

Exercise of AM Digital Shadow/Twin

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# Preface

The objective of this report is to manage the diverse and complex data in modern digital manufacturing. We will explore it by combining different types of data, such as measurements from microscopy images, sensor readings, and X-ray CT analysis, to pinpoint potential risk areas in operational processes. The focus of the report is to establish a correlation between various process parameters – both controlled and uncontrolled – and the resulting properties of manufactured parts, such as roughness and hardness. This creation is the creation of a digital shadow/twin of the powder bed fusion metal additive manufacturing process, utilizing a combination of experimental data from multiple sources. This will provide practical insights into the complexities and methodologies involved in digital twin creation within additive manufacturing, (“Exercise of AM Digital Shadow/Twin”, 23 November 2023).

# Introduction

# Step 1: Filling in the table on the sheet “Result of DoE.”

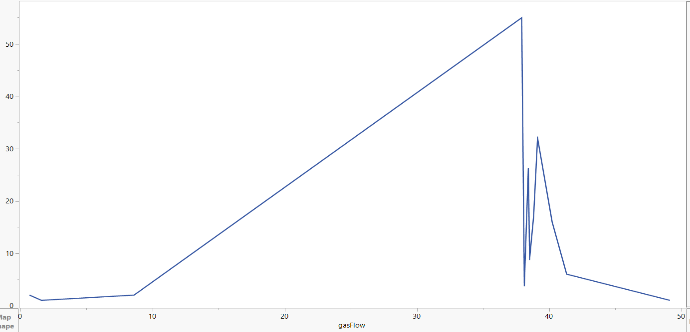
In the section of step 1, we are going to fill in the table on the sheet for the “Result of DoE”, based on the file “DoE and results”. This part it is 5 sub-parts: filling the “Real GFS”, “Real O”, and “Real O STD” columns, filling the Porosity column, filling the Hardness column, filling the Converted GFS column, and a discussion with the group about which of the scaling approach is more suitable.

## JMP and Graph Analysis

The “DoE and results” xl-spreadsheet contained 14 components with recorded sensor data with variables like layer data, oxygen value, and measured gas flow. It also contained an unfilled DoE and a porosity sample, (“Exercise of AM Digital Shadow/Twin”, 23 November 2023).

Firstly, we selected the gas flow column of the file that was imported and used the graph builder feature in JMP to plot a 2D line graph to observe the trend of Sample 1 of the gas flow speed. The graph had multiple sudden rises/drops in the sensor reading and some were bigger than others, but it corresponded to the process being interrupted (either because the process ended or because the production of support structures had started), (“Exercise of AM Digital Shadow/Twin”, 23 November 2023).

Figure 1: 2D plot of the gas flow speed including rises and drops.

Analyzing Sample 1, the graph shows a very clear trend in the gas flow speed with a significant rise/drop toward the end of the process. To evaluate what is the appropriate way to calculate the mean and standard deviation for the observed data it is important to first determine the range of data points before the sudden rise/drop, which represents the stable operation of the process. Secondly, based on Figure 1 to the right, the data shows a relatively stable trend before the sudden rise/drop, which suggests that the process was operating in a consistent manner during the period. As mentioned earlier, the rise/drop is likely an outlier or a result of a different process condition, such as the end of the process or the start of support structure production, and that data should not be included in the calculation of the mean for the normal operation conditions. So, based on the trend of the graph the appropriate way to calculate the mean of the gas flow speed is to use the arithmetic mean, and that is because the arithmetic mean is straightforward to calculate. Also, the two other mean calculations geometric mean are more appropriate for data that are log-normally distributed, and the root mean square (RMS) is useful for variables where the magnitude is important regardless of the direction, that’s why the arithmetic mean is more appropriate. (Write more about the step, talk about the data points and the graph from the JMP, then the arithmetic mean and why, other possibilities of mean, and standard deviation. And discussion at the end about why I chose that.)

## Calculation of Arithmetic Mean and Standard Deviation

For the calculation of the chosen mean and standard deviation, the first to do was to create a range for the data points so that the calculation that was made was only made when the data points were normally distributed. So, after observing the rise/drops in the graph the values that were out of normal were excluded in the calculations. The range for the data points that was used in the calculations for normal distribution was from [37.9, 41.3], and for the calculation of the arithmetic mean:

After using JMP for this calculation in Sample 1, the result for the arithmetic mean was:

Further, to calculate the standard deviation of the set for the range of the data points that is chosen, we can now since we know the arithmetic mean, calculate the standard deviation, and follow the following formula:

* represents each value in the data set.
* is the arithmetic mean of the data set, which in our case is 38.688484848.
* is the number of values in the data set.
* the sum over all the values .

After using the JMP for the standard deviation calculations, the result for the standard deviation was:

So, the arithmetic means and standard deviation for Sample 1 was and where we will know to do the same for the oxygen %, and repeat this for all the 13 other Samples, (Wikipedia, 2023).

## Calculation for the Converted GFS

Now that almost all the columns in the xl-spreadsheet are filled with the analysis from the JMP, the calculations will help us calculate the converted GFS. So, to calculate the GFS we need to apply a formula that adjusts the real Gas Flow Speed (GFS) values to a scale that fits between 1.5 and 2.5. This is a linear transformation, where we map the original range of GFS to the target range of 1.5 to 2.5. The formula for scaling the numbers from its original range to a new range is:

, where:

* is the scaled value.
* (the minimum of the new scale)
* (the maximum of the new scale)
* is the original GFS value.
* is the minimum GFS value in the original data.
* is the maximum GFS value in the original data.

With this formula and using JMP to calculate and implement the , , , , and , the next step is to insert the given formula above to insert the given values under the column, (Han, J., Kamber, M. and Pei, J, 2012).

## Filling the Porosity column

# List of Figures

[Figure 1: 2D plot of the gas flow speed including rises and drops. 3](file:///H:\github\cs-ntnu\ntnu-dtu\5-semester-dtu-exchange\41740\assignment-2\report\DigitalManufacturing-Report-2.docx#_Toc151713126)

# References

[1] “Exercise of AM Digital Shadow/Twin”, 23 November 2023. [Exercise of AM Digital Shadow/Twin]

[2] Wikipedia (2023) *Standard Deviation, Wikipedia.* Available at: <https://en.wikipedia.org/wiki/Standard_deviation> (Accessed: 24 November 2023).

[3] Han, J., Kamber, M. and Pei, J. (2012) *Max normalization, Max Normalization – an overview | ScienceDirect Topics.* Available at: <https://www.sciencedirect.com/topics/computer-science/max-normalization> (Accessed: 24 November 2023).

# Appendix

[1] JMP®, Version <17.2>. SAS Institute Inc., Cary, NC, 1989-2023