WAYS TO ROBUST PART DESIGNS FOR ADDITIVELY MANUFACTURED SINTER PARTS THROUGH LIGHTWEIGHT DESIGN TECHNIQUES

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CONTENT

PROJECT OVERVIEW

The SIGNAL-Project deals with:

- sinter-based Additive Manufacturing (abbr.: SBAM)
- of light metals (titanium and aluminum)
- for use in various mobility sectors (aviation, railway and automotive).

SIGNAL

Official (translated) title:
“Development of sinter-based generative process routes for aluminum and titanium alloys for topology-optimized lightweight components for the mobility sector”

The consortium project is funded by the Federal Ministry for Economic Affairs and Climate Action (BMWK) in the Lightweight Technology Transfer Program (TTP LB) under the funding code **03LB2060** and supervised by Project Management Jülich (PtJ).

Supported by:

Federal Ministry for Economic Affairs and Climate Action

on the basis of a decision by the German Bundestag

PROJECT OVERVIEW

2/6 PARTNER PROFILES

Hamburg University of Applied Sciences

- Officially founded in 1970
- Approx. 16500 students, around 6000 of whom are enrolled in the Faculty of Engineering and Computer Science

Focus within SIGNAL:

- Extrusion-based SBAM processes
- Design Rules for SBAM
- SBAM-specific topology optimization

Element22 GmbH, Kiel

- Founded in 2011 with Ti MIM-expert team
- 50+ employees including 7 working students
- Offers materials, debind and sinter services as well as design and manufacturing of components

Focus within SIGNAL:

- Powder-based SBAM processes
- Development of aluminum-feedstock
- Sinter-simulation

OVERVIEW SINTER-BASED ADDITIVE MANUFACTURING
COLD METAL FUSION

- Selective Laser Sintering of Ti-6Al-4V-Feedstock
- Industrial SLS-Printer EOS FORMIGA with 40 W Laser and 0.1 mm layer height
- After printing green parts have to be:
  - depowdered manually (first dry, then with a water jet)
  - chemically debinded (10+ hours in an aceton bath)
  - thermically debinded and sintered (up to 10 hours with a max. temperature of 1300 °C)
- Parts experience a homogeneous shrinkage of 13.9%

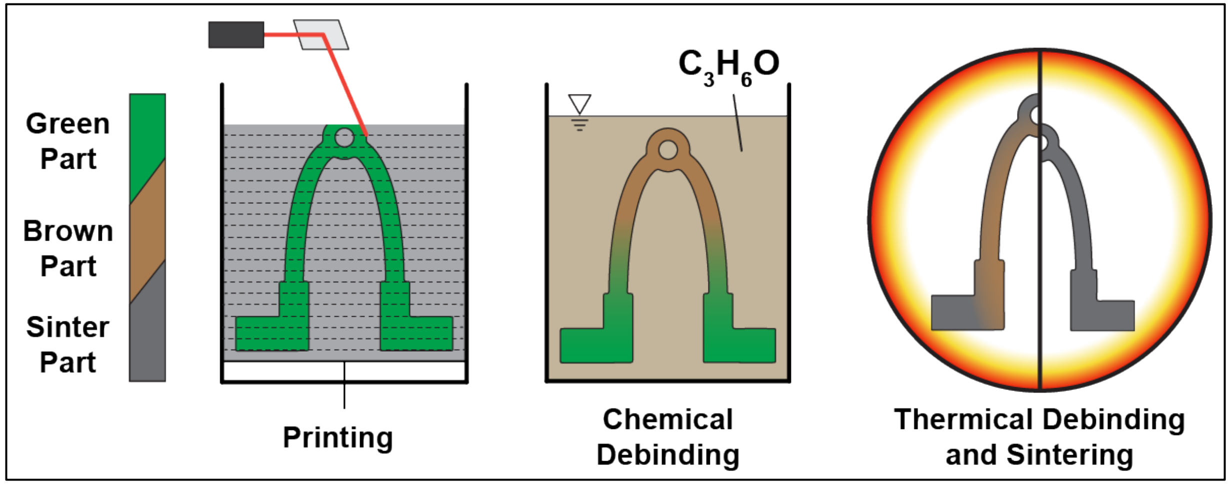

Fig. 1: Process steps of Cold Metal Fusion

PART CRACKING DURING DEBINDING DUE TO DEAD LOAD

Background

- Part cracking during debinding can occur due to stresses induced by the parts' dead load [1-4]
- Determining the critical stress level via conventional methods (e.g. tensile testing) poses several practical difficulties
- A simulation-driven approach based on finite element analysis is being utilizied for this purpose

So far

- Different specimen geometries with different stress values were investigated
- It seems likely that the main principal stress is responsible for the component failure (suits a brittle material model)
- It seems likely that the density of the part after debinding and sintering can be used for evaluation in the design-phase

WARPING BEHAVIOR WITH RESPECT TO GREEN PART STIFFNESS

EXPERIMENTAL DESIGN

Idea behind the Investigation

- Components deform during the debinding and sintering process due to the stresses caused by their dead load [2-4]
- In the context of part application, deformation is prevented by using structural stiffness [5,6]
- There are recommendations for the design of sintered components to make them as robust as possible in the sintering process [2,7,8]
- Design principles from lightweight construction (e.g. increasing stiffness) have not so far been utilized in this field

WARPING BEHAVIOR WITH RESPECT TO GREEN PART STIFFNESS
EXPERIMENTAL DESIGN

Idea behind the Investigation

Thesis:

A higher component stiffness has a positive effect on the deformation behavior during debinding and sintering

Experimental Design

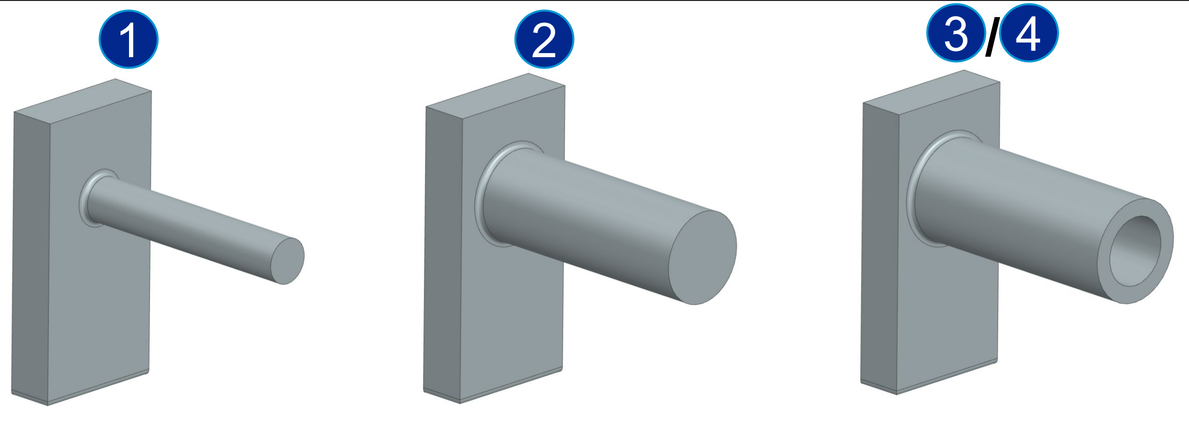

Fig. 2: Geometries for investigation on the influence of stiffness

Table 1: Design of experiments for the influence of stiffness

ID	I mm^4	A_{cs} mm^2	σ kPa	D_{green} mm	t_{green} mm	L_{green} mm
1	10	11.23	32.5	3.78	-	21.35
2	230	53.70	30.2	8.27	-	24.50
3	230	36.80	22.3	8.57	1.71	24.50
4	491	53.55	19.3	10.36	2.05	24.50

WARPING BEHAVIOR WITH RESPECT TO GREEN PART STIFFNESS
MEASUREMENT

Measurement set-up

- Tactile measurement conducted with CMM ZEISS MICURA
- Measuring range: 500^3 mm^3
- Measuring uncertainty: 0.7 µm + L/400 µm
- Measurement parameters acc. to [9]

Measurement strategy

- Two circles (Gauss circles)
- Defined distance betw. circles in x-direction (17 mm resp. 14 mm)
- x-distance results from dimensions of the CMM-probe

Definition of deflection

- The circles' centers are the reference for the deflection
- The z-distance betw. centers is taken into account for deflection

Fig. 3: CMM ZEISS MICURA

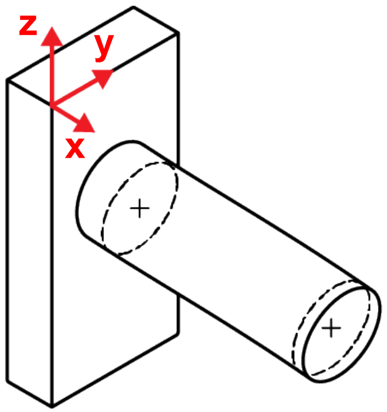

Fig. 4: Gauss circles on specimen

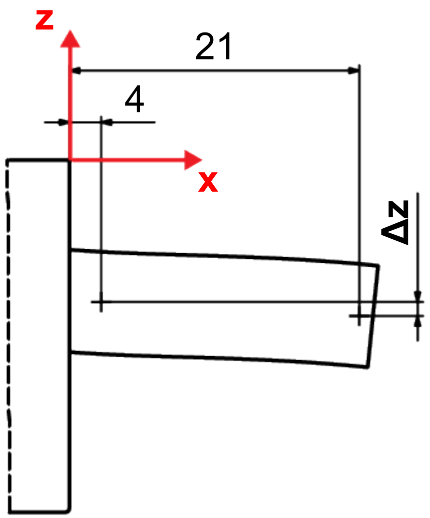

Fig. 5: Measure for deflection

WARPING BEHAVIOR WITH RESPECT TO GREEN PART STIFFNESS

RESULTS

- The geometry with the lowest stiffness experiences the greatest deflection (over a shorter distance) – 1
- The geometry with a lower load experiences less deflection than the geometry with a higher load and the same stiffness – 3 / 2
- The geometry with the highest stiffness experiences less deflection than the other geometries, even with the same load – 4

However

- No measurements in green state were conducted
  → Analysis of warping/deflection in y-direction for evaluation (s. table 3)
  → Influence of gravity on warping is distinct
- Positive Value for z-deflection of geometry 4 is suspicious
  → green part dimensions + high stiffness or material inhomogeneity?
- The number of samples is very small (4 per geometry)

Table 2: Results of the investigations on the influence of stiffness

ID	I mm⁴	A_{cs} mm²	σ kPa	$\overline{\Delta z}$ mm	$s_{\Delta z}$ mm
1	10	11.23	32.5	-0.483	0.065
2	230	53.70	30.2	-0.191	0.017
3	230	36.80	22.3	-0.156	0.085
4	491	53.55	19.3	0.097	0.039

Table 3: Mean and standard deviation for z and y

Direction	$\overline{\Delta}$ mm	s_{Δ} mm
z	-0.183	0.219
y	-0.055	0.102

OUTLOOK

As next steps…

… the case study is going to be extended with parts with varying stiffnesses

… the number of samples for stiffness investigations is going to be increased

… investigation on part cracking due to dead load is going to be continued with a new set of specimen

… findings are going to be transferred to the test design of the other SBAM technologies (starting with FFF)

SOURCES

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THANK YOU FOR YOUR ATTENTION!

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