

Dimensional and Form Characterization of a Benchmarking Specimen Subjected to Different Post-Processing Technologies for Metal Additive Manufacturing

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Abstract

The major interest for the use of Metal Additive Manufacturing (MAM) in precision tooling have led to a large demand of increased dimensional and form accuracy. In order to characterize both the manufacturing process itself as well as the subsequent post-processing that is inevitable in many cases, a benchmarking specimen has been designed and manufactured. The benchmarking specimen consists of several geometries including external and internal features. The external features include protruding as well as intruding geometries while the internal features range in two different categories relating to channels with square and circular cross-sections respectively. Several identical units of the benchmarking specimen have been manufactured using MAM with stainless steel 316L. After the characterization of selected geometrical parameters including measurands like dimensions and form, the specimens have been subjected to different post-processing technologies such as Functional Coatings (Sol-Gel), Electrochemical Polishing, Dry Electro Polishing and Plasma Electrolytic Polishing. Following post-processing of the specimens the geometrical characterization has been repeated and compared to the initial characterization. The results show that geometrical dimensions are largely dependent on the subjected post-processing technology while form parameters deviate less with different post-processing technologies. By implementing post-processing correction factors, it would be possible to manufacture parts with an increased final accuracy thereby increasing the final quality of specimens manufactured using MAM technology.

Post-Processing, Metal Additive Manufacturing, Quality Assurance

1. Introduction

Major technological improvements within metal additive manufacturing have resulted in a shift from the domain of rapid prototyping (RP) towards the domain of rapid tooling (RT). The RP domain is characterized by its low demand for dimensional accuracy and stability whereas the RT domain have high demands for both these characteristics due to the inheritance of flaws from the tool to products manufactured.[1]

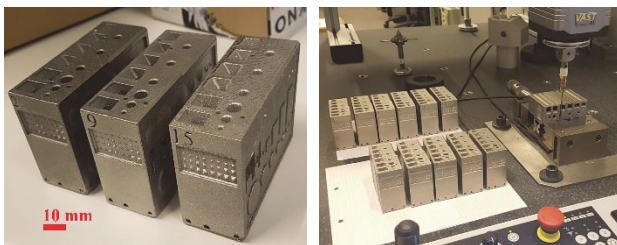


Figure 1. Picture showing specimens subjected to different post-processing technologies as well as the specimens mounted in the CMM measurement setup.

Selective Laser Melting (SLM) is one of the most widely used metal additive manufacturing technologies within the domain of RT. It belongs to the group Powder Bed Fusion (PBF), where a bed of metal powder is fused together in a layer-based manner using laser as the melting source. Within recent years the final manufactured quality both regarding surface parameters as well as dimensional accuracy has increased significantly towards a

point where SLM can be used in the fabrication of complex tools used for manufacturing in several different industries.[2]

This research investigates the capability of the SLM MAM process in the fabrication of a test specimen containing external and internal geometries selected based on industry suggestions for relevant geometries within the field of polymer manufacturing. By subjecting similar units of the same specimen towards different post processing technologies a comparison of said technologies has been performed.

2. Experiments

2.1. Specimen design and fabrication

The specimen has been designed as a square block with a volume of 144cm³ containing both internal and external geometries. The internal geometries are accessed by electron discharge machining (EDM) wire cutting, thus splitting the specimen into three pieces. Each of the two cutting lines will reveal two series of square channels and circular channels respectively. Examples of the specimen can be seen in figure 1.

The specimen contains flat faces as well as curved features with different orientations towards the build direction. Due to the large variety of design features, the investigation of a few selected key features will be presented in this article while the remaining features and geometries may be investigated later.

A total of 18 specimens were manufactured during a single build-job using a SLM solutions 280 2.0 machine fitted with 316L stainless steel. All specimens were separated from the build-plate and subjected to a variety of different carefully selected post processing procedures as described later.

2.2. Specimen post-processing

The current industry practice for the post-process treatment of MAM components is abrasive blasting and/or vibration deburring typically using a ceramic abrasive medium. The abrasive blasting is typically performed using either glass or corundum particles. In order to replicate industry practice, all 18 manufactured specimens were subjected to both glass blasting and vibration deburring using ceramic abrasive particles prior to any additional post processing.

Following the standard post-process treatment, three specimen units were delivered to five different suppliers respectively who each subjected the specimens to a specific type of post-processing. The five different post-processing technologies included in this investigation are comprised of: 1) Functional Coating (Sol-Gel), 2) Dry Electropolishing, 3) Optimized Abrasion Process, 4) Electrochemical Polishing and 5) Plasma Electrolytic Polishing. A more thorough description of the specimen MAM fabrication process as well as each of the post processes has been presented in another study.

2.3. Dimensional and form measurements

In this research the external length dimension has been measured. Furthermore, the flatness of the sidewall surfaces as well as the top surface of the specimens has been characterized.

Prior to any post-processing of the specimens, a characterization of the selected geometrical measurands was performed, thus also yielding a characterization of the as printed specimen, the vibration deburred specimen and the vibration deburred + glass blasted.

The measurement procedure has been performed using scanning measurements with a scanning speed of $v=2.5\text{m/s}$. All measurements were performed in a temperature-controlled environment at 20 degrees Celsius using a Zeiss PRISMO CMM with a VAST XT Gold scanning head fitted and a synthetic ruby spherical probe of diameter $\varnothing 3\text{ mm}$ for external measurements and diameter $\varnothing 2\text{mm}$ for internal measurements. A total of five repetitions of all presented measurements were acquired.

3. Results and Analysis

3.1. External dimensions

The large external length of the specimen with a nominal value of 80 mm has been measured by characterizing a plane on each opposing face and evaluating the distance in between these planes. From figure 2 it can be seen that the As-Printed specimen is deviating from the nominal value while the vibration deburring and glass blasting increases this deviation as would also be expected due to the abrasive nature of both these processes. The same result is found for all other post processing technologies except #1 being a functional coating.

3.2. Surface flatness

The surface flatness has been measured on both surfaces being parallel to the AM build plate (horizontal surfaces) as well as perpendicular to the AM build plate (vertical surfaces).

Larger horizontal surface flatness with a larger standard deviation observed in comparison to the vertical surfaces as shown in figure 3.

It can be seen from the figure that a decreased flatness is experienced when subjecting the specimen towards vibration deburring and glass blasting. The largest decreasing contribution is found from glass blasting which would also be expected due to the manual nature of this particular process. Furthermore, the selected five post-processing technologies does not seem to differ with regards to their resulting plane flatness for neither horizontal nor vertical surfaces.

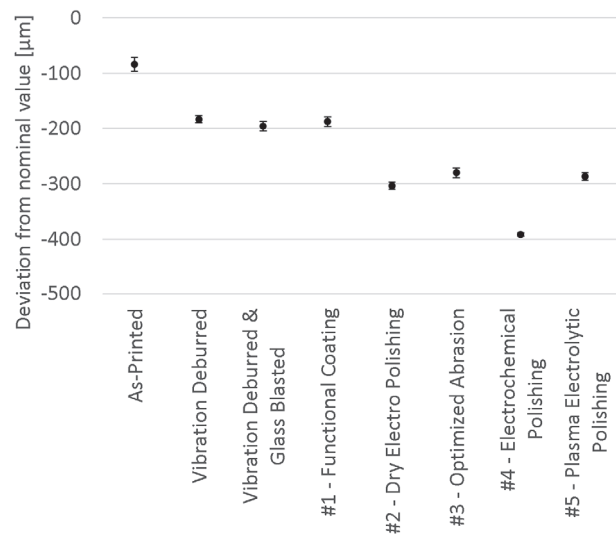


Figure 2 Absolute length deviations from the nominal value of 80mm of the benchmarking specimen dependent on the type of post processing. STD as error bars.

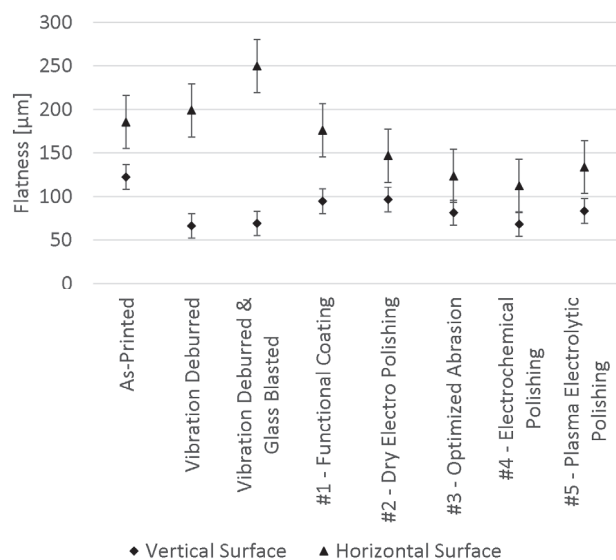


Figure 3 Plane flatness dependent on both plane orientation with regards to the build direction (vertical = perpendicular and horizontal = parallel) as well as subjected post process technology. STD as error bars.

4. Conclusion

The investigation has shown the AM manufactured part with deviation of nominal geometry before and after the industry standard post processing procedure involving abrasive blasting and/or deburring. Furthermore, it was found that the investigated post processing technologies contribute the dimensional deviation. It was also found that the form deviation relating to flatness is highly dependent on the implemented type of post processing technology.

The results from this investigation contribute by providing basic information about the industry practice as well as how to adjust and apply compensating means to achieve increased quality within MAM technologies.

References

- [1] Chua C K, Leong K F, and Liu Z H. 2015, *Handbook of Manufacturing Engineering and Technology*, London (Springer-Verlag), 2525-47
- [2] T. Wohlers, "Wohlers report," *Wohlers Assoc. Inc.*, 2018.