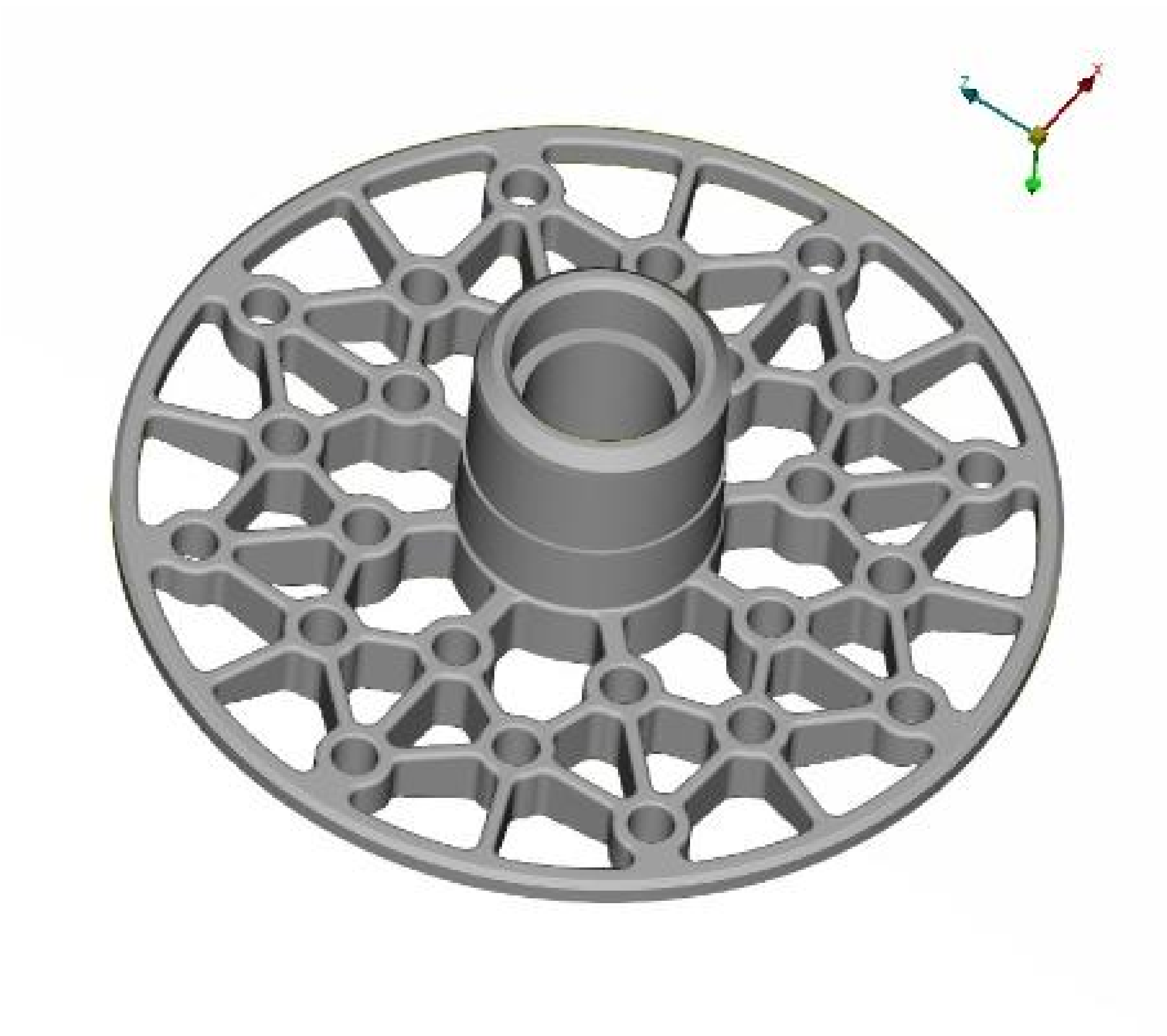
Evaluating additively manufactured lightweight components: with computer-aided engineering

About this project



CAEaddFert

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Markets:

Material: Aluminium, Steel

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About this project

This project is funded by the Technology Transfer Programme Leichtbau (TTP LB) of the Federal Ministry of Economics and Energy.

Technology Transfer Program Leichtbau

Context

Computer-aided engineering (CAE) supports topology optimisation in lightweight construction in virtual product development. This results in component designs with very complex geometries that can only be manufactured additively. Additive manufacturing is a layer-by-layer process in which material is applied. In this way, components can be produced that cannot be manufactured using ablation processes or demoulded during casting due to undercuts, for example.

In selective laser melting, a laser melts metal powder layer by layer. This results in direction-dependent material properties, the metal becomes anisotropic - i.e. it has different strengths or stiffnesses depending on the direction of loading. Depending on the metal, geometry and process parameters, pores or other structural defects can occur and the material becomes inhomogeneous. Directional solidification under high local temperature differences can also lead to residual stresses and distortion.

The current CAE process lacks reliable data on anisotropy, inhomogeneity and residual stresses for metallic components. As a result, topology-optimised additively manufactured components cannot be reliably evaluated. This gap limits the use of additive manufacturing in series development. This is where the CAEaddFert research project comes in.

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Purpose

The researchers are developing a virtual test bench for additively manufactured lightweight components. They want to ensure that these components can be evaluated in the computer-aided product development process, both as individual parts and as an assembly. The aim is to enable the increased use of additively manufactured components and to help additive manufacturing achieve a further breakthrough.

The project team is designing the test bench as modular software based on experimental values. To this end, the researchers produce test specimens of different geometries and materials and analyse them for material homogeneity. They also measure direction-dependent material properties and residual stress depth profiles and merge all data into a common basis.

These values are taken into account in the finite element simulation, in which the component and assembly are tested for stiffness and strength under defined load cases. The heat treatment for residual stress relaxation is simulated as creep according to Norton's law. The test bench predicts stresses, strains, distortion and service life, marks critical points and enables the component to be designed. A decision module provides recommendations for possible post-treatments. This shortens development times, reduces costs and saves weight and CO#.

Procedure

The researchers manufacture test specimens from stainless steel (S316L) and aluminium alloy (AlSi10Mg). To do this, they vary the build-up direction and individual geometric features such as radii and edges. They examine the samples using micro-computed tomography to visualise material inhomogeneities such as pores, inclusions and cracks. They use ultrasound to measure the material's elastic properties depending on the direction. They determine the residual stresses using X-ray diffraction in different measuring planes and angles to the direction of build-up. They determine the residual stress depth profile using step-by-step chemical etching. They carry out all measurements at different points on the samples in order to check possible influences of the local geometry.

The researchers store all the measurement data in a database. The analysis shows no dependence of the values on the local geometry, but a clear angular dependence on the build-up direction. They then transfer the anisotropy and inhomogeneity to a global component material model. Using a script, they assign residual stresses to the finite elements of the component surface layer, both tangentially and normal to the surface. In doing so, they take into account the angle of each surface segment to the structural direction. They then calculate static and cyclical load cases on the basis of stored equivalent Woehler curves and finally compare the simulation results with measurements on the component.

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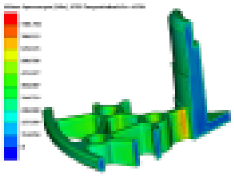

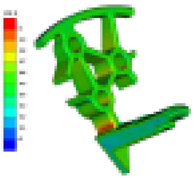

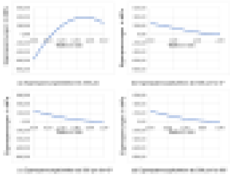

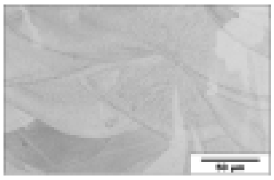

Funding duration:

Funding sign:	03LB1010	**Funding amount:**	EUR 672 thousand

Final report

Further websites foerderportal.bund.de/foekat/jsp/SucheAction.do?actionMode=view&fkz=03LB1010A - CAEaddFert in the federal funding catalogue

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Project coordination

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English (EN){{ Projektpartner }}

Lightweighting classification

	Realisation
Offer	
Products Parts and components, Machines and plants, Software & databases	✓
Services & consulting Prototyping, Simulation	✓

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Lightweighting classification

	Realisation
Field of technology	
Design & layout Lightweight manufacturing, Lightweight design, Lightweight construction concepts	✓
Functional integration	
Measuring and testing technology Component and part analysis, Visual analysis (e.g. microscopy, metallography), Non-destructive analysis	✓
Modelling and simulation Loads & stress, Optimisation, Structural mechanics, Materials	✓
Plant construction & automation Others (Mechanical engineering)	✓
Recycling technologies	
Manufacturing process	
Additive manufacturing 3D printing, Selective laser melting (SLM, LPBF, ...)	✓
Coating (surface engineering)	
Fibre composite technology	
Forming	
Joining	
Material property alteration Mechanical treatment, Heat treatment, Others (Sandblasting, bead blasting, hot isostatic pressing, stress-relief annealing, hot ageing)	✓
Primary forming	
Processing and separating	
Textile technology	

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Lightweighting classification

	Realisation
Material	
Biogenic materials	
Cellular materials (foam materials)	
Composites	
Fibres	
Functional materials	
Metals Aluminium, Steel	✓
Plastics	
Structural ceramics	
(Technical) textiles	