IOWA STATE UNIVERSITY
Department of Mechanical Engineering

Honors Poster Presentation
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The effect of DMLS (direct metal laser sintering) additive manufacturing laser power and laser speed on part surface finish and hardness.

Introduction & Objective

This research project focusses on test parts produced using direct metal laser sintering (DMLS) technology which is often referred to as metal 3D printing.

In metal 3D printing, surface finish is often in question as the DMLS process is limited in the surface roughness it is able to achieve. It is common for people to question the ability of a metal 3D printer to produce a certain surface finish and often researchers want to know what effect the changing of speed and laser power will have on surface finish.

Common techniques used to achieve a finer surface finish after metal 3D printing include shot peening, abrasive blasting, polishing, grinding, and a few others [2]. It would be ideal if an industry part could be produced using DMLS technology and not require much, if any, post processing before the part is put into service. As a result, it is important to learn about the effect of changing system parameters on the ability to achieve a desired surface finish. Thus, this project evaluates the effect changing laser speed and power has on a test part's surface roughness.

During this project, the hardness of parts produced is also examined. Hardness is a property of metals often considered when a material is chosen for a specific application. It is a measure of how resistant a solid is to permanent deformation when a force is applied to it and can have an effect on a material's ability to withstand wear or its ability to be easily machined or ground [3].

Although it would be ideal to produce all metal 3D printed parts and put them into service without requiring any post-processing, this is generally not always the case. Post-processing typically occurs on parts that require an extremely fine surface finish and the ability to grind or machine a metal 3D printed part is important. So, hardness data was also collected on two surfaces of the test parts in this project.

Methodology

A 3D Systems, Inc. ProX® DMP 300 direct metal printer was used during this project. Some specifications of the machine are the following [1]:

- Laser Power: 500 W
- Laser Wavelength: 1070 nm
- Layer Thickness: 40 µm
- Build Volume: 250 x 250 x 300 mm
- Material Deposition: Roller
- Material Used: 17-4 PH stainless steel powder

Stock Settings of the ProX® DMP 300 printer used by CIRAS (Center for Industrial Research and Service) at Iowa State University:

- Laser Power: 60% (300 W) laser power
- Laser Speed: 2500 mm/s

The settings changed during this project can be defined as the following:

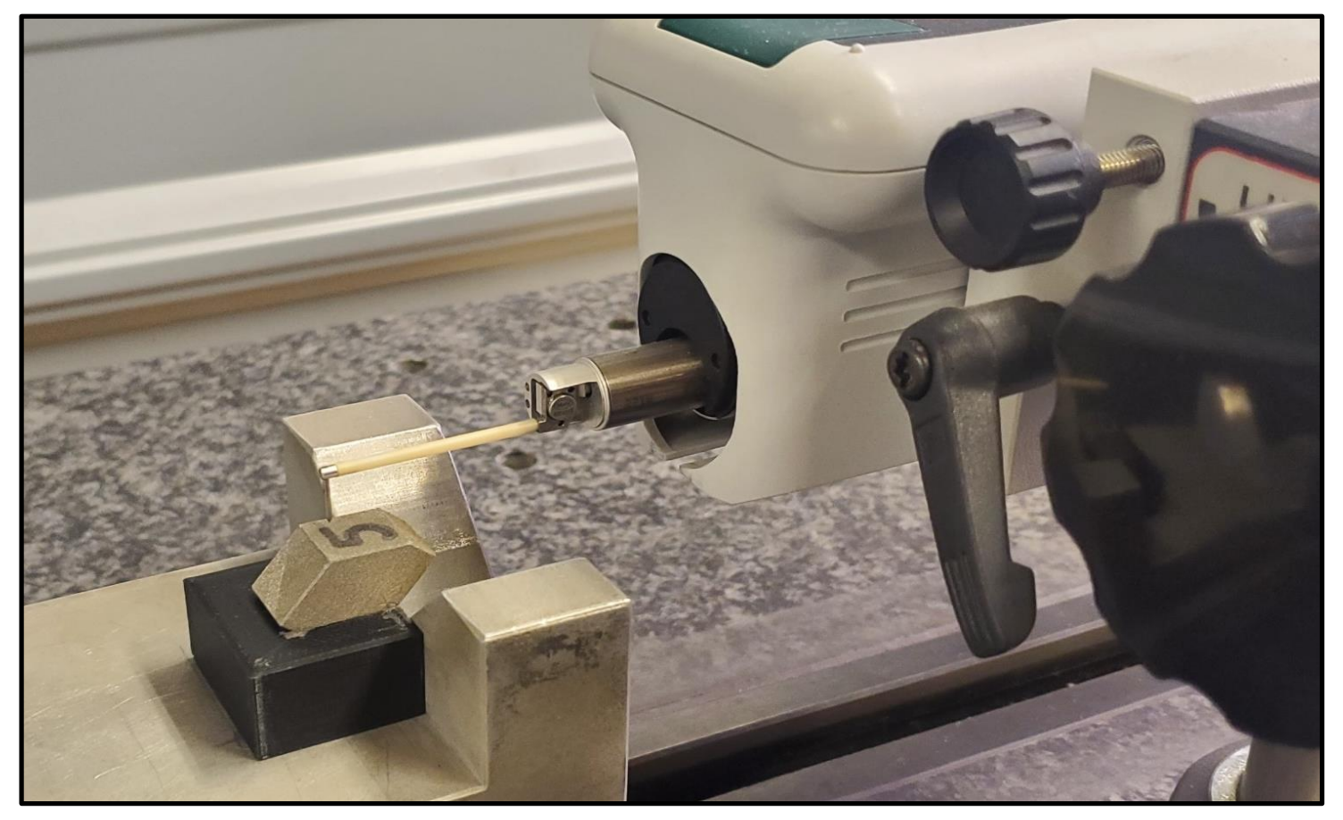
- Low Power, Low Speed
- Low Power, High Speed
- High Power, Low Speed
- High Power, High Speed
- Mid Power, Mid Speed

Low Speed: 1800 mm/s
Mid Speed: 2350 mm/s
High Speed: 2900 mm/s
Low Power: 200 W
Mid Power: 275 W
High Power: 350 W

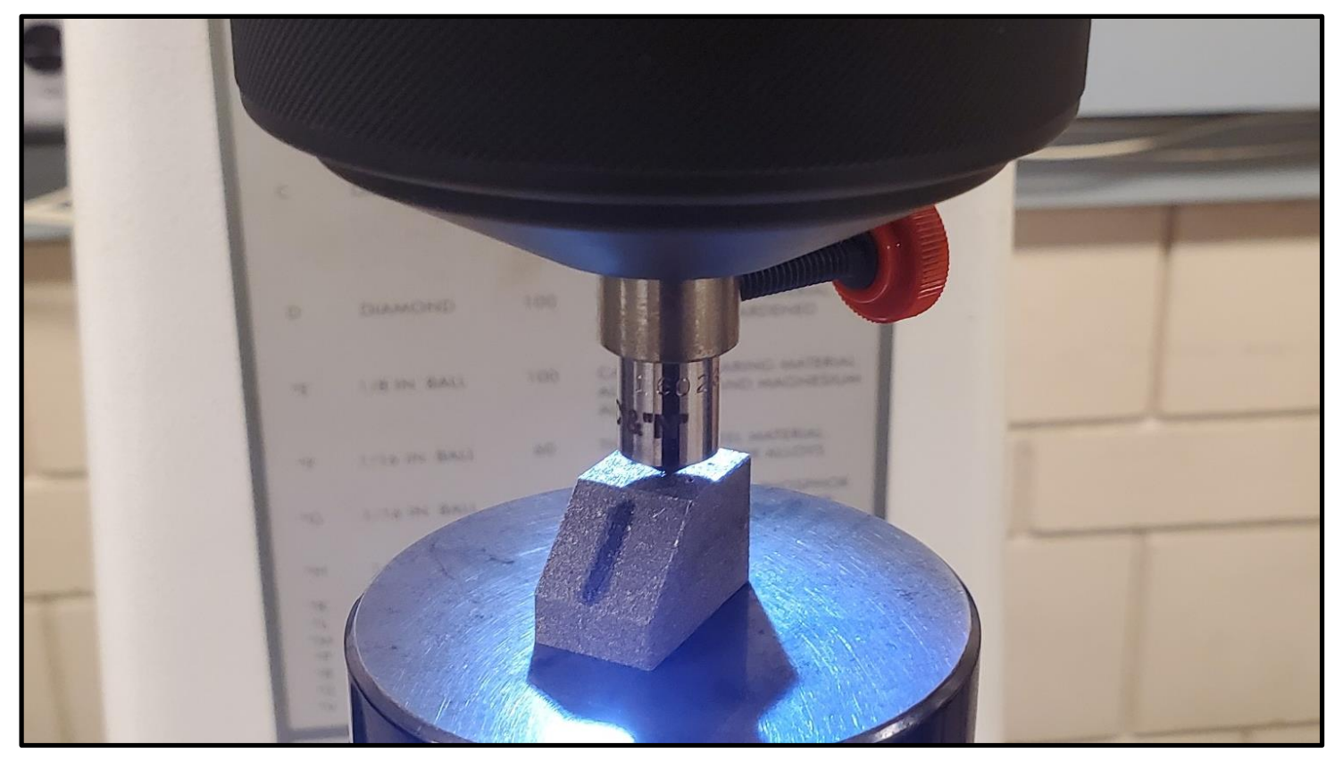
Surface finish data was collected using a Mahr MarSurf SD 26 contact profilometer with a 60-degree diamond tip contacting probe.

Hardness data was collected using a Leco LR-Type Rockwell Hardness Tester with a diamond-tip indenter.

The data collected was fitted into the above-mentioned groups and was analyzed using Minitab statistical analysis software.



Roughness Data Collection Set-up



Hardness Data Collection Set-up

Results

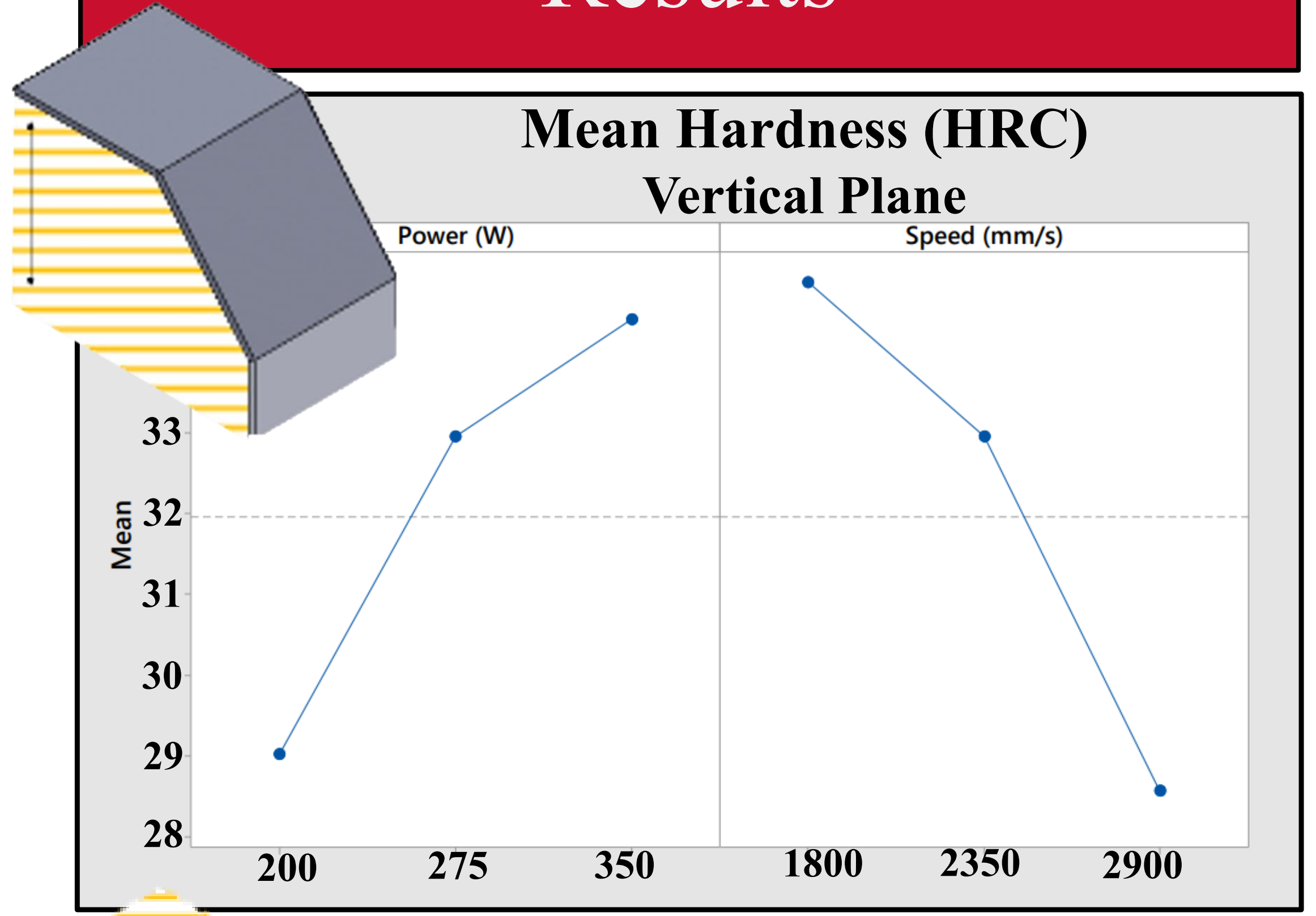


Figure 1.0

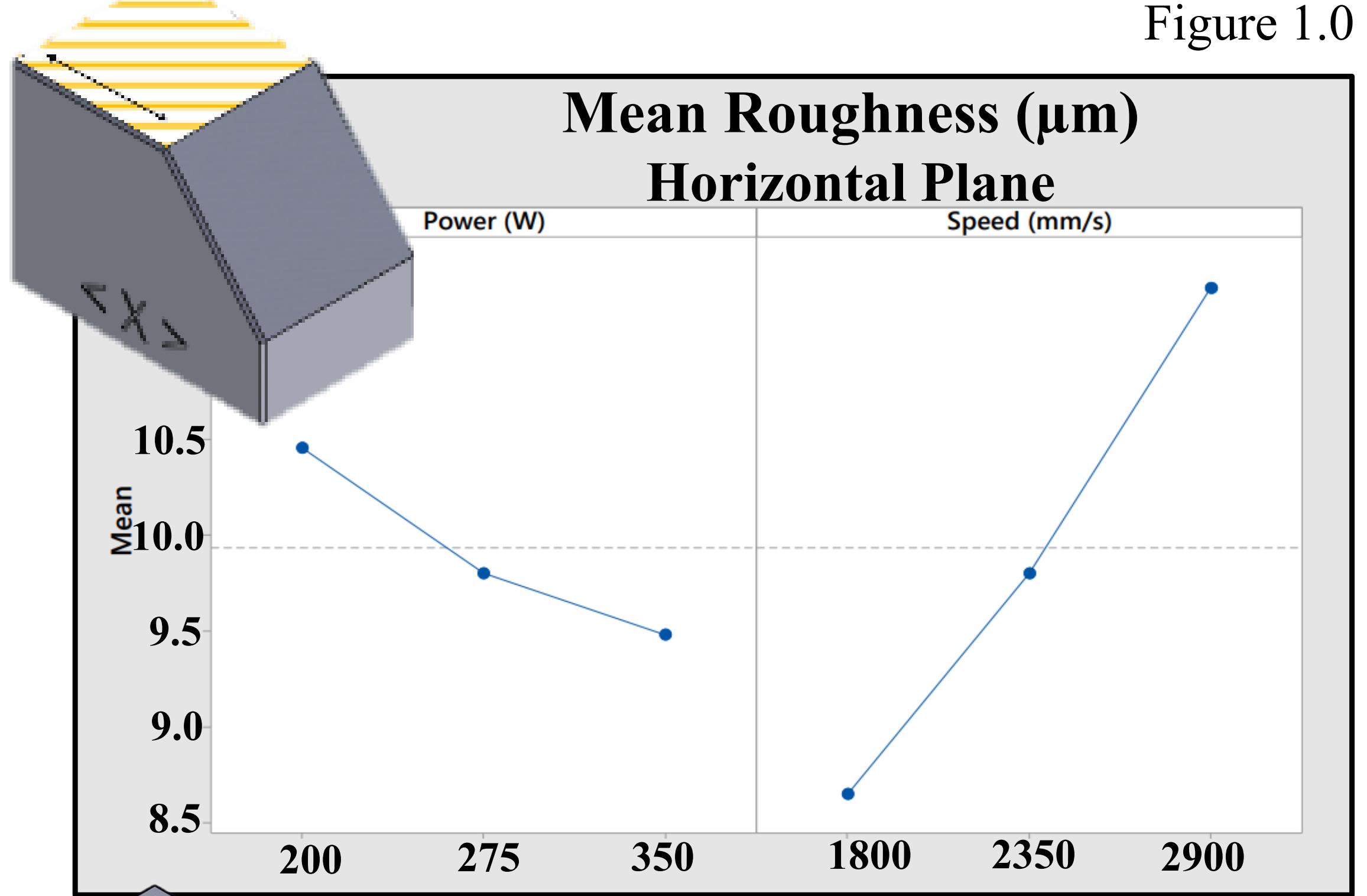


Figure 2.0

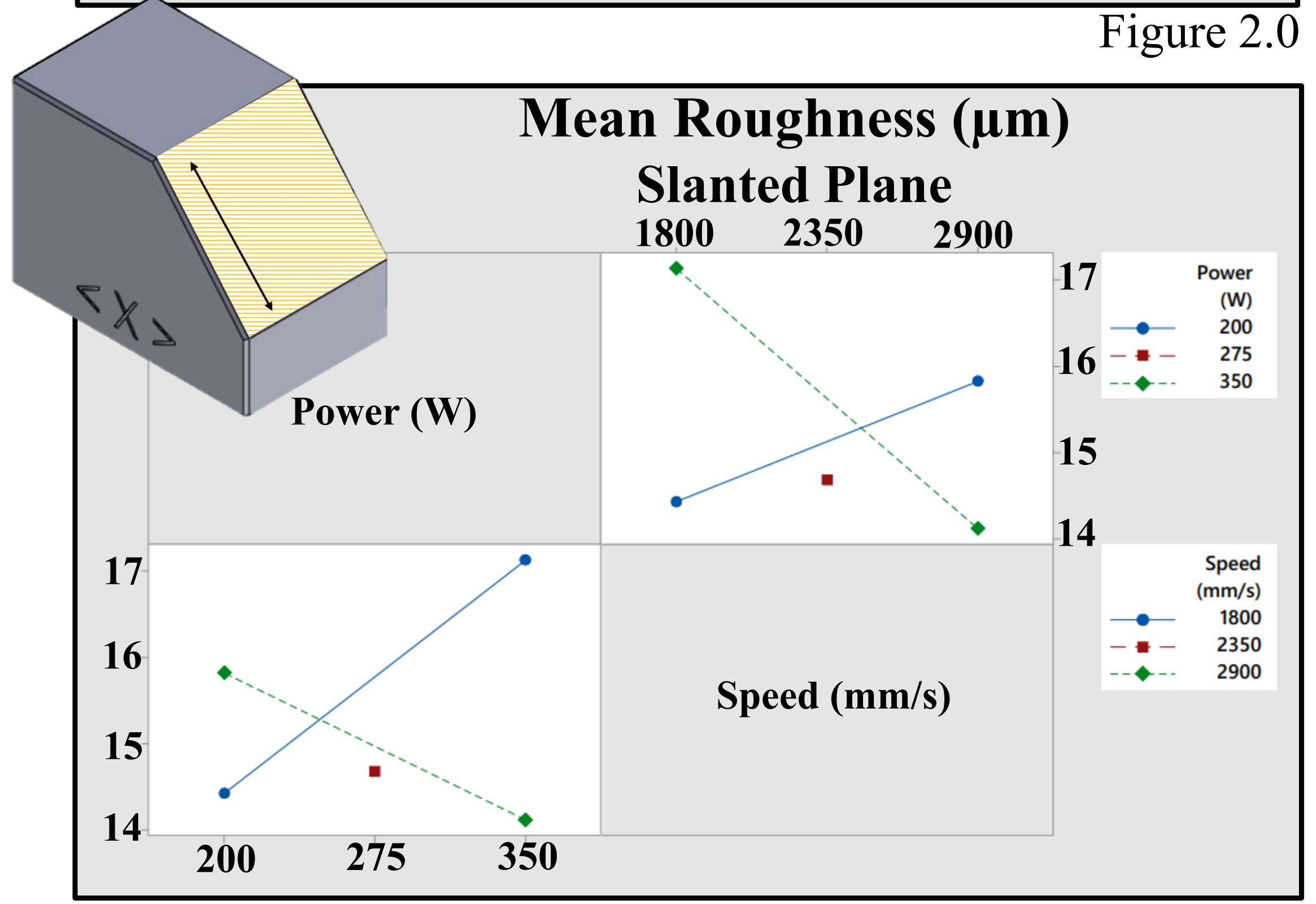


Figure 3.0

Trends from this data appear to be relatively benign, but there are still some relationships and effects of changing laser power and laser speed.

Figure 1.0 shows a relationship between changing laser speed and laser power on the hardness of the vertical side (side 4) of the test part. The same relationship is also true on the horizontal side (side 1) of the test part.

Trends and Interactions Discovered:

1. **As laser speed increases, the hardness of the surface decreases and as laser power increases the hardness of the surface increases on the vertical surface.**
   - The Main Effects Plot of hardness for the horizontal surface is not shown in this poster; however, the trend appears to be the same as it is for the vertical surface.
2. **On the horizontal surface, as speed increases, the surface finish becomes rougher. Also, as the power level increases, the surface finish becomes less rough.**
   - Figure 2.0 shows that there is a relationship between laser speed and average roughness.
3. **Increased speed and decreased power both result in a less rough finish on the vertical surface.**
   - There also appears to be a reaction between laser speed and laser power on this surface. A surface finish that would not be obtained by changing only one of the variables is able to be obtained by changing both.
4. **There is an antagonistic interaction between power and laser speed on the slanted surface.**
   - The independent variables have an effect on each other and the surface finish. A surface finish that would not be obtained by changing only one of the variables is able to be obtained by changing both variables.

- Relationships are visible in the main effects and interaction plots but are not significant.
- Figure 4.0 shows the effects of roughness on the horizontal surface. Speed has the greatest effect on surface roughness on the horizontal face. This is also true for the vertical face.
- On the slanted surface, the combination of the two variables (speed and power) have a greater effect than the variables have individually.

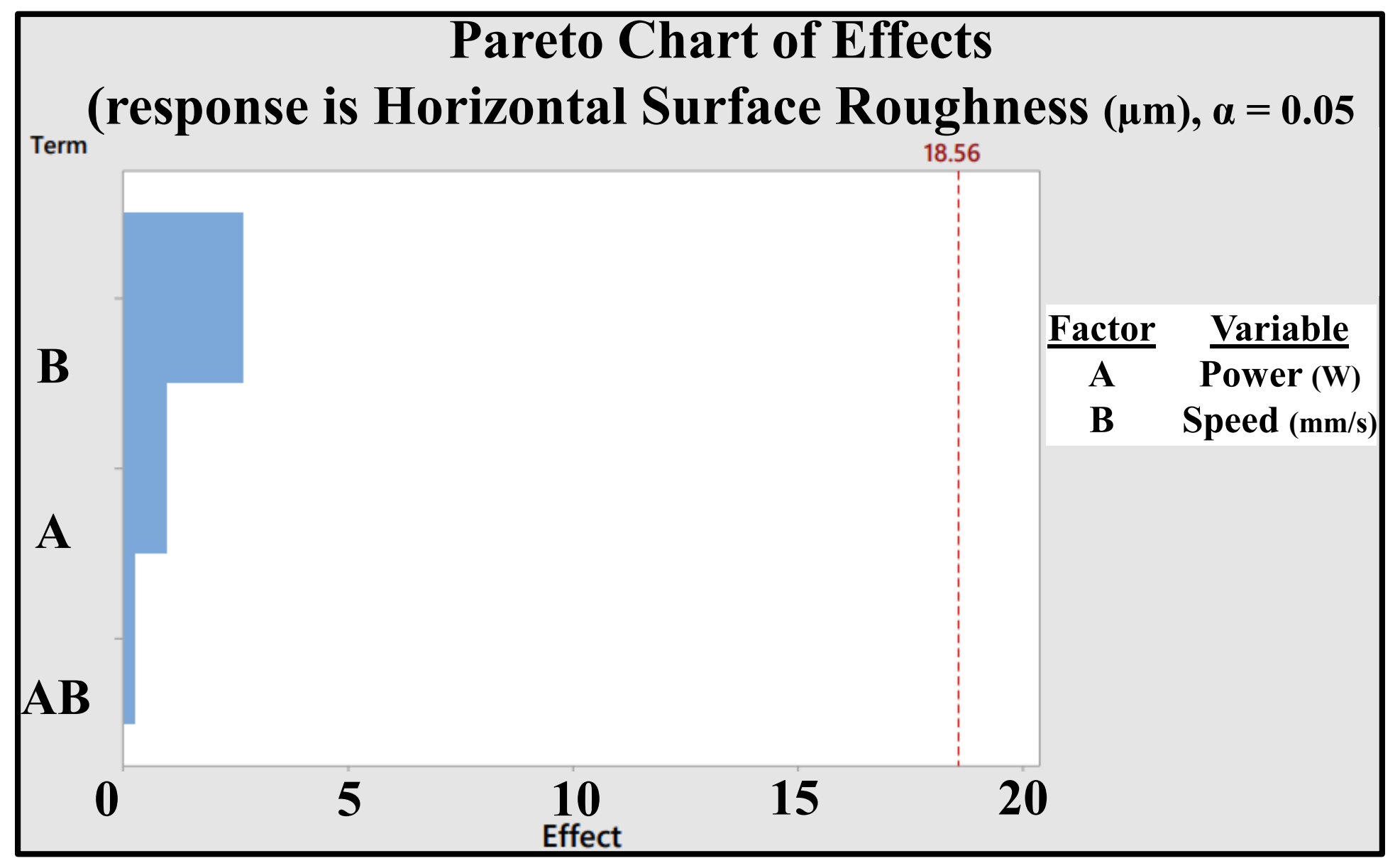
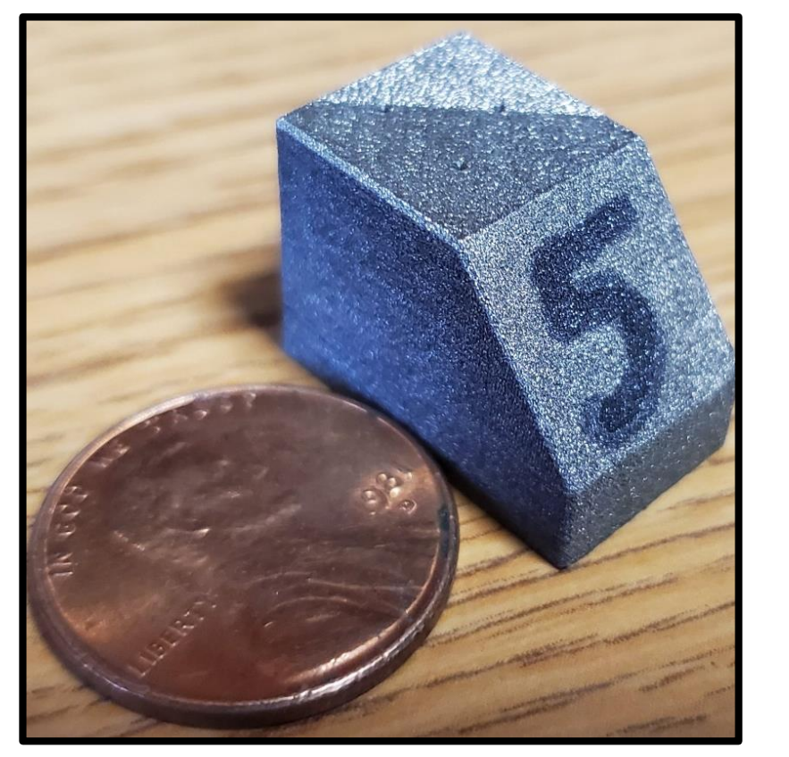


Figure 4.0



Close-up view of 17-4 SS test part

Conclusion

- Changing both speed and laser power have an effect on surface finish and hardness.
- This effect is not a critical factor in achieving a desired output surface finish or roughness and requires further investigation to determine a statistically significant effect of these variables.
- The trends shown above may be used to obtain a general desired surface finish on future parts although there may still be some uncertainty.

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References:

[1] ProX DMP 300. (2020, September 14). Retrieved November 24, 2020, from https://www.3dsystems.com/3d-printers/prox-dmp-300

[2] KV. Wong, A., RI. Campbell, M., PM. Pandey, N., LM. Galantucci, F., Chil-Chyuan. Kuo, S., & A. Lamikiz, J. (1970, January 01). Post Processing Methods used to Improve Surface Finish of Products which are Manufactured by Additive Manufacturing Technologies: A Review. Retrieved November 24, 2020, from https://link.springer.com/article/10.1007/s40032-016-0340-z

[3] Hardness. Retrieved November 24, 2020, from https://www.sciencedirect.com/topics/engineering/hardness