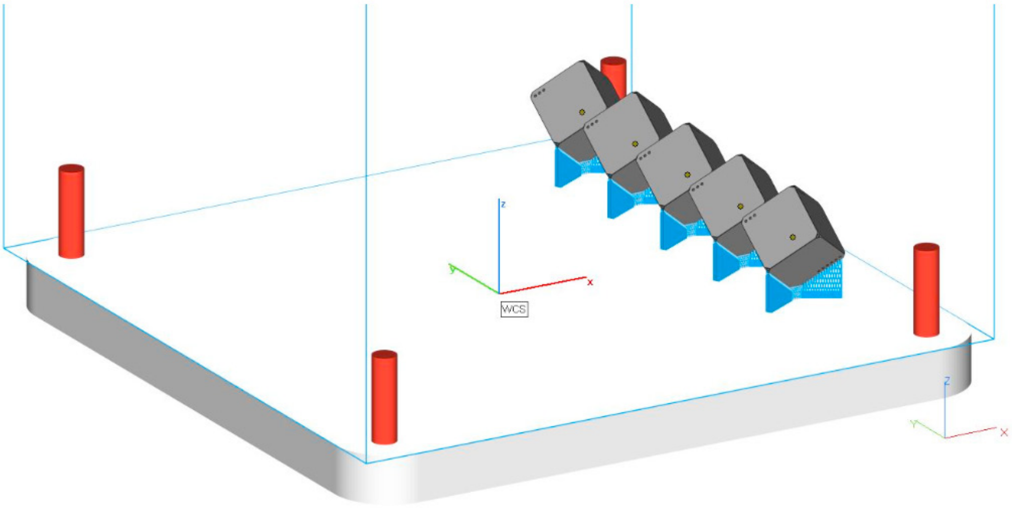

Fig. 1. Placement and orientation of the test specimen on the platform

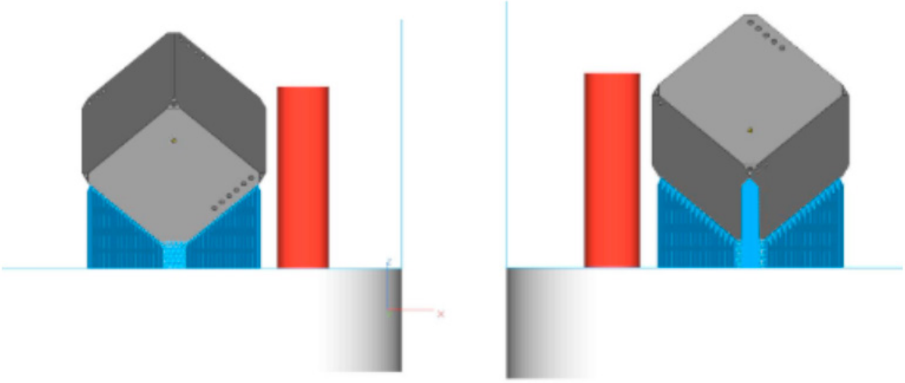

Fig. 2. Closer detail of the test specimen orientation on the platform. Front of the platform looking from the build chamber door on the left and the back view on the right.

2.2. Measured surface quality before surface heat treatment

The focus on this study was to improve the surface quality of the specimen but some tests were also made to roughen the surface. In both cases, it is very important to know the initial condition of the surfaces before any alterations are made so that the results can be compared to them. This was carried out with a profilometer (Mitutoyo Surftest 211) measurement. Several measurements were made for each side and averages and standard deviations were calculated accordingly. These measured Ra values for the initial conditions on each side are presented in Table 1.

Measured results show the predicted effect of side orientation to the build direction on the surface quality. Cube sides that are seen when viewed from below (sides 1,2 and 6) are built in 45 degrees in respect to the platform and the build layers are only partly supported by the previous layer. This results in poor surface quality compared to upper sides that are completely built on preceding layers. Comparing the measurement results show that the upper sides have around three times smaller Ra values than the lower sides.

Table 1. Measured average Ra values for one specimen before surface treatment

Side	Average	Standard deviation
1	15.8	2.03
2	10.2	1.03
3	4.1	0.88
4	7.1	0.77
5	4.4	0.79
6	18.6	3.17

2.3. Surface treatment methods

Surface treatments were carried out by first experimenting with the laser parameters to achieve improved surface quality. Laser power, speed and focus all have an effect to the result and the amount of overlap between the laser paths. These all were considered and in addition, pulsed and continuous wave laser were both studied. Finally, the effect of repeating the same treatment on the surface was experimented with. After the surface heat treatment, the specimen were blasted with glass beads for further improvement. The test setup with one specimen is shown in Figure 3 a) where the angle (15 degrees) between the test specimen and the laser source is also visible. This angle was used to protect the laser equipment from the laser projecting back from the melting aluminium.

Selected parameters and setups for this study are presented in Table 2. Continuous wave laser with a power of 1100 watts with one and two treatments was used with speed of 16 mm/s and +40 mm focus. Beam spacing was 1,5 mm. Results for pulsed laser with power of 2300 W and same speed with varied focus of +40 and +35 are also presented. Detailed pulse shape is shown in Figure 3 b). Wider spacing of 2,5 mm was used for the pulsed laser.

Surface roughening was tested with a pulsed laser and the pulse shape is presented in Figure 3 c). Laser peak power was 1000 watts, speed 25 mm/s and 0 mm focus and the beam spacing was 0.5 mm.

Table 2. Used laser parameters for the surface heat treatments

Set 1	Laser power [W]	Speed [mm/s]	Focus [mm]	Hatch [mm]	Treatments
1	1100 continuous wave	16	+40	1.5	1
2	1100 continuous wave	16	+40	1.5	2
3	2300 pulsed	16	+40	2.5	1
4	2300 pulsed	16	+35	2.5	1
5	1000 pulsed	25	0	0.5	1

3. Measured results for the surface heat treatments

Measured results for the surface heat treatments are collected in Table 3. Results show that a clear improvement was achieved with all the used parameter sets. Relatively best improvements were achieved with sets 1 and 3 where the Ra values more than halved and on set 4 it was also nearly halved. Direct comparison of the results is somewhat difficult as the initial roughness varies between the surfaces quite a lot. Laser parameters in sets 1 and 2 were identical but the treatment was done twice in set 2. Final surface quality is better in Set 2 but Set 1 had around 2.5 times rougher starting point. As the experiments were done, it was visually viewed that doing the treatment twice improved the quality so repeating the treatment for set 1 would further improve the surface quality on it. It is evident that the rougher the surface is the better the improvement is. Surface roughening test results for the parameter set 5 are also presented in Table 3. Using the proposed parameters, the surface is a little over four times rougher in terms of Ra.

Glass bead blasting can be used to further improve the surface quality as can be seen from the measurement results. Like in the heat treatment, improvement is clearly dependent on the initial roughness. If the surface is already smooth

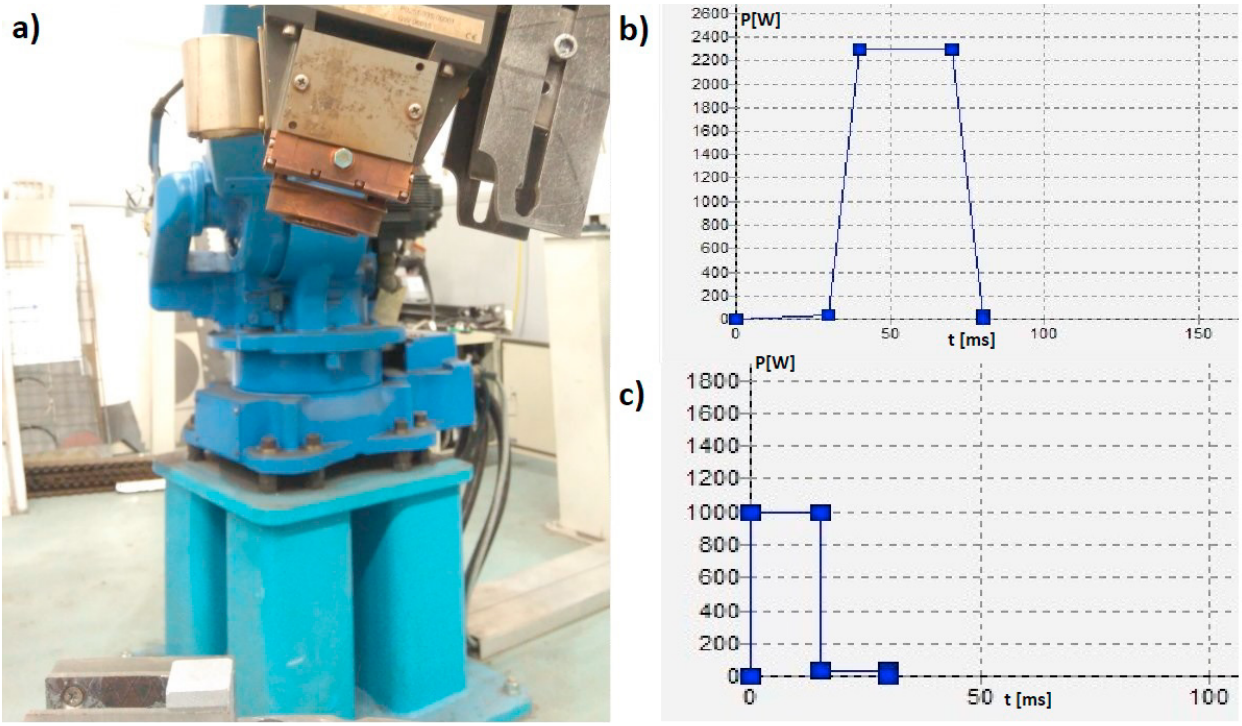

Fig. 3 a) Test setup for surface treatments with laser. b) Pulsed laser for surface quality improvement c) Pulsed laser for surface roughening

no improvement is achieved as can be seen from set 3 where before and after results are within the measurement error. Sets 1 and 2 have and improvement of around 5% but when the initial roughness is higher as in set 4 the improvement with glass beads is also a lot higher, around 20%.

Table 3. Measured average Ra values before and after treatment and after glass bead blasting

Set	Ra before	S.D.	Ra after	S.D.	Ra after blasting	S.D.
1	10.58	2.00	4.09	0.89	3.90	0.53
2	4.20	0.38	3.35	0.63	3.17	0.12
3	5.00	0.79	2.20	0.61	2.52	0.28
4	7.95	1.00	4.37	0.82	3.50	1.25
5	4.12	0.88	18.8	2.17	-	-

4. Conclusions

This study showed that the surface quality of the AlSi10Mg parts produced by SLM can be altered with a disk laser assisted heat treatments. Several parameter sets for the laser treatments were tested and found applicable and the glass bead blasting could be used to further improve the surface quality. Main challenge of the study arose from the SLM method and the inconsistent surface quality between the parts and build orientation. Surface quality straight from the platform is affected by many variables, most notably the location on the build platform (gas flow varies across the platform), powder quality and the orientation of the surface to the build direction. This resulted in variation in the surface quality of the specimen so direct comparison with the tested treatments was more difficult.

It was shown that the studied parameter sets have clearly better impact on the surface quality when the initial quality is rougher. Also, the glass bead blasting after heat treatment has a lot greater effect on rougher surface and at least some of it can be explained by small visible defects on the surface that are partially removed by the blasting. Visual improvement with blasting is clear on all cases regardless.

Both pulsed and continuous laser treatments were shown viable for surface quality improvement. This study was made on planar surfaces for measurability, but the authors believe these methods can be applied to more complex shapes. One limitation of the laser is that it can only be used on directly visual surfaces and very complex structures or cavities would need some other method.

Acknowledgement

The authors would like to acknowledge the financial support received from the European Union (European Regional Development Fund) and the Council of Oulu Region for the “Hybridi” and “Me3Lab” projects and EU, Regional Council of Lapland and County Administrative Board Norbotten for the “C3TS” project.

References

[1] Leon, A. and Aghion, E., 2017. Effect of surface roughness on corrosion fatigue performance of AlSi10Mg alloy produced by Selective Laser Melting (SLM). Materials Characterization, vol. 131, pp. 188-194.
[2] Yang Tian, Dacian Tomus, Paul Rometsch, Xinhua Wu, Influences of processing parameters on surface roughness of Hastelloy X produced by selective laser melting
[3] Strano, G., Hao, L., Everson, R.M. and Evans, K.E., 2013. Surface roughness analysis, modelling and prediction in selective laser melting. Journal of Materials Processing Technology, vol. 213, no. 4, pp. 589-597.
[4] Elijah Kannatey-asibu, J., 2009. Principles of Laser Materials Processing. US: Wiley, Apr ISBN 9780470459195.
[5] Tsion, I., 2005. State of the art in laser surface texturing. Journal of Tribology, vol. 127, no. 1, pp. 248-253.
[6] Temmler A., Willenborg E. and Wissenbach K. Design surfaces by laser remelting, Physics Procedia, 2011
[7] Temmler A., Willenborg E. and Wissenbach K. Laser polishing Proceedings of SPIE - The International Society for Optical Engineering, 2012.
[8] Kempen, K., Thijs, L., Van Humbeeck, J.And Kruth, J.-., 2012. Mechanical Properties of AlSi10Mg Produced by Selective Laser Melting.