Additive Manufacturing and Reverse Engineering Project Report

311.172 - Industry 4.0 - Integrated Framework of Advanced Production and Metrology Technologies

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1. What is Additive Manufacturing and Reverse Engineering

1.A. Definition, Methods and Tools

Additive Manufacturing means that units of feedstock material are brought together and joined (e.g. fused or bonded), most commonly layer by layer to build a part (3D). There are some differentiations on use of materials, since the technical properties of different materials and therefore different principles of fusion or adhesion. For the AM processing, the products' fundamental properties are determined by;

- Type of the material (polymer, metal, ceramic, composite)
- Principle applied fusion or bonding (melting, curing, sintering, etc.)
- Feedstock that is used for adding material (liquid, powder, suspension, filament, sheet, etc.)
- How the material is brought together, i.e. machine architecture

Reverse Engineering (RE) is the process of duplicating of a man-made object, by deconstructing (in aim to reveal its design and measurements) or getting the technical data of the product with several various object measuring methods to create a virtual model of the product and produce it again using this virtual model and collected data.

In principle, it is a reproduction of the finished product that does not publish its properties or information solely by looking and investigating by the original manufacturer. It is therefore generally utilized in organizations and countries that are not very developed and are intended to produce a similar product without having to invest high sums of money.

Reverse Engineering is mostly important for the Industries, when for example, the technical data (2D Drawing or 3D – CAD Model) of a product is missing or lost. And RE of surfaces is also very important for the modelling of free form / non-parametrizable surfaces with the curves, planes and bores.

The standard for reverse engineering of geometrical data is VDI 5620:2017. "The description of potential application scenarios and the selection of each use case-oriented technology for 3D data acquisition and reconditioning are central to the description in the standard."

2. Our Project

In our project, we practiced the methods and the processes of reverse engineering.

We have used the high-technologic measuring machines throughout the practice. The machines we have used in the laboratory was the co-ordinate measuring machine and computed tomography machine.

2.A. Measuring of the original object

At first, we measured our original object with a slide caliper to get the measurements of the object and noted them to use the values for the next step, 3D-Drawing of the object in SolidWorks.



Figure 1: Slide clipper and the original Object (Spannzylinder)

This step is the most important step at the beginning of the project, since the measurement which is made with a slide caliper should give us the correct measurements of the object.

2.B. 3D-Drawing of the original object using SolidWorks

Following step, drawing of the Object using SolidWorks. According to the measured dimensions, we constructed a 3D Model of our workpiece. This drawing is going to be used on the next step – 3D-Printing. In order to print our prototype with 3D-Printer, the CAD-Document should be converted to .STL format.

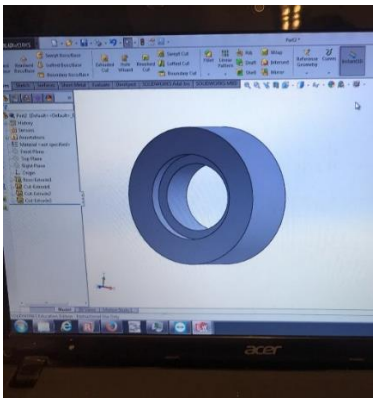


Figure 2: Visualization of the 3D-Modelling Process using SolidWorks

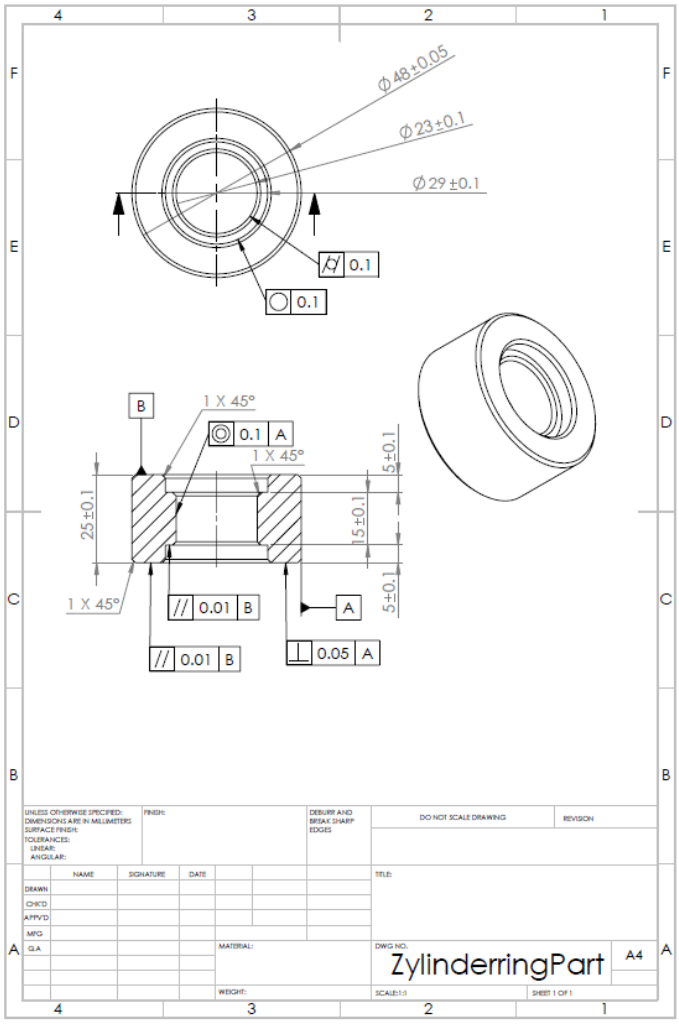


Figure 2: Technical drawing of the constructed 3D-Model

After that we finished constructing step, we prepared the technical drawing by taking all the diameters, dimensions, tolerances and the specified deviations from the measured values into consideration.

This technical drawing is also our reference document to compare our 3D-printed object with the original one and then analyze all the deviations and possibly inexact/defective parts of the printed object.

2.C. 3D-Printing of the Prototype

Using our Renkforce RF1000 3D printer, we printed our Prototype according to the measurements of the 3D-Model (which was constructed using SolidWorks).

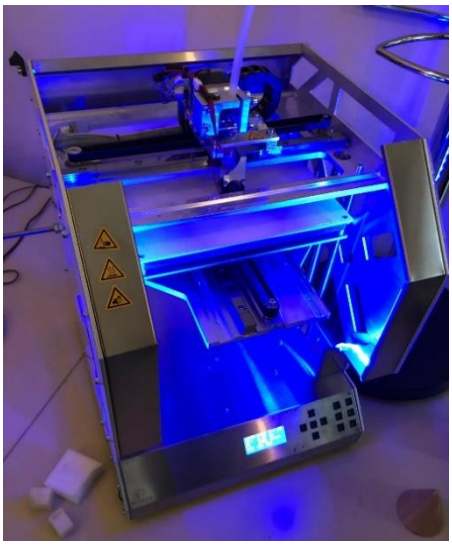


Figure 4: 3D-Printing Process of the Prototype

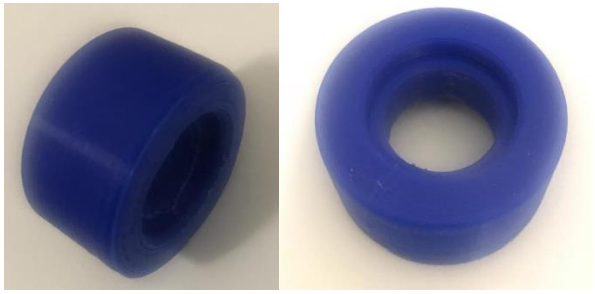


Figure 5: 3D printed Prototype

2.D. Measuring of the Prototype using CMM and CT

Measuring with CT

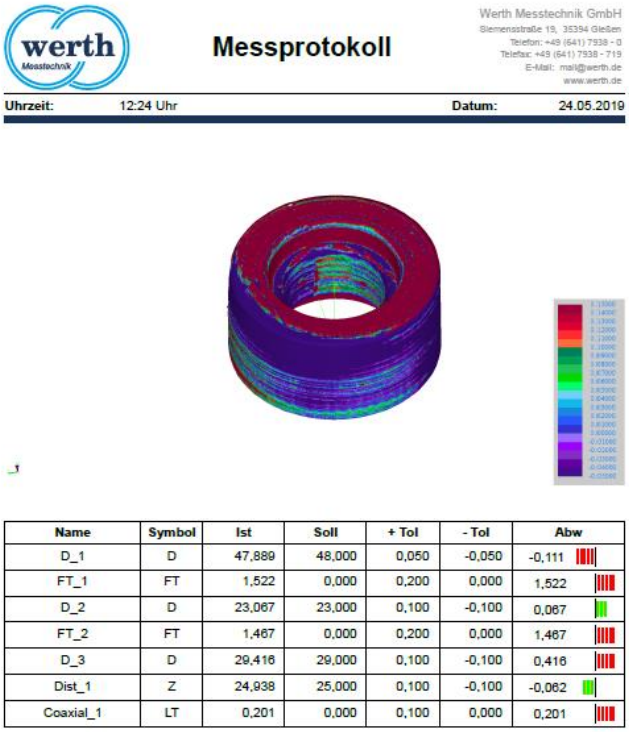
Using two different types of machines which use different methods of measurement, we measured the dimensions of our 3D printed prototype. This gives us first the opportunity to compare the prototype and the original object by their surface deviations, tolerance differences, pores or defects and secondly to see how well the prototype produced (printed).

By measuring our prototype with two different machines, we are also able to compare the machines by comparing the report data, which received from both machines separately.

At first, we realized the measuring process with Werth TomoScope® XS - Computed Tomography Machine.



Figure 6: Measuring of the Prototype with Computed Tomography (CT) Machine



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Messprotokoll

Uhrzeit: 12:24 Uhr **Datum:** 24.05.2019

Name	Symbol	Ist	Soll	+ Tol	- Tol	Abw
D_1	D	47,889	48,000	0,050	-0,050	-0,111
FT_1	FT	1,522	0,000	0,200	0,000	1,522
D_2	D	23,067	23,000	0,100	-0,100	0,067
FT_2	FT	1,467	0,000	0,200	0,000	1,467
D_3	D	29,416	29,000	0,100	-0,100	0,416
Dist_1	Z	24,938	25,000	0,100	-0,100	-0,062
Coaxial_1	LT	0,201	0,000	0,100	0,000	0,201

Figure 7: Report after measurement with CT Machine

At the end of the measurement, we were able to compare the 3D-Model (CAD-Model from section 2.B.) with our printed prototype.

The results were interesting, because only the two of seven measured tolerances were matching with the from us given tolerance interval.

The other five tolerances were unacceptable, since the deviations were too high to accept, therefore the production of the prototype was not successful as we expected it to be.

Measuring with CMM

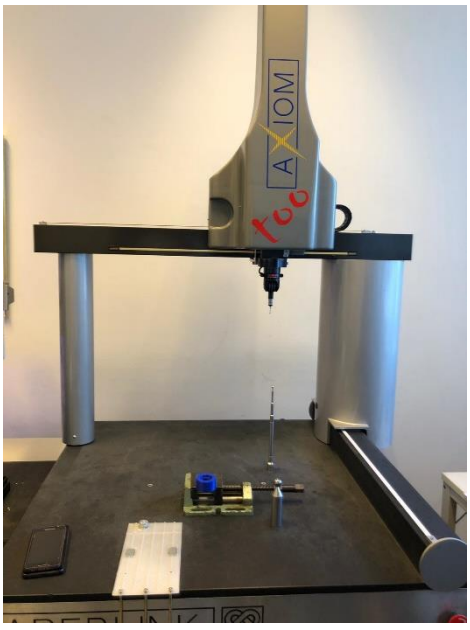


Figure 8: Measuring of the Prototype with CMM

After using the CT Machine, we realized the measuring process with ABERLINK Axiom too CNC CMM (Coordinate-Measuring Machine).

We placed our prototype in the machine and then we made a manual touching onto our workpiece to define the coarse dimensions of the prototype.

Next, we started the machine using the CNC Program to measure our workpiece to get the dimensional data.

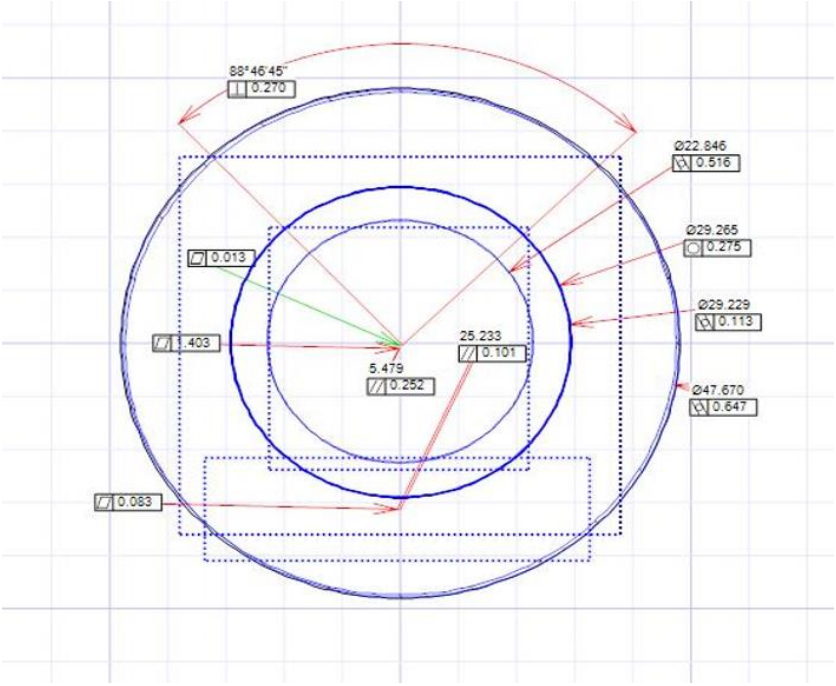


Figure 9: Measured dimensions and tolerances - CMM

AuM

Zeichnungsnr.		Auftragsnr.		Datum	24.05.2019 11:41
Bezeichnung		Serien Nr.		Prüfer	
Kunde		Werkstoff		Bemerkungen	

1		i	j	k	Punkte		Ebenheit
Ebene		0,009	-0,004	1,000	4		0,013

2	Durchmesser	Anfang X	Anfang Y	Anfang Z	Punkte	Länge	Zylindrizität
Zylinder	48,075	0,000	0,000	4,751	8	9,502	0,080
		Ende X	Ende Y	Ende Z	i	j	k
		0,000	0,000	-4,751	0,000	0,000	-1,000

3	Durchmesser	Anfang X	Anfang Y	Anfang Z	Punkte	Länge	Zylindrizität
Zylinder	47,670	-0,078	0,108	-6,312	50	12,672	0,647
		Ende X	Ende Y	Ende Z	i	j	k
		0,177	-0,168	6,355	0,020	-0,022	1,000

4	Durchmesser	Anfang X	Anfang Y	Anfang Z	Punkte	Länge	Zylindrizität
Zylinder	22,846	-0,013	0,196	-4,394	50	5,905	0,516
		Ende X	Ende Y	Ende Z	i	j	k
		-0,016	0,120	-10,298	0,000	-0,013	-1,000

5		i	j	k	Punkte		Ebenheit
Ebene		0,001	0,000	1,000	26		1,403

6		i	j	k	Punkte		Ebenheit
Ebene		-0,006	0,001	-1,000	22		0,083

7	Durchmesser	X	Y	Z	Punkte	Proj Ebene	Punkt Spanne
Kreis	29,265	0,052	0,094	6,076	50	1	0,275

8	Durchmesser	Anfang X	Anfang Y	Anfang Z	Punkte	Länge	Zylindrizität
Zylinder	29,229	0,040	0,112	5,486	20	2,622	0,113
		Ende X	Ende Y	Ende Z	i	j	k
		0,017	0,088	2,865	-0,009	-0,009	-1,000

Figure 10: The table-view of the measurements of the printed product - CMM

AuM

Zeichnungsnr.		Auftragsnr.		Datum	24.05.2019 11:41
Bezeichnung		Serien Nr.		Prüfer	
Kunde		Werkstoff		Bemerkungen	

Benennung	Maßangabe			Gr./Tol.			Form & Lagetoleranz		
	Sollwert	Istwert	Abweichung	Obere	Untere	Gut/Schlecht	Istwert	Toleranzgrenze	Gut/Schlecht
47.7mm Zylinder	47,700	47,670	-0,030	48,000	47,400	GUT	0,647	0,050	i.O.?
29.3mm Kreis	29,300	29,265	-0,035	29,500	29,100	GUT	0,275	0,050	i.O.?
22.9mm Zylinder	22,900	22,846	-0,054	23,100	22,700	GUT	0,516	0,050	i.O.?
0mm Ebene							0,083	0,050	i.O.?
0mm Ebene							1,403	0,050	i.O.?
5.5mm zwischen Ebene und Ebene	5,500	5,479	-0,021	5,600	5,400	GUT	0,252	0,050	i.O.?
25.3mm zwischen Ebene und Ebene	25,300	25,233	-0,067	25,500	25,100	GUT	0,101	0,050	i.O.?
0mm Ebene							0,013	0,050	GUT
90.7° von Ebene nach Zylinder	90°42'00"	88°46'45"	-01°55'15"	91°12'00"	90°12'00"	i.O.?	0,270	0,050	i.O.?
29.3mm Zylinder	29,300	29,229	-0,071	29,500	29,100	GUT	0,113	0,050	i.O.?

Figure 11: Evaluation and analyze of the measurements -CMM

2.E. Analyze of the Data and Comparison between original object and prototype - Conclusion

After the evaluations of the obtained reports from both machines (CT and CMM) we clarified the differences between original object and the with 3D-Printer produced object (Prototype). Some Values are in the tolerance rage and some are not. Which means, even we wanted to copy the original product as much as possible, because of some defects or problems during the printing, we were not able to minimize the deviations.

Also, in both machines the measured dimensions differ from each other to the technical drawing accordingly, therefore we are sure that the correctness of the measurements are also depends on the used Machine/Method & Material convenience. On the other hand, this fact means that not all machines are on the same sensitivity/correctness level.

To improve the Production Quality and the sustainability of the methods, producers should consider the factors explained above.

3. References

References - Reverse Engineering:

- VDI 5620 : 2017 Reverse Engineering von Geometriedaten
- ISO 10303-210:2014 Industrial automation systems and integration
- Product data representation and exchange ; Part210
- DIN SPEC 91303:2015-03 Bestandteile und Struktur einer Lebenslaufakte für erneuerbare Energieanlagen
- VDI 1000:2017-02 VDI-RICHTLINIENARBEIT; Grundsaetze und Anleitungen
- VDI 2219:2016-19 Informationsverarbeitung in der Produktentwicklung
- VDI/VDE 2630 Blatt 1.1:2016-11 Computertomografie in der dimensionellen Messtechnik

References - Additive Manufacturing:

- ISO 841 Industrial automation systems and integration
- ISO 10241-1 Terminological entries in standards
- EN ISO ASTM 52900:2018 Additive Manufacturing

References – Machine Informations :

https://www.werth.de/en/unser-angebot/products/coordinate-measuring-machines-for/ct-applications/werth-tomoscope-xs.html

https://www.aberlink.com/products/cmm/axiom-too-cnc/