Designing copper-aluminium connections safely: Axle for electronic drives

About this project

Solid4E

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Markets:

Material: Aluminium, Steel, Others (Copper), Others (Aluminium-copper composite)

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

Technology Transfer Program Leichtbau

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Context

Electric drive systems place new demands on design and production. This applies in particular to battery module connectors, high-current cables and compact electric axles. These components must fulfil electrical, thermal and mechanical requirements at the same time and be designed to be material and resource efficient. To achieve this, manufacturers often combine copper and aluminium: copper is primarily used in areas with high electrical loads, while aluminium is used in areas where weight needs to be reduced.

However, joining these materials is challenging. With fusion-based joining processes, brittle intermetallic phases and cracks can occur. They reduce strength and impair electrical conductivity. They can also increase the tendency to corrode.

For copper-aluminium joints, there is currently no reliable method for assessing and designing their behaviour in virtual product development.

Purpose

In the Solid4E research project, the researchers are creating the basis for the targeted design and reliable prediction of copper-aluminium connections in electric drive components. To do this, they are recording the behaviour of these connections and transferring the results into simulation models for virtual product development. This will enable developers to evaluate the components earlier and in a more informed manner in future.

At the same time, the project partners are developing production routes that utilise both materials according to their function: Copper where high electrical or thermal conductivity is crucial, aluminium where weight and raw materials can be saved. In this way, they are creating the conditions for robust, resource-efficient and industrially producible components. This is particularly important for electric drive systems, which use materials sparingly and have to withstand high demands during operation.

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Procedure

The researchers are organising the project into two parallel tracks that will lead to a demonstrator for a functionally integrated e-drive axle. On the one hand, a process route for hybrid battery module connectors and high-current cables is being created. The partners are joining simple copper and aluminium semi-finished products by friction welding. During solid-phase joining, the materials do not melt completely. They then mould the hybrid blanks into more complex components using digital free-form bending systems. At the same time, the team develops the necessary welding and forming systems and couples them into flexibly controllable systems.

Secondly, the partners are developing a design methodology for highly integrative lightweight structures for the drive axle. To this end, they are recording the geometric, manufacturing and functional degrees of freedom of the entire value chain for the first time and utilising them for the design. Digital twins virtually map the component and production. Stochastic topology optimisation uses Six Sigma to analyse and reduce process variations as well as Design of Experiments (DoE), the systematic planning of experiments. This allows process fluctuations to be taken into account.

The team also analyses how defects such as casting blowholes, pores and inclusions influence subsequent production steps.
The end result is an experimentally validated quality assurance strategy for the entire process chain as well as a virtually and experimentally validated fatigue strength model.

Funding duration:

Funding sign:	03LB3069	**Funding amount:**	EUR 4.8 million

Final report

Further websites foerderportal.bund.de/foekat/jsp/SucheAction.do?actionMode=view&fkz=03LB3069A - Solid4E in the federal funding catalogue

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Project coordination

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English (EN){{ Projektpartner }}

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Lightweighting classification

	Realisation
Offer	
Products Parts and components, Machines and plants, Tools and moulds	✓
Services & consulting Training, Testing and trials, Engineering, Prototyping, Validation, Simulation, Technology transfer	✓
Field of technology	
Design & layout Lightweight manufacturing, Hybrid structures, Lightweight construction concepts, Lightweight material construction	✓
Functional integration Media conductivity, Others (Heat conduction, electrical conductivity)	✓
Measuring and testing technology Component and part analysis, Visual analysis (e.g. microscopy, metallography), Materials analysis	✓
Modelling and simulation Loads & stress, Life-cycle analysis, Optimisation, Processes, Materials, Reliability validation	✓
Plant construction & automation Plant construction, Automation technology, Robotics	✓
Recycling technologies Recycling	✓

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Lightweighting classification

	Realisation
Manufacturing process	
Additive manufacturing Others (Friction welding and friction stir welding)	✓
Coating (surface engineering)	
Fibre composite technology	
Forming	
Joining Welding, Others (Friction welding and friction stir welding)	✓
Material property alteration Others (FSP (Friction Stir Processing))	✓
Primary forming Casting	✓
Processing and separating Drilling, Turning, Milling	✓
Textile technology	

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Lightweighting classification

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