HESSEN

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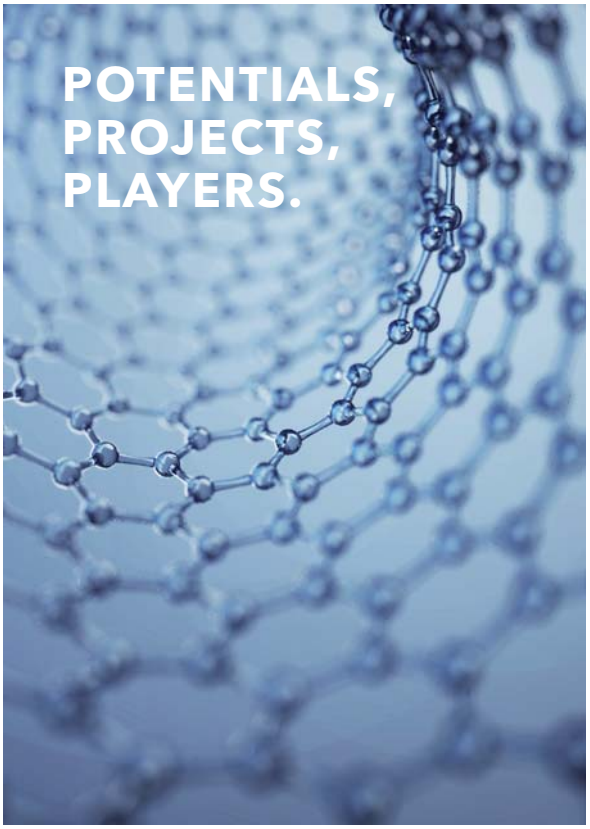
LIGHTWEIGHT DESIGN IN HESSEN.



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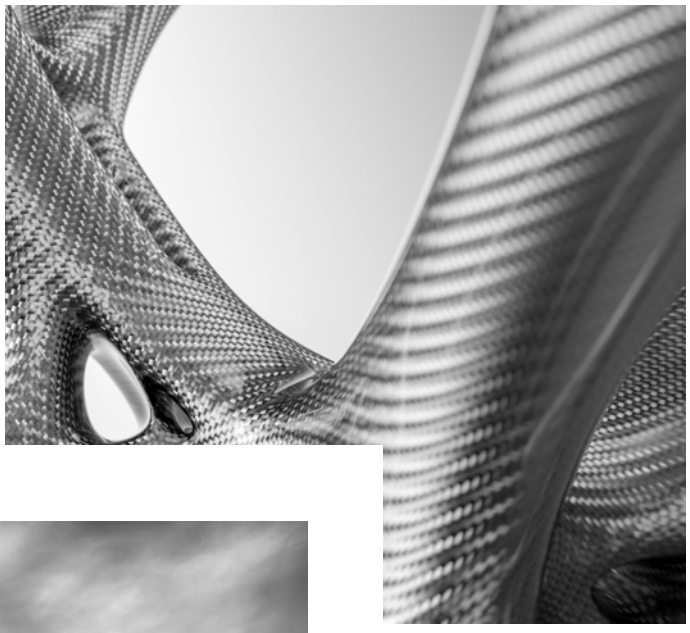
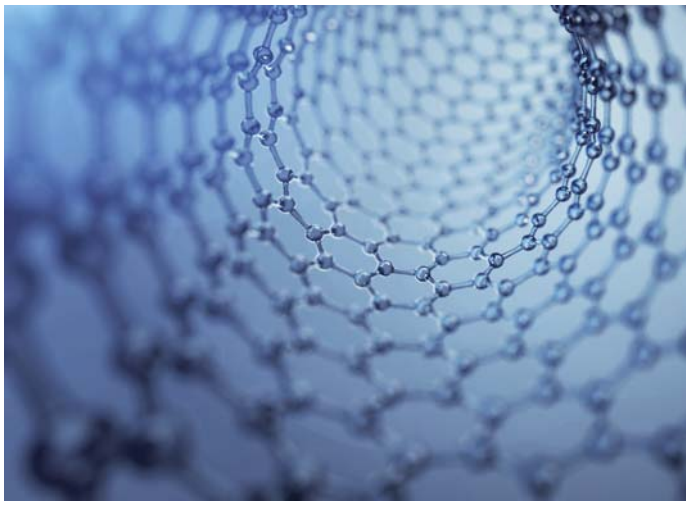




CONTENT

„Lightweight design offers numerous opportunities to build a sustainable future. The technology upon which it is built should, however, not be taken lightly. Fortunately, there is an abundance of skills around this field in the high-tech region of Hessen."

Tarek Al-Wazir
Hessian Minister of Economics, Energy,
Transport and Regional Development

INTRODUCTION

Lighter vehicles require less fuel, optimum weight structures less materials. For instance, reducing the zero-fuel weight of a passenger aircraft, such as the A320, by 100 kilogrammes helps to improve its fuel consumption by roughly 10,000 litres a year. So it comes as little surprise that aviation, automotive and transportation industries are the biggest drivers of innovation in lightweight design. But the significance of this technology is also increasing in the construction sector, medical engineering and other disciplines. Since lightweight design offers numerous opportunities to build a sustainable future.

Towards a lightweight future

Lightweight design also remains a technological challenge, however. Constructing lighter structures is not simply a question of switching the applied materials. After all, the stability of a product depends on how loads are distributed and which functional requirements need to be met. This complex interaction demands extensive know-how.

Hessen does lightweight design

The good news: In the high-tech region of Hessen, we are well positioned to deliver in this sector. We have several hundred companies that offer established lightweight design technologies and twenty-seven research institutes with outstanding strengths in key areas of lightweight design. Science and industry are inextricably linked, and the region offers attractive funding opportunities under the umbrella brand "Technologieland Hessen".

Use this brochure to learn about the diverse potentials of lightweight design in Hessen, to gain new ideas and to broaden your network.

We also look forward to receiving your contributions so as to provide you with guidance and support on your journey.

Friedrich Schiller once wrote, "A beautiful mind carries the heaviest burdens lightly". On this note, I hope you find the following pages both informative and inspiring reading.

Yours,

Hessian Minister of Economics, Energy,
Transport and Regional Development

1 WHAT IS LIGHTWEIGHT DESIGN? AND WHY IS IT USED?

What do a Gothic cathedral, Zeppelin airships and an Airbus A380 have in common?

They are all amazing lightweight structures that used some of the most advanced technologies available at the time. All three examples underline the era-spanning significance of lightweight design, while representing milestones of methodical approaches, tool development and the resulting new technologies and business segments.

Lightweight design sees itself as a product development expertise: It comprises the entire life cycle of a product; from the idea and choice of material to the finished component. From the perspective of an engineer, lightweight design is the challenge of "achieving the minimum possible weight of the entire structure", as expressed by German engineer Heinrich Hertel in his lightweight design standard work "Leichtbau". "This can only be achieved by ensuring the weight of each individual part is minimal or plays a significant part in minimising the weight of a larger unit."[1]

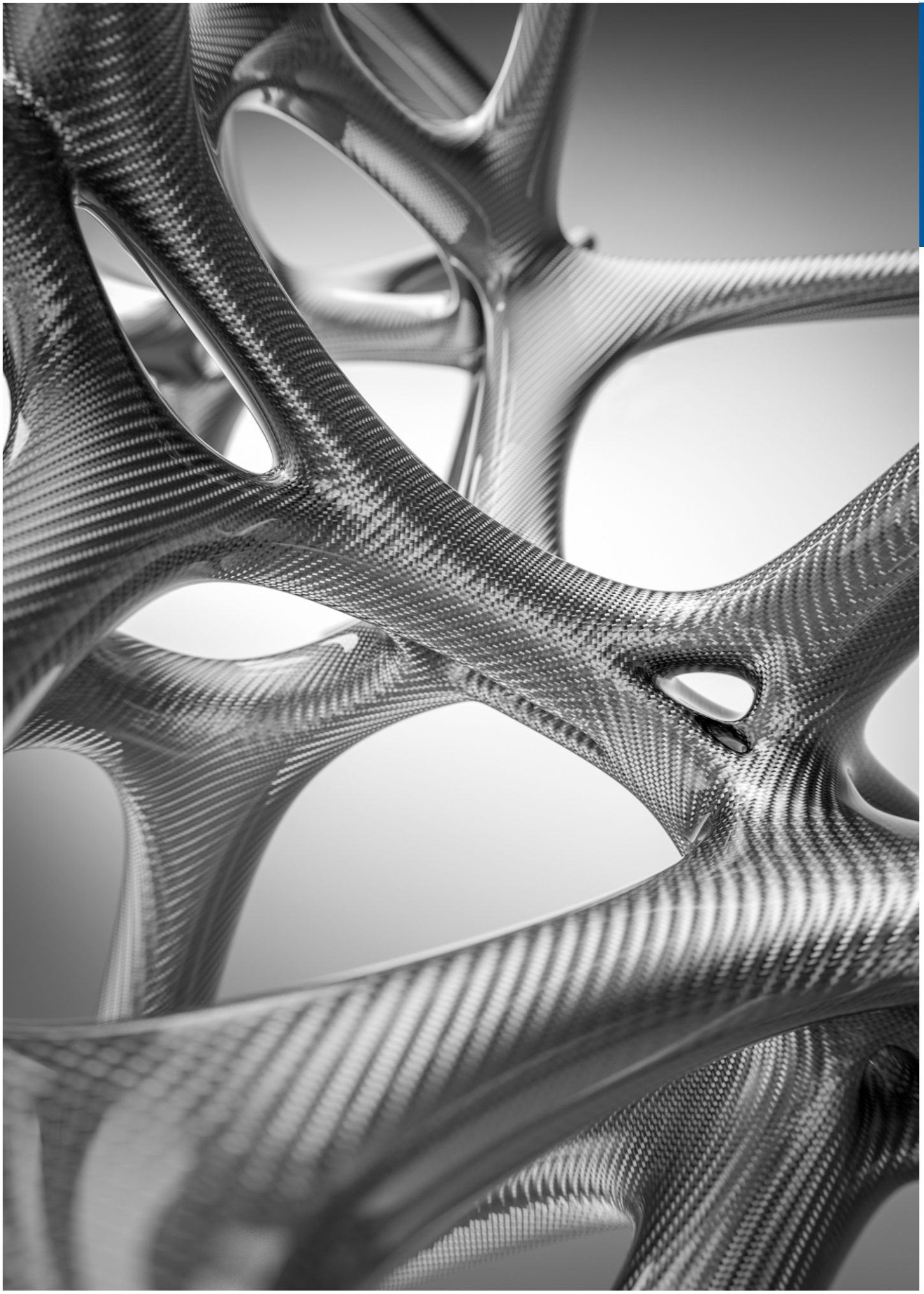
Lightweight design refers to a minimum net weight[2] that still guarantees full functionality. As long as the component costs do not rise and the component's suitability and capability are not negatively impacted, this idea does not really need to promote its advantages. Higher costs are, however, justifiable if the lightweight design offers additional savings or benefits.[3]

According to Gustav Niemann, this may have the following reasons:

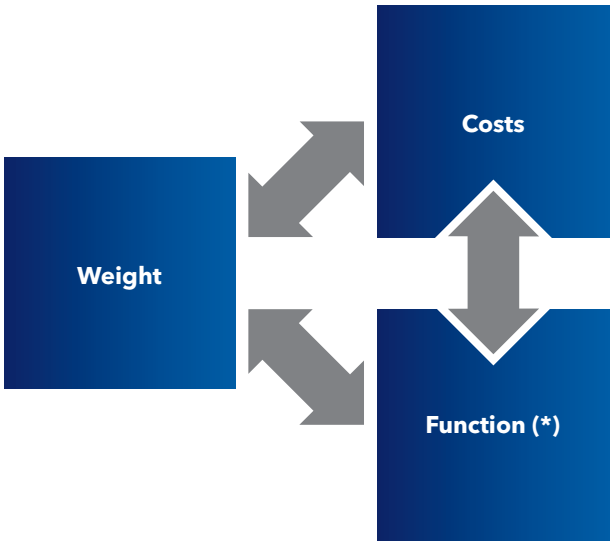
- The burden on other components is reduced significantly, allowing in their lightweight design.
- The reduction in weight enables a larger load capacity at the same overall weight (transport vehicle).
- Running, variable and, possibly, fixed costs may be reduced (e.g. aircrafts, vehicles and mobile machinery).
- Operating or handling is facilitated (e.g. baggage, home appliances and sporting equipment, packaging and electronics).
- A structure is only made possible in the first place because of lightweight design (e.g. wind power, bridge construction, aerospace).
- Tax benefits are achievable through an improved ecological balance (e.g. when less fuel results in reduced CO_2 emissions).

These savings are some of the potentials offered by lightweight design and can – depending on the field of application – provide key competitive advantages for a company.

[1] Heinrich Hertel: Leichtbau, ISBN 3-540-09765-1, Springer-Verlag 1980
[2] Minimum net weight can be seen here as a way of conserving resources.
[3] Gustav Niemann: Maschinenelemente, ISBN 3-540-06809-0, Springer Verlag 1981



2 WHAT INFLUENCES LIGHTWEIGHT DESIGN AND WHICH TYPES EXIST?



(*) Function, e.g.: Static and dynamic rigidity and strength, crash and deformation characteristics, energy absorption

Image 1: Potentially conflicting demands of lightweight construction in the design phase (according to Fraunhofer LBF)

Structural mechanics describes lightweight design as a process of optimisation to reduce weight at acceptable costs while taking physical properties, such as sufficient rigidity and strength, into account.

Lightweight design performs a delicate balancing act between three potentially conflicting areas: function, weight and costs. Depending on the desired mechanical function of a component, suitable materials and parameters, such as geometry and method of construction, need to be defined. They guarantee that the developed components and structures function properly and safely throughout their entire life cycle.[4]

Factors, such as the rigidity of a structure, are defined by design parameters, including material selection, shaping and method of construction.[5] Resulting costs also have an indirect effect on these factors.

Moreover, adequate component performance requires adequate strength based on a state-of-the-art and material-appropriate design. The design takes into consideration the materials, the constructional features and the respective mechanical loads. In addition, it incorporates environmental conditions, such as temperature, moisture and media.[6]

The justifiable degree of optimisation for the respective component depends on the time and costs invested in the design process, on the expenditure for materials and method of construction as well as on the chosen production process.

Büter[6] categorises the various forms of lightweight design according to the actual focus of the optimisation efforts:

- Requirements-based lightweight design means limiting efforts to only really essential requirements. For instance, with regard to loads it is imperative to have exact knowledge of the load level, the load distribution and the frequency of occurrence. The following applies when designing a component: The more you know about the loads and the load-bearing capacity of the structure, the lighter the component (structurally durable lightweight design).

- The main focus of material lightweight design is the optimisation of materials (substitution). Weight-related material properties and a material-appropriate or process-oriented design[7] become relevant here.

[4] Andreas Büter: Immer ein ökonomischer Kompromiss: Leichtbau, S. 56 ff., Internationales Verkehrswesen (64) 2 /2012
[5] In this case, the method of construction describes the specified layout of load-bearing structural elements.
[6] Andreas Büter: Immer ein ökonomischer Kompromiss: Leichtbau, S. 56 ff., Internationales Verkehrswesen (64) 2 /2012
[7] The manufacturing process influences the local material properties. This can be taken into account by performing an "integrative simulation".

Quality indicators describe general suitability for lightweight design through specific values

	Property	Quality indicator	Al alloy	Magnesium	Steel	CFRP	Thermoplastic	Wood (pine)
1	Static strength (tensile)	$\frac{\sigma_{allowable}}{\rho}$	1.00	0.81	1.19	5.39	1.19	1.40
2	Longitudinal rigidity	$\frac{E}{\rho}$	1.00	0.82	1.00	1.60	0.27	0.60
3	Buckling rigidity (rod)	$\frac{\sqrt{E}}{\rho}$	1.00	1.12	0.58	1.57	0.73	1.61
4	Dent & flexural rigidity (plate)	$\frac{\sqrt[3]{E}}{\rho}$	1.00	1.24	0.49	1.56	1.00	2.24
5	Elastic energy capacity	$\frac{\sigma^2}{E \cdot \rho}$	1.00	0.79	1.43	18.15	5.17	3.23
6	Fatigue strength (R=-1, Kt=2.5)	$\frac{\sigma_A}{\rho}$	1.00	1.67	1.36	8.59	1.27	3.38*

* without notch (Kt=1)

Image 2: Different density-related mechanical properties for various materials in comparison to aluminium. Larger values indicate a greater potential for lightweight design.

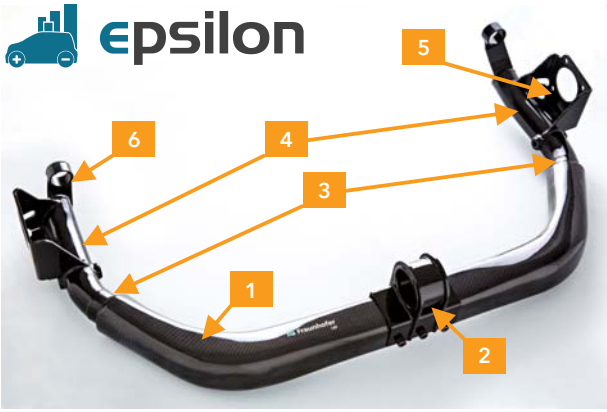
Depending on the desired material requirements specified in the design process, various material classes with differing, density-related mechanical properties are available (Image 2).

Fibre-reinforced plastics (FRP) are highly suited for large, slender, thin-walled structures with simple geometries (such as shells, pressure vessels and beams/joists). For components with a complex shape, metals or short and long fibre-reinforced plastics are particularly suitable.

Combining various materials in one component (material hybrids) provides design engineers with a range of material properties to choose from. The principle of choice is then: The right material at the right place.

The application of material hybrids brings along new challenges. Design engineers must, among other things, select suitable joining methods, guarantee that recycling is achievable (material separation) and consider the promotion of corrosion processes (electrolysis). Additionally, they have to take into account the risk of crack formation caused by internal stress resulting from divergent coefficients of thermal expansion.

Image 3 shows an example of hybrid-lightweight design: The EU research project "epsilon" developed a hybrid "CFRP-metal" based lightweight rear axle. Its weight, compared to a conventional metal design, was reduced by 35 per cent

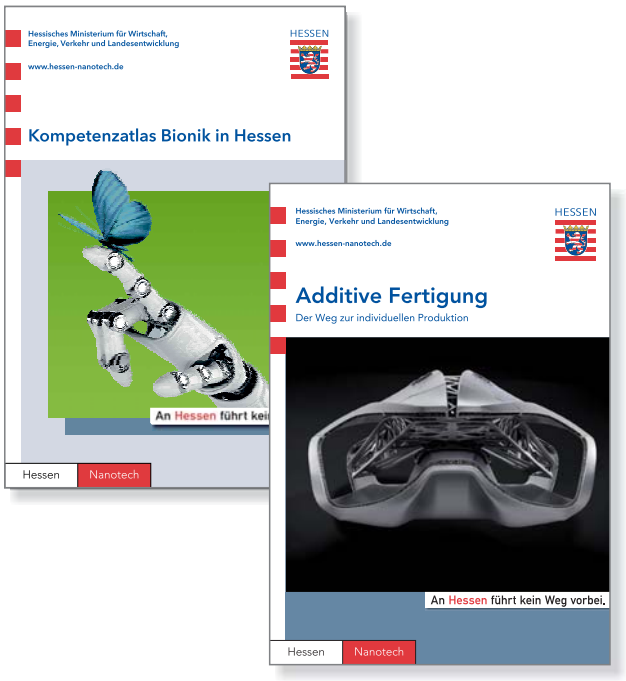


1: Middle section
2: Connection of central joint (metal)
3: Connection between middle section and side section
4: Side section (metal)
5: Wheel carrier (metal)
6: Connection of watt-linkage (metal)

Image 3: Thanks to the metal and carbon fibre-reinforced plastic (CFRP) hybrid lightweight rear axle, developed as part of the EU research project "epsilon", it was possible to reduce the weight by roughly 35 per cent. (Image: Fraunhofer LBF)

The objective of lightweight mould making is to develope the ideal shape for a component or the ideal method of construction for a structure system. The rigidity of a structure system is influenced significantly by the shape and layout of the load-bearing structural elements. Nowadays, topology optimisation increasingly applies bionic principles. In the field of bionics, nature provides the inspiration to solve technical challenges. It demonstrates numerous approaches for optimising the ability to support loads. The available production techniques determine whether and how lightweight mould making can be implemented. Shape optimisation is therefore intrinsically linked to lightweight construction.

Through the opportunities provided by additive manufacturing, the importance of applied bionic principles is becoming increasingly relevant. An example is the concept car from EDAG AG whose load-bearing structure was bionically optimised and additively manufactured.



Publications on bionics and additive manufacturing can be found at www.technologieland-hessen.de

Image 4: The design engineers took nature as their inspiration by using a tortoise shell as the blueprint for the development of the concept car EDAG Soulmate (2016). (Image: EDAG Engineering GmbH)

- Lightweight construction focuses on the demands of qualitatively high-grade production throughout all phases of optimisation. The available production and joining technologies define whether a proposed form is viable or not. Furthermore, they determine the local material properties of the component and the quality and load-bearing capacity of the structure. The objective is to choose those production and joining procedures that enable you to construct the desired weight-optimised form at the best possible price while still guaranteeing the maximum load-bearing capacity. In this case, the quality can be quantified through non-destructive and destructive testing. A tool and process-oriented design reduces production costs, which represents a key decision criterion for the application of lightweight design optimisation.

- Function-integrated lightweight design is a special branch of lightweight design that focuses on integrating various functions within a component, thereby reducing the weight. In this discipline, function integration refers to the grouping of several passive, active or sensory functions in a single component. Integration ideally occurs as a method of fusion production[8], in other words: It is considered during the design phase. The component itself thus becomes more complex, but there are actually less components in the final design. At system level, function integration reduces costs, assembly effort, space and weight.

A wonderful example of this is the fibre composite rotor blade of the Airbus helicopter H135. The trunnion bearing, flap hinge and drag hinge have been integrated as flexure hinges in a torsionally flexible, fibre-plastic composite rotor blade root. This measure has led to the rotor head of the H135 being lighter and more aerodynamic.

Image 5: Lightweight design through function integration – bearing and hingeless rotor system of the Airbus helicopter H135 (previously EC135, below) compared to a fully hinged rotor system. (Image top: "Airbus")

(Image: Burkhard Domke)

[8] Method of fusion production: Integrating method of production using interconnected individual elements. Structural components are comprised of a large number of individual parts, but the method of actual connection ensures the joining process has no or very few disadvantages for the finished part resulting from notching effects or pre-stressing.

3 LIGHTWEIGHT DESIGN MEETS CONFLICTING MARKET DEMANDS

When a business considers entering the lightweight design market, the related costs are always the biggest barrier.
Higher development costs should invariably be anticipated for optimisation processes that lead to more complex geometries and increased investment in production activities. However, it must be able to generate enough money to cover all these costs through the sale of a product. A company should therefore ask itself: How much more is a customer prepared to pay for a lighter product? This fundamental question gives rise to an array of conflicting demands between technology, costs and resource efficiency that must be taken into account when making a decision.

- Within this context, technology encompasses the special know-how required for development engineering[9] (design and planning method), for material[10] and manufacturing processes[11].This is additionally underlined by the importance of the current 'hot topic' of Industry 4.0. Expert knowledge and the level of technical innovation are key aspects of the technology. They are needed to decide whether and how lightweight design can be implemented. Thus guaranteeing the technical expertise and the competitive edge of a company.

- In this case, the costs include material, development, investment and staff expenses. While on the opposite end of the scale there is the image[12]. It is defined by the design or the benefit of the product and by the status of the manufacturer's brand. The image creates a typical perception of the product with the customer who, in the best case scenario, will demonstrate a willingness to pay more. The image of carbon fibre-reinforced plastics (CFRP) is defined, for instance, by its beneficial characteristic of being particularly lightweight. Just like other sectors, lightweight design must ensure: The total costs are in relation to the product's marketability. If a company decides to invest in lightweight design, it will have to charge a higher retail price to cover its initial outlay.

Marketing approaches such as “making technical performance visible” or “lightweight construction through design” ensure the spotlight is not directly on the actual lightweight design process. Design and visual performance exert a greater positive impact on purchasing decisions than weight or economic benefits.When it comes to sports cars, for example,customers are prepared to pay more for CFRP (“visible carbon”) dashboards or exhaust systems and for car door panels made of CFRP fabric.

- On one hand, resource efficiency refers to the qualitative customer benefits provided by lightweight design that include greater load capacities, enhanced operation or reduced CO_2 emissions. On the other hand, resource efficiency meets the social and political demand for the responsible use of resources such as energy and materials. Therefore, a high level of recycling efficiency also plays a key role (Image 7).

[9] Examples: Bionic design methods, integrative simulation, adaptronics
[10] Examples: Fibre composites, nanotechnology
[11] Example: Additive manufacturing processes
[12] Example: Made in Germany

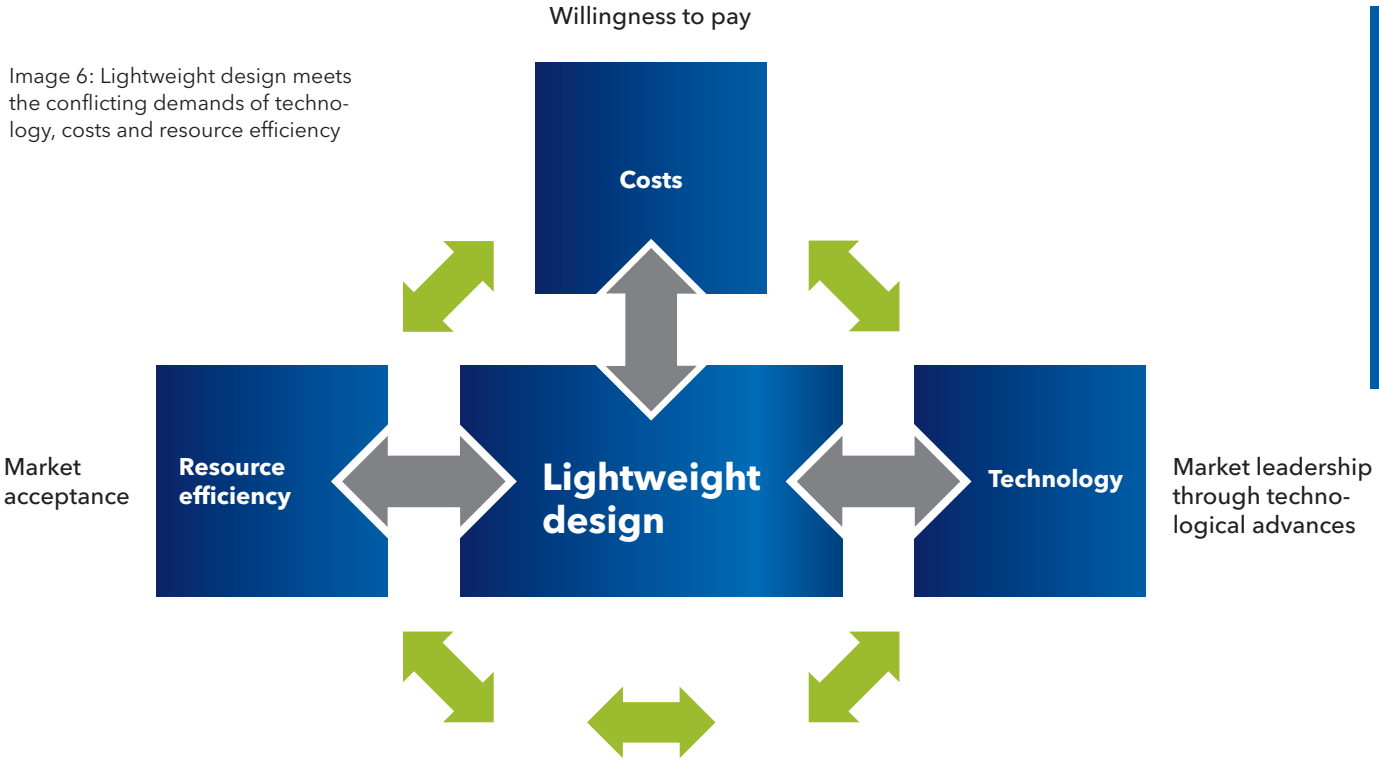


Image 6: Lightweight design meets the conflicting demands of technology, costs and resource efficiency

The life cycle covers all the product's phases of existence, from the idea all the way through to disposal. Bearing all this in mind, the importance of technology for lightweight design becomes quite clear: Adapted manufacturing processes unlock the potential of lightweight design and adapted creative processes optimise the design. Both can demand an increased consumption of resources at the start of the life cycle but eventually lead to energy savings in the utilisation phase thanks to the product's lighter weight. During the actual design phase, factors such as material selection and assembly play a key role in terms of a product's recycling potential and its design for recycling.

Each material offers its own special characteristics. As a result, development engineers have to use the right materials and suitable joining techniques at the right places. Then again compromises always have to be made when employing multi-material systems[14]. They are considered difficult to recycle, since the different materials have to be separated from one another. In relation to the consumption of resources, the level of benefit should always be high enough to ensure resources are conserved across the entire product life cycle.

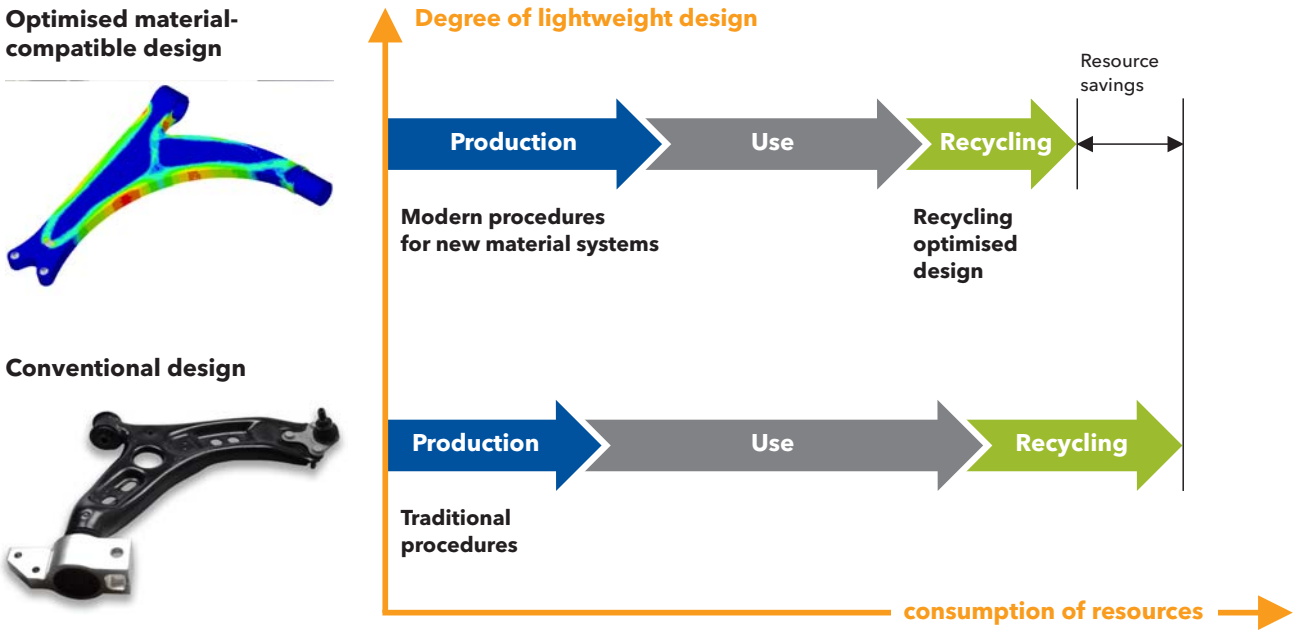


Image 7: Life cycle of lightweight design – the required employment of resources for various designs[13]

[13] Andreas Büter: Leicht Konstruieren, Pg. 18, K-Magazin 1/2017
[14] Multi-material systems consist of several materials, for instance reinforced concrete.

4 FROM INTELLIGENT TO SUCCESSFUL LIGHTWEIGHT DESIGN – A QUESTION OF EXPERTISE

To unlock all the potentials, lightweight design considers the entire product development process and links the necessary skills by bringing together all the experts required to solve a problem. According to Heinrich Hertel's definition of lightweight design, the minimum possible weight of the entire structure is achieved by ensuring the weight of each individual part is minimal[15]. To complete this undertaking successfully, each process step has to be integrated in the optimisation methods and contribute to this minimum efficiently. The further development of design and calculation techniques, the testing of new production procedures and the modification of test methods constantly create new opportunities and ideas to unlock lightweight design potentials.[16]

4.1 Combination of lightweight design methods

The potentials of lightweight design are frequently not fully exploited as the focus of development is overly weighted on individual aspects of optimisation rather than on the whole. For example, material substitutes are used predominantly to minimise the weight. However, this does not go far enough: Material-compatible, intelligent lightweight design utilises experimentally verified material data for structuring and designing. Besides production and assembly requirements, recycling is also taken into account.[16] The integration of additional functions within a component is a corresponding approach to a solution (turn to page 8, image 5 for an example). It is increasingly being used in practical applications as it reduces the amount of assembly effort required, thus helping to cut weight.

In the future, intelligent lightweight design should always have access to reliable load data and be aware of the requirements that have to be met. Based on this information, calculation of the structure's shape and materials must guarantee that a component performs as intended and can be produced and installed at the price desired. This procedure is referred to as lightweight design by material and geometrical optimisation. The chosen production process must be able to manufacture a precise component in the quantity and quality desired while maintaining price stability (manufacturing-oriented lightweight design).[16]

In this context, additive manufacturing provides new opportunities to produce geometrically complex components – similar to those offered by bionic optimisation methods[17]. Additive manufacturing additionally enables the cost-effective production of parts made of lightweight materials, such as titanium, which are difficult to produce using traditional methods.

4.2 It's all down to dimensioning and know-how

The quality of a component determines the success of a lightweight design project. In this case, quality is defined, for instance, according to the point in time when a component no longer functions correctly or fails completely. The actual time when this occurs is based on factors such as strength and rigidity resulting from variances in material properties and manufacturing processes.

A safety factor is used to take these variances into account for the computational design of a component. The smaller the variances, i.e. the deviations from the target value, the smaller the safety factor. The smaller the safety factor, the thinner the material of the component can be, without impacting its strength.

[15] Heinrich Hertel: Leichtbau, ISBN 3-540-09765-1, Springer-Verlag 1980
[16] Andreas Büter: Leicht Konstruieren, Pg.18, K-Magazin 1/2017
[17] Bionic optimisation refers to the structure-mechanical optimisation of technical components with the aid of biological laws of growth. (VDI 6224 Sheet 2, 2012)

Airbus S.A.S. 2012
(Image: W. Schroll)

However, purely computational design approaches are often inadequate for primary components (safety components). A component's probability of failure needs to be determined through actual experiments. These verification tests are an integral part of the product development process for such components. With plastic components, in particular, they are intrinsically linked to structure monitoring concepts for the verification of the damage tolerance. Integrated load and structural monitoring systems (structural health monitoring, SHM) help to detect operating loads and damage during ongoing operation. As a result, improper modifications can be detected in a timely fashion and damaged structural components either repaired or replaced.[16]

As shown, process-related manufacturing quality has a direct impact on lightweight design. For instance, dimensioning must take into account unwanted thickness variations, poor surface qualities or pore formation.

The in-line monitoring of manufacturing operations reduces manufacturing variances by integrating sensory systems, for example, in the manufacturing process. This indicates that Industry 4.0 can also provide a positive contribution to lightweight design. It creates the basis for a transparent data platform through which reliable material data and its dispersion can be supplied. This type of platform will be realised by Materials Data Space, which is currently being developed by the Fraunhofer Group MATERIALS. Technicians and engineers involved in future lightweight design projects will be able to anticipate which materials can be applied, thus raising the quality of component dimensioning.[16]

This clearly demonstrates that intelligent lightweight design requires an efficient networking system and constructive exchange between the various players and experts.

Together with its partners, the German Federal Ministry for Economic Affairs and Energy has developed an internet database to support and enhance the networking of lightweight design experts **(www.leichtbauatlas.de**). It enables database users to search for appropriate resources and to share their own profile.

Go to **https://go.leichtbauatlas.de/de/HE** to find lightweight design experts[18] in and around Hessen.

www.leichtbauatlas.de

[18] If your data is entered in the database, you can also be found.

4.3 Lightweight design in the focus of the entire value-added chain

In the end, only a marketable product can be successful. When pursuing this strategy for lightweight design, it requires a strategic decision that involves weighing up the costs and benefits. It should always be considered that such know-how generation also enhances competitiveness.

In addition to the various lightweight design sectors, there is also the field of lightweight design research where a distinction is made between basic research[19] and applied research[20]. Research and teaching play a key role for the lightweight design industry in Hessen.

As the educational and training facilities for young engineers and scientists, they supply the experts of the future for both German and Hessian companies. As research institutions, they focus on current problems. In cooperation with industrial companies, they frequently develop existing technologies further and move into new areas of activity, thus creating growth for Germany, a country with high wages, which is facing increasing global competition.

Research is usually carried out at universities of applied sciences and universities, in major research institutions or by external research service providers. Research can be split into three broad categories:

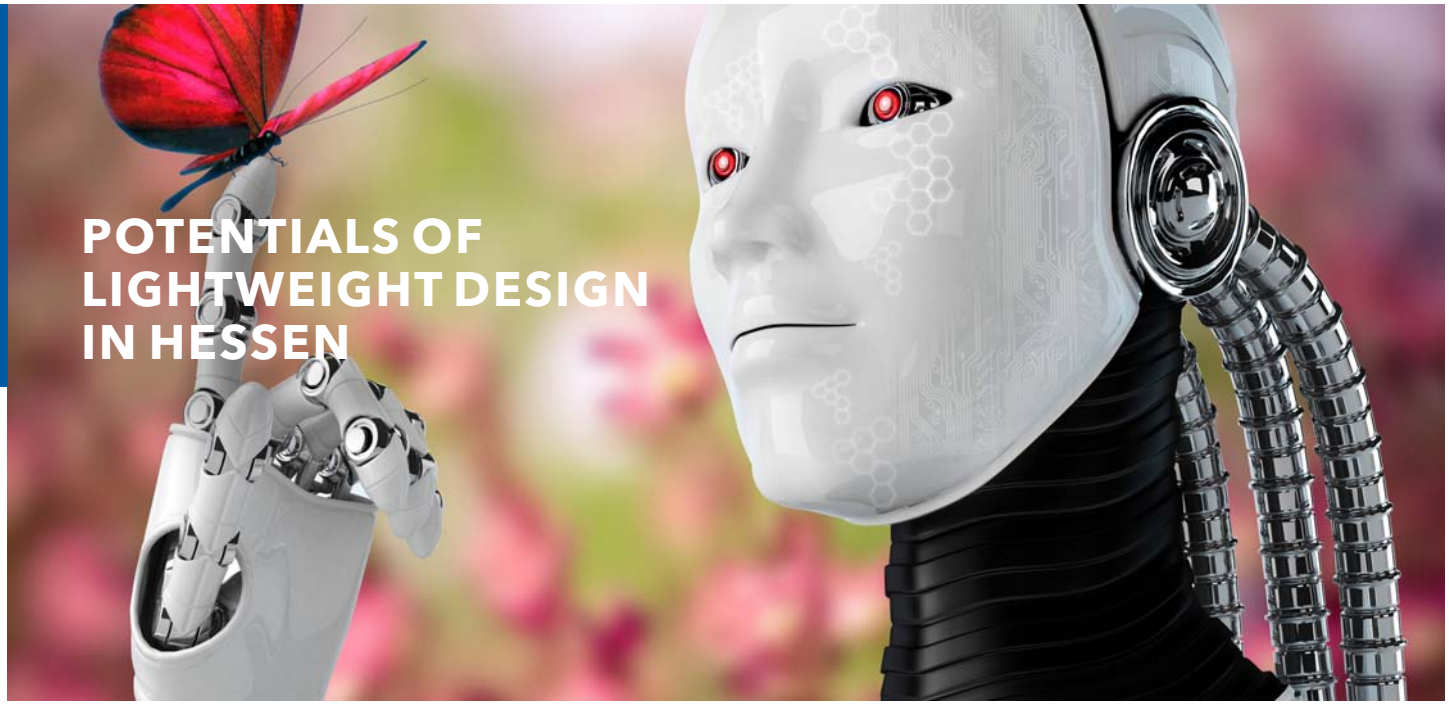
- Basic research demonstrates what is possible. It provides inspiring solutions for future problems and challenges while highlighting present-day limits. The idea and new technology are still very much in their infancy during basic research: The development risks are comparatively high and the journey to the final product is long. Those issues commonly discourage industrial companies from becoming actively involved in basic research. Nevertheless, this area of research is very important, as it opens up new fields of applications and paves the way for innovative solutions. Companies that do not shy away from the risks involved can, if everything goes right, develop a technological lead.

- In contrast, solution-focused applied research shows how projects can be implemented in real-world settings. This might even include producing initial prototypes. Applied research commences with a problem associated with future products or technologies. Cooperation with industry users is therefore quite shrewd. The development risks are lower than with basic research, as the opportunities have already been demonstrated in the lab. In this phase, it is all about paving the way for a new product. This usually motivates innovative industrial enterprises to get involved and engage financially. Applied research projects account for the majority of current research activities.

- Product development (industrial research and development) is the journey to the marketable product. This role is commonly assumed by the industry, although research institutes are often commissioned to provide valuable support through contract research projects. Lightweight design as a driver of product development expertise is a key element of industrial research. The success of lightweight design and the image of Germany as a high-tech location depend on how the various players in this field interact. It is essential that lightweight design methods are constantly developed and brought to life through basic and applied research.

[19] Basic research:
For example, development up to a laboratory demonstrator
[20] Applied research:
For example, development from laboratory demonstrator to an initial prototype

Image: HA Hessen Agentur GmbH – Jan Michael Hosan



5 POTENTIALS OF LIGHTWEIGHT DESIGN IN HESSEN

5.1 Structure of the lightweight design market

The Fraunhofer Institute for Structural Durability and System Reliability LBF has looked at the lightweight design activities of the corporate and research landscape in Hessen as part of a study. The aim of the study was to investigate activities and future potentials in the interdisciplinary technology of lightweight design. The examined lightweight activities include, first and foremost, these three spheres of activity:

- Methods and design principles
- Production of lightweight materials, for example fibre composites, and semi-finished products
- Production of machinery: From the manufacturing of machines, their machining, and their application for the production of components and assemblies in which lightweight materials are applied.

With that in mind, offerings from both companies and research institutes can be split into specific supplier and user industries for lightweight design:

- Lightweight design suppliers incorporate all manufacturers and suppliers whose materials and semi-finished products are used to produce lightweight components and final products. This also includes methods and tools that facilitate the development and design of lightweight products. The key lightweight design suppliers in Hessen are the chemical and plastics industry, the glass, ceramics and construction supply industry as well as the sector of engineering service providers.
- In contrast, lightweight design users further process these materials and semi-finished products in their products. Or they employ lightweight design specific planning and design principles to develop products. The key user industries in Hessen include the transportation sector, especially the automotive industry, the aerospace sector, the construction and architecture industry and medical engineering.

Overview of key supplier industries for lightweight design:

1. Metals and metal ware
2. Rubber and plastic products
3. Glass, ceramics, minerals
4. Textiles, textile products, leather, leather products
5. Timber, paper, print products
6. Chemical products
7. Mining

Overview of key user industries for lightweight design:

1. Transportation (aerospace, automotive, rail vehicles, vessels, others)
2. Machines and plants
3. Building materials, construction engineering
4. Furniture, home appliances, office equipment
5. Energy technology
6. Electrical appliances, electronic and optical instruments
7. Medical engineering
8. Pharmaceutical products
9. Petroleum and refineries
10. Security and defence[1]

[1] The security and defence sector was considered highly relevant due to its high application potential and intensive R&D activities in lightweight design. However, it was not possible to investigate this in more detail during further analysis as there was insufficient corporate information available.

5.2 Potentials of industry in Hessen

Fraunhofer LBF has accessed various corporate databases (incl. Markus, Amadeus, Hoppenstedt) to help identify Hessian companies with lightweight design activities and future lightweight design relevance. The analysis initially showed that the percentage of lightweight design activities relates to the actual size of the respective company: Lightweight design activities are still relatively rare in the group of companies with less than twenty employees. As the number of employees increases, so do the lightweight design offers and applications. The role played by lightweight design is most distinctive at companies in Hessen with more than 250 employees. Today, more than a quarter of the companies of this size use lightweight design methods (users), produce lightweight design materials or parts (suppliers) or process them further into products (users).

Lightweight design – indicator of sales and growth

A look at the top ten most profitable industries of the manufacturing sector in Hessen shows that the majority of them also belong to those industries currently most involved in lightweight design and development (Image 2). At the top of the list is the chemical industry with an annual turnover of almost €16 bn. Moreover, these industries are growth areas in which some businesses in Hessen are growing at a greater rate than the national average.

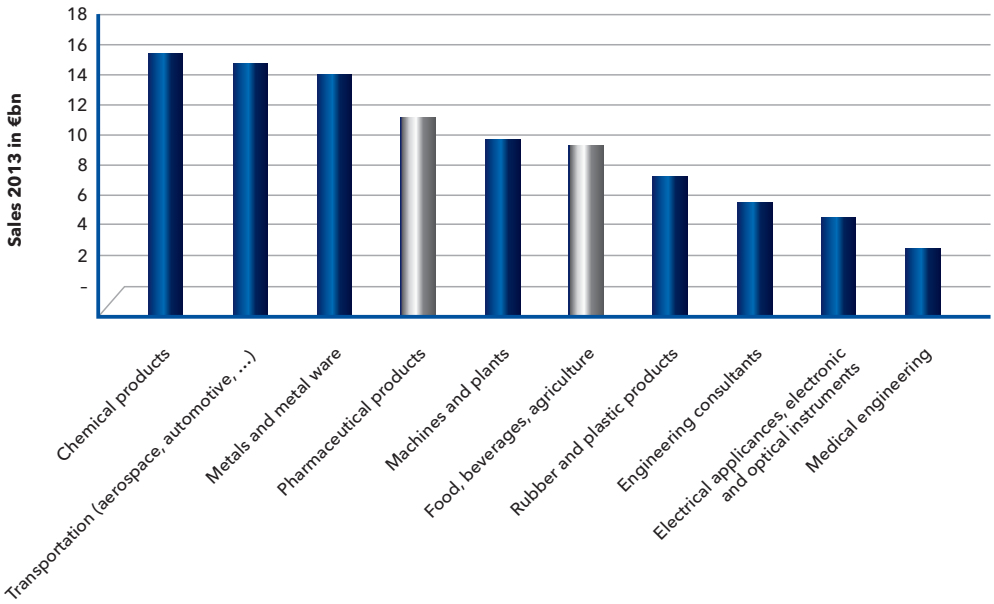


Image 2: Lightweight design (blue bar) plays a key role in almost all of the top ten most profitable industries in Hessen.

High concentration of skills in South Hessen

A regional comparison of lightweight design and development in Hessen showed that the majority of those involved in this field are located in the south of Hessen, especially in the administrative district of Darmstadt (Image 3). Suppliers in South Hessen are typically companies from the chemical and plastics industry. Conversely, users are primarily companies from the fields of mechanical engineering, electrical engineering, electronics and optics, the transportation sector and the branch of engineering consultancy.

The epicentre of lightweight design sources in the field of metal and wood processing is North and Middle Hessen – predominantly in the administrative districts of Kassel and Giessen. In terms of user companies, the spotlight here is firmly on mechanical engineering, the electronics and optics industry as well as furniture construction.

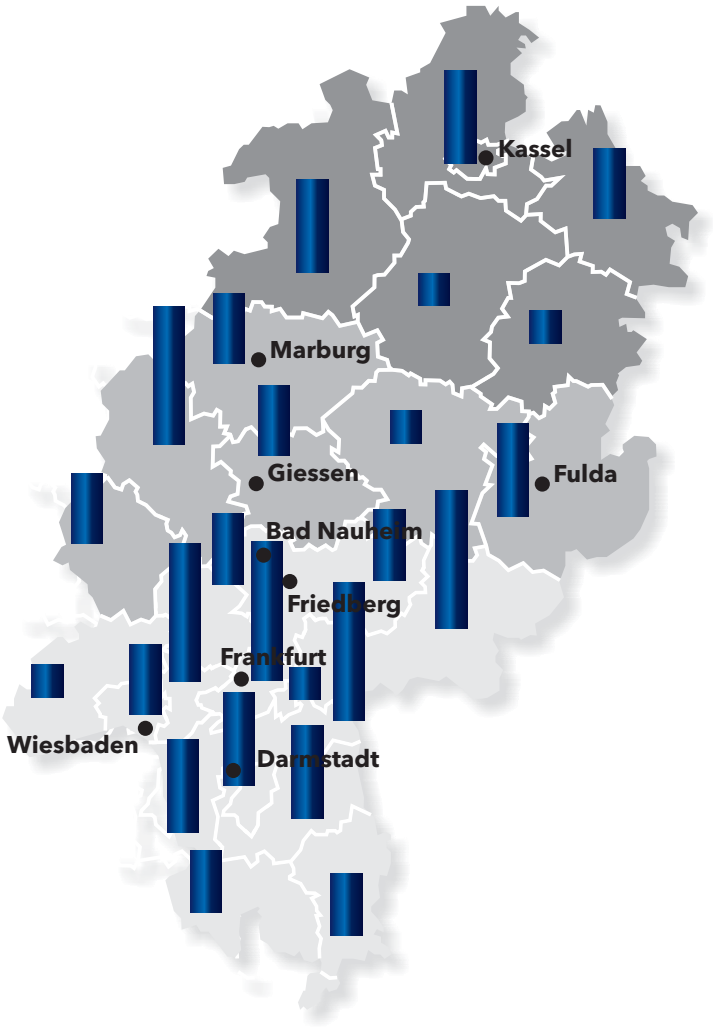
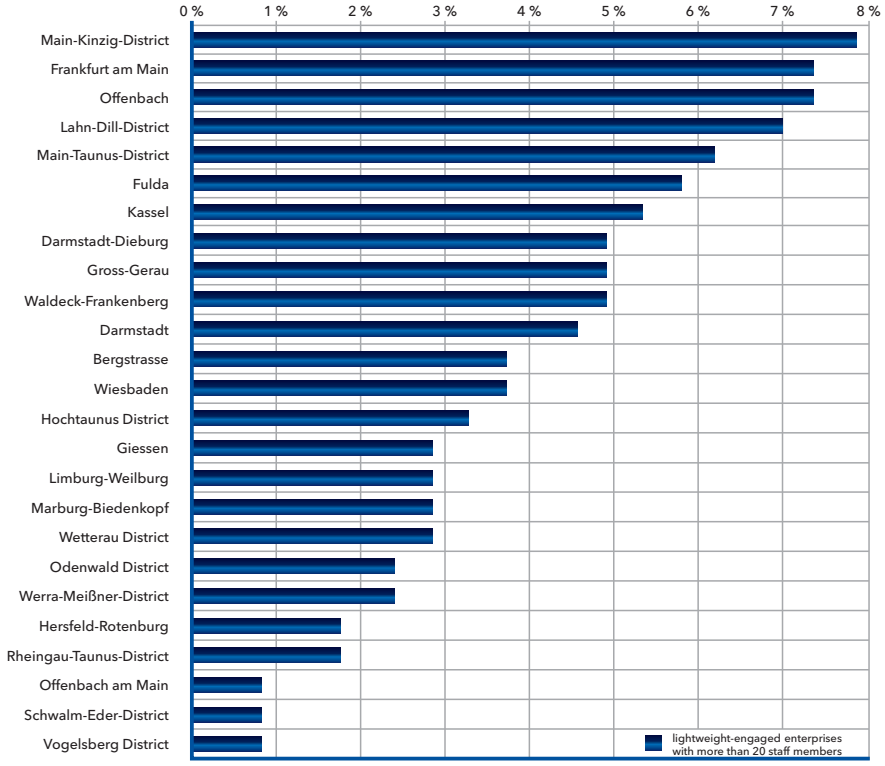


Image 3: The illustration shows the regional distribution of lightweight design companies in Hessen according to rural districts and administrative districts.



Focus on the innovative lightweight design sector

The study has shown that the number of user companies involved in lightweight design is on average greater than source companies. However, based on the number of companies, there is a balanced ratio between lightweight design suppliers and users in Hessen.

The transportation sector - with almost 25 per cent of companies involved in lightweight design - is the largest lightweight design sector in Hessen. It is governed, in particular, by carmakers and their numerous component suppliers. This is obviously strengthened by the endeavour to design and build lighter vehicles, thereby reducing emissions. With this in mind, weight reduction also plays a key role in electromobility. Consequently, the automotive industry in Hessen is in step with the general technological trend and driving innovative lightweight design developments forwards.

Above-average lightweight design and development can also be seen in mechanical engineering, medical engineering and the furniture industry. Similar to the transportation sector, lightweight design is a key topic in mechanical engineering. Again, the goal is to optimise energy expenditure, thereby increasing efficiency. Just as important is the range of machines and tools to process lightweight materials. Mechanical engineering is therefore one of the chief growth sectors for lightweight design. Roughly 10 per cent of the mechanical engineering companies based in Hessen are already key players in the marketplace with a reputation for lightweight design. This has resulted in a balanced ratio between the amount of lightweight components that are used in machines and the number of machines that can be used to process lightweight materials.

In terms of materials in the field of medical engineering, lightweight design is an ongoing trend, especially for prostheses, orthoses and mobility aids. In addition, there is an increasing amount of lightweight components for diagnostic instruments in mobile applications.

Lightweight design remains a niche topic in the furniture sector but is being positively influenced by rising commodity prices, growing environmental awareness and increasing mobility.

In terms of supplier companies, the chemical industry demonstrates a high level of activity in lightweight design. It manufactures, among other things, chemical fibres and plastics, which are basic materials for lightweight components. Furthermore, this sector includes the "traditional" areas of lightweight design: The production of metals and metal wares, such as aluminium or metal foams, the production of rubber and plastics, including fibre-reinforced plastics, and the production of glass and ceramic fibres.

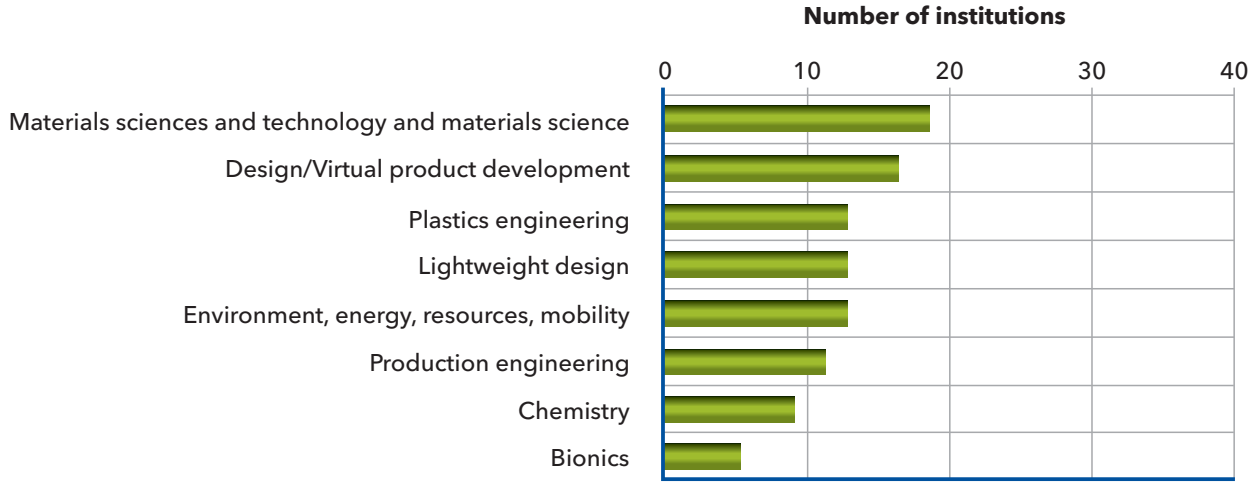
In terms of its economic performance, Hessen is definitely above the national average in all the stated sectors. Moreover, there is a noticeable large potential for new developments that will continue to drive forward the industrial utilisation of lightweight design technologies.

In the service sector, one group is particularly noteworthy: The engineering consultants. The main focus of lightweight design and development here is primarily on the development and application of structural lightweight design methods. As service providers, engineers offer their skills and know-how to optimise material selection and to apply new materials. This is also an area with a high potential for development, especially in terms of the development of methods and concepts for structural lightweight design – for instance simulations.

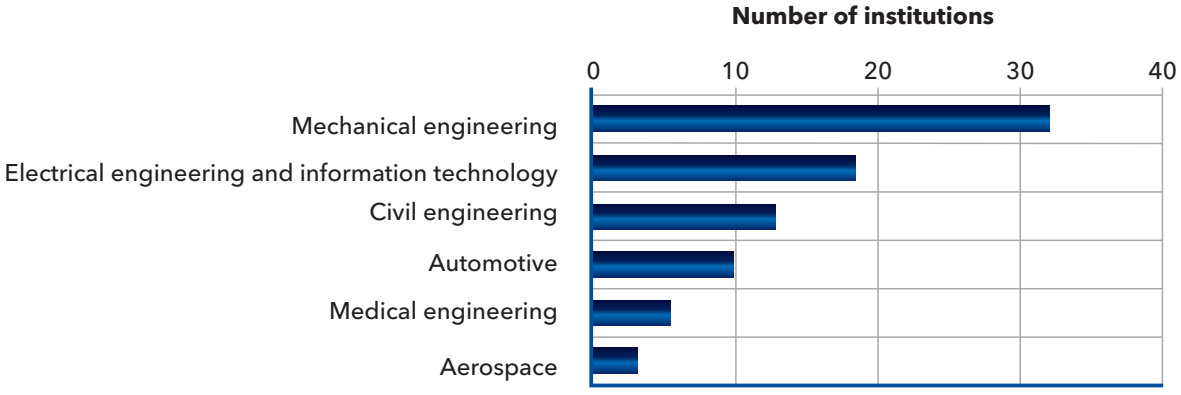
5.3 Potentials of Hessian research

Within the scientific landscape in Hessen, the study has identified numerous institutions that deal directly and indirectly with lightweight design. Of the 35 universities, universities of applied sciences and universities of co-operative education in Hessen, nine engage in lightweight design. Within these institutions, there are 26 specialist departments or institutes that focus on lightweight design-relevant topics. Furthermore, Hessen boasts three non-university research institutions as well as seven competence centres and clusters which also deal with lightweight design-related topics. Overall, 38 technical research and educational institutions were examined with regard to their core competencies.

Just like the corporate landscape, it is possible to group the scientific landscape in Hessen into suppliers and users of lightweight design-relevant expertise (Image 4). Suppliers are institutions that conduct research throughout the value-added chain, thereby contributing to the lightweight design product. Users are institutions that develop and utilise lightweight materials and methods. Finally, the core competencies of the research institutions were assigned to an industrial sector.



Suppliers of lightweight design-relevant expertise at technical educational and research institutions in Hessen



Users of lightweight design-relevant expertise at technical educational and research institutions in Hessen

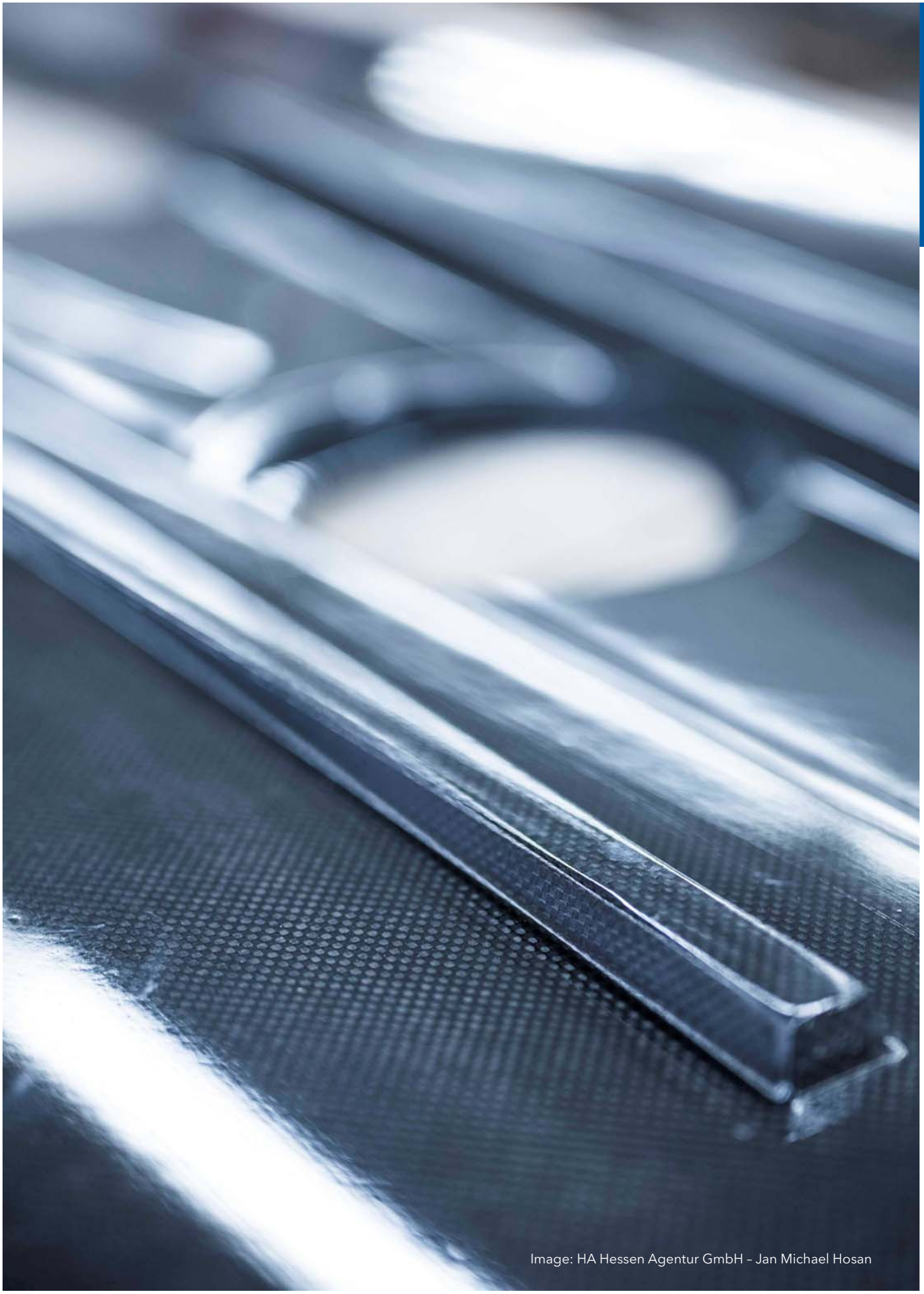


Image: HA Hessen Agentur GmbH – Jan Michael Hosan

Lightweight design expertise throughout Hessen

When it comes to the regional distribution of lightweight design expertise, the structure is similar to the one in the industrial sector: For instance, South Hessen is, to a large extent, home to lightweight design suppliers: From general materials sciences and plastics engineering to bionics.
In terms of user companies, this refers, by and large, to research institutions located in the fields of mechanical engineering, electrical engineering and information technology or civil engineering. Despite this particular focus on the South Hessen area, it has been shown that high levels of expertise in various lightweight design disciplines are available throughout the whole of Hessen (Image 5).

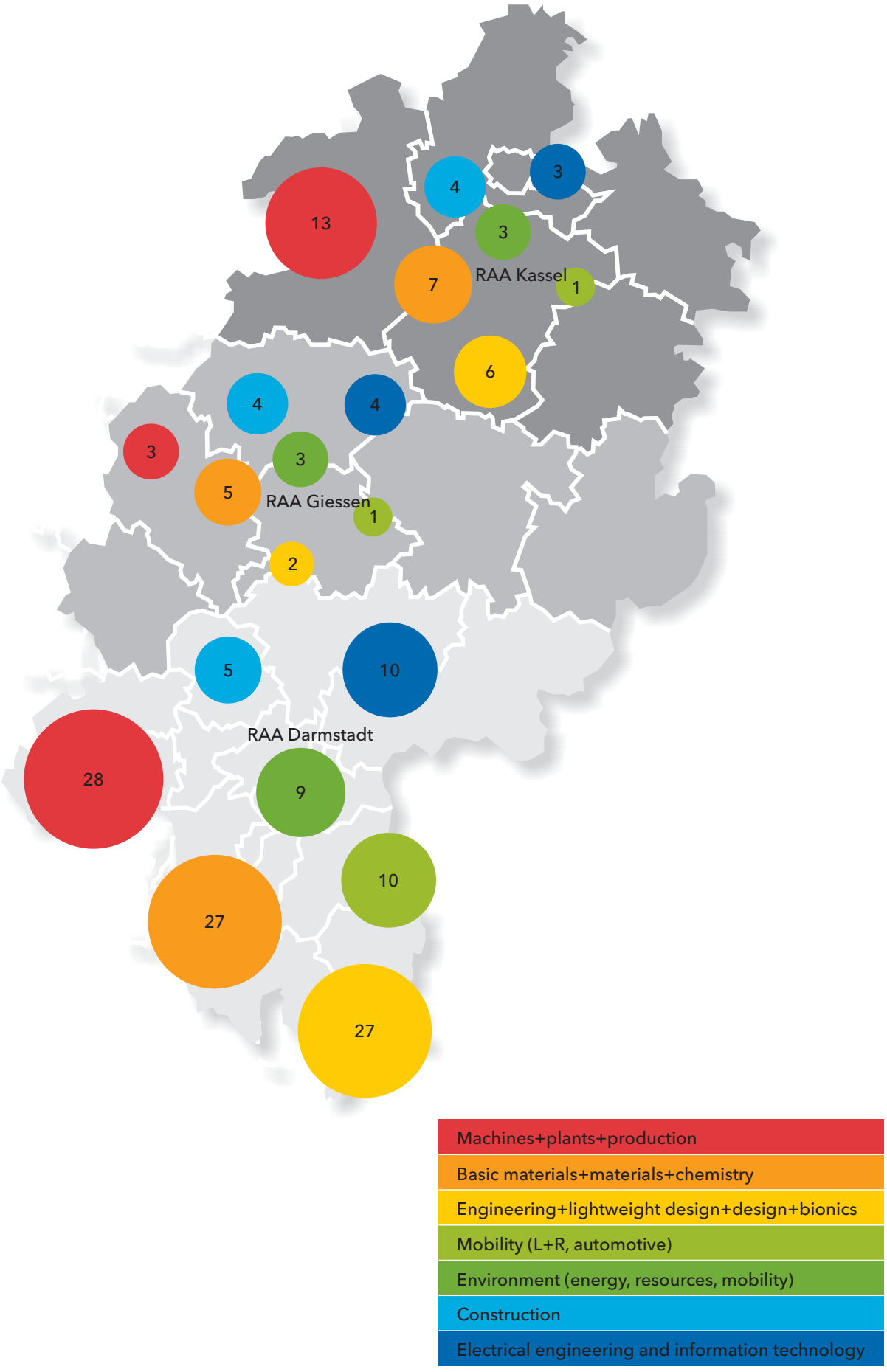
Strong networking potential of science and industry

Overall, the results clearly show that the research landscape in Hessen concentrates more on lightweight design technologies than industry does. This applies, in particular, to materials and basic materials, methods, (production) processes and concept development. The focus of materials and basic materials – particularly in plastics engineering – corresponds significantly with the sectors of industrial suppliers. They thus provide a strong networking potential of science and industry.

This networking also presents a significant potential for innovation. In the future, the aim is to further merge – more material-related – research with areas of industrial lightweight design application located throughout Hessen: e.g. with automotive engineering, mechanical engineering, medical engineering and electrical industry.

The following examples show those technologies, processes and skills in which the potential for lightweight design players in Hessen is increased.

Image 5: Focus of research institutions with a potential for lightweight design in Hessen according to regional administrative authorities (Kassel, Giessen, Darmstadt)



6 UNLOCKING LIGHTWEIGHT DESIGN POTENTIALS – FUNDING OPTIONS FOR R&D PROJECTS

The public funding of research and development projects is, particularly in new fields of technology, a key financial component when it comes to creating innovative products and developing new fields of business. In addition to monetary sponsorships, easier access to know-how and networking with public research institutions play an important role here.

The following chapter provides an overview of the various regional and national funding programmes available, which are well suited to lightweight design and development.

6.1 Funding opportunities of the Federal State of Hessen

The Federal State of Hessen offers a number of funding and finance schemes to fund technology-based, innovative research and development projects at the interface between science and industry. Depending on the actual funding programme, Hessen Agentur acts as the project's executing agency or technical support agency and is the direct contact during the application phase and the entire project life-cycle.

New programme: Exemplary R&D projects

The Hessian Ministry of Economics, Energy, Transport and Regional Development uses financing from the European Regional Development Fund (ERDF) to support innovative projects that focus on creating and investigating new products, procedures and services. As from now, small and medium-sized enterprises (SMEs), in particular, and universities in Hessen can seek expert advice in specialist areas.

Joint research projects between SMEs and universities, research institutions or businesses are funded. In-house projects are also possible. Funding is awarded as a pro-rata grant. The funding quota is up to 50 per cent of the eligible expenditure incurred by a project.

The focus is on R&D projects in the fields of technology & innovation (open to all research topics), CO_2 reduction and digitisation.

The team of experts at Hessen Agentur discusses project ideas with potential applicants and checks the content of their project proposals before a formal application is submitted to Wirtschaft- und Infrastrukturbank Hessen (WIBank).
www.technologieland-hessen.de/efre

Further funding opportunities: LOEWE funding line 3, electromobility, logistics and mobility

LOEWE stands for "Landes-Offensive zur Entwicklung wissenschaftlich-ökonomischer Exzellenz" (State Initiative for the Development of Scientific and Economic Excellence) and was founded by the State of Hessen to fund outstanding joint scientific projects conducted by universities and research institutions in the region. In the third funding line of the LOEWE programme (SME joint projects), Hessen Agentur, on behalf of the Hessen State Ministry for Higher Education, Research and the Arts, supervises interested enterprises and universities that wish to jointly develop new, marketable products, procedures and services.
www.innovationsfoerderung-hessen.de/loewe-foerderlinie-3

While LOEWE support is available to all sectors, the Federal State of Hessen also provides grants for selected areas of application:

- The funding of electromobility focuses on measures that are intended to assess and establish the practicality and suitability of electromobility for daily use.
  www.innovationsfoerderung-hessen.de/elektromobilitaet

- To further strengthen Hessen as a hub of logistics and mobility expertise, the State of Hessen funds the development of innovative concepts, technologies and procedures as well as business models in this sector.
  www.innovationsfoerderung-hessen.de/logistik-und-mobilitaet

HA Hessen Agentur GmbH

Hessen Agentur is a state-supported agency that provides comprehensive information for research and business opportunities in Hessen. It supports the delivery of projects, campaigns and funding activities and additionally acts as an adviser and think tank. Advice and assistance for funded R&D projects is provided by experts. The innovation funding team has managed over 500 funding projects successfully since 2008.
www.innovationsfoerderung-hessen.de

HESSEN HessenAgentur
HA Hessen Agentur GmbH

New programme: PIUS-Invest funding programme

The PIUS-Invest funding programme allows small and medium-sized enterprises to apply for an up to 30 per cent grant for investment in the reduction of their CO_2 emissions. Eligible projects must contribute significantly to improving the CO_2 balance as part of process and/or organisational innovations, exceed current minimum statutory standards, if applicable, and address at least one of the following aims:

- Improving energy and resource efficiency,

- Storing energy, production, distributing and utilising renewable energies, adapting to climate change,

- Saving supplies and establishing recovered substance cycles, utilising advanced manufacturing techniques

Replacement or extension investments that simply correspond to the current statutory standard are not eligible.
www.wibank.de/pius-invest-efre

Innovationskredit Hessen

Innovationskredit Hessen offers low-interest financing for innovative small and medium-sized enterprises and relieves principal banks from default risks as a result of the 70 per cent release from liability. The tangible and intangible investments and working capital of innovative and fast-growing small and medium-sized enterprises, start-ups and business transfers can be financed (i.e. up to 100 per cent of expenses eligible for funding). The loan amount ranges from €100,000 to €7.5m.
www.wibank.de/innovationskredit-hessen

Wirtschafts- und Infrastrukturbank Hessen (WIBank)

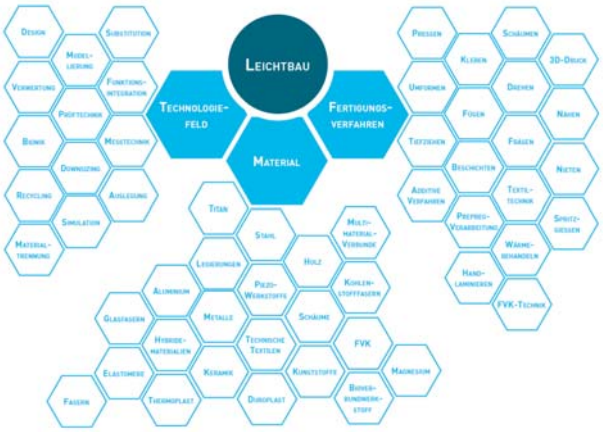
The WIBank is the contact for general funding advice. The Hessen-based funding body provides advisory services to companies and founders on public funding. Activities focus on all the offerings provided by the Federal State, the Federal Government and the EU to support companies through financing sources consisting of bond, equity and loan funding and subsidies. Independent and free funding consultancy is offered.
www.foerderberatung-hessen.de

WI Bank
Wirtschafts- und Infrastrukturbank Hessen

6.2 Initiatives and funding activities of the Federal Government

Lightweighting Initiative – national and international platform for lightweight design in Germany

Lightweight design is of crucial importance for the competitiveness of many sectors and the thorough modernisation of the industrial sector in Germany.



Technological aspects of lightweight design

Besides increasing know-how, implementing safe lightweight structures and getting them onto the market, lightweight design delivers greater material and energy efficiency, thereby enhancing environmental and climate protection. The Federal Ministry for Economic Affairs and Energy will therefore continue and expand its efforts to fund this technology of the future. This relates, in particular, to backing initiatives for more widespread industrial roll-out of lightweight design and its use in mass production.

To achieve this goal, The Federal Ministry for Economic Affairs and Energy has set up the Lightweighting Initiative Coordination Office in Berlin. As part of the Lightweighting Initiative, the Coordination Office (also see www.inititativeleichtbau.de) is to act as a national and international network hub for German companies, especially SMEs, supporting the implementation of lightweight design and fostering the cross-sectoral transfer of technology. Through practical recommendations for companies and policy makers, as well as customised support, it additionally provides the sector with a decisive boost.

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www.initiativeleichtbau.de

INITIATIVE LEICHTBAU

Lightweight design skills in Germany at a glance – Leichtbauatlas (the lightweight atlas)

The Leichtbauatlas is an interactive portal and pools cross-sectoral and material-neutral information on national and international lightweight design players and their lightweight-relevant skills and activities. The fast-growing portal supports both enterprises and research institutions as well as other organisations in, for example, their quest to find solution providers or project partners.
www.leichtbauatlas.de

www.bmwi.de

Bundesministerium
für Wirtschaft
und Energie

Relevant funding programmes of the Federal Ministry for Economic Affairs and Energy that can also be used, in particular, for lightweight design:

- The ZIM is a federal, technology and sector-open funding programme for medium-sized enterprises and cooperating research institutions.
  www.zim-bmwi.de
- Industrial collective research acts as the bridge between basic research and industrial application.
  www.aif.de/igf
- The aviation research programme ("LuFo") supports research and technology for civil aviation in Germany.
  www.dlr.de

BMBF funds lightweight design innovations

The Federal Ministry of Education and Research (BMBF) supports the strengthening of industrial competitiveness in Germany through material-based product and process innovations. Lightweight design technologies can make important contributions in this respect. This is the reason why many measures, especially in the field of "lightweight design", have been funded in the past. These were specifically accomplished through the BMBF framework programmes for research: "Material Innovation for Industry and Society", "From Material to Innovation" and "Innovations for Production, Services and Work in the Future". In other BMBF funding programmes, for instance the Leading-Edge Cluster MAI Carbon, ARENA 2036, FOREL or Open Hybrid LabFactory, industry and research partners have collaborated successfully to strengthen Germany's position in the lightweight design sector through their research results and product developments.

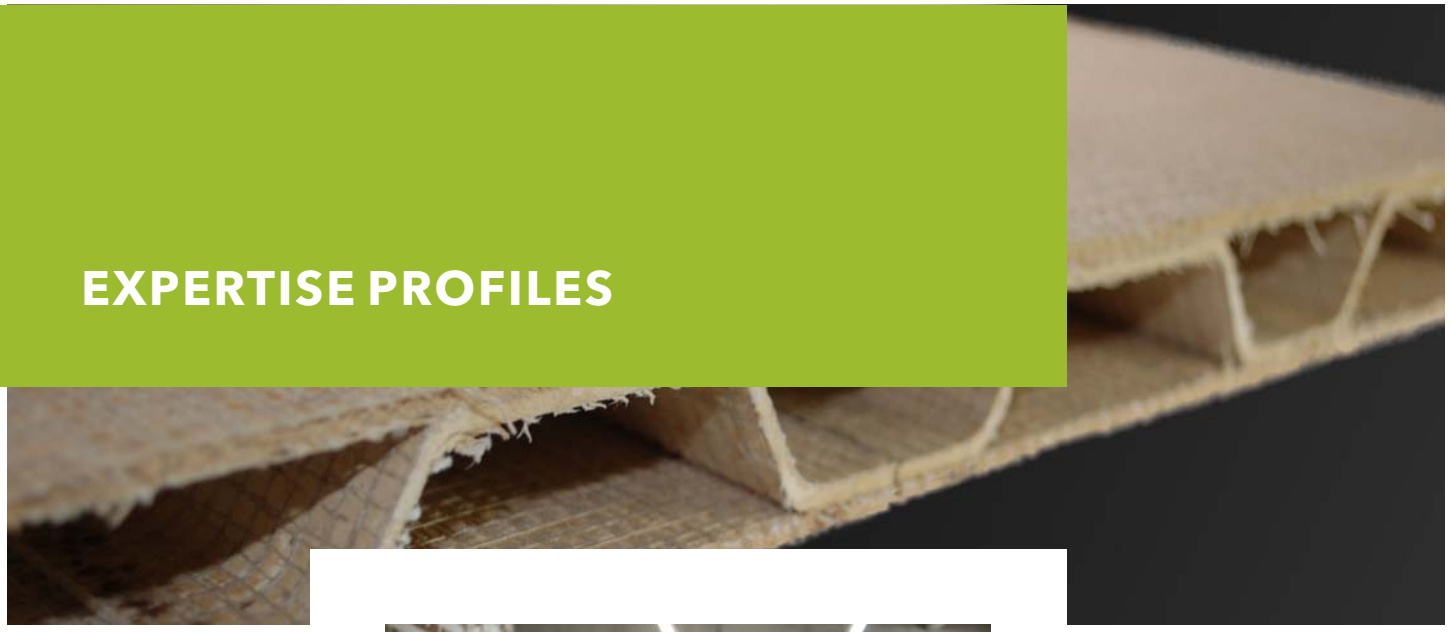
The materials platform "Hybrid Materials – New Opportunities, New Market Potentials (HyMat)" is currently addressing the commercial viability of materials-based technologies for the elimination of existing barriers to innovation. This is where lightweight design ideas are formed and implemented by combining various properties (hybrid materials) to provide the optimum solution, especially in response to the increasing demands placed on technical materials. Moreover, additional funding measures within the framework of materials research funding, which do not address lightweight design explicitly, still focus on issue-related and innovative project proposals featuring lightweight design aspects, particularly within the funding programme "SME Innovative: Materials research (ProMat_KMU)".

Funding is provided to support the financing of research and development expenditures of universities, research institutions and commercial enterprises working together in industrially led collaborative projects. A joint funding quota of up to 50 per cent is possible depending on the level of innovation and range of application of the project ideas and their economic and social importance. To strengthen Germany's position as a leading source of lightweight materials and construction, relevant topics will continue to be taken into account in future BMBF measures.

www.bmbf.de
www.werkstofftechnologien.de

Bundesministerium
für Bildung
und Forschung

7 EXPERTISE PROFILES



7.1 Hexagon xperion GmbH

7.2 TH Mittelhessen University of Applied SciencesCompetence Centre AutoM for Automotive – Mobility – Materials Research

7.3 Fraunhofer Institute for Structural Durability and System Reliability LBF

7.4 compoScience GmbH

7.5 Competence Centre for Automotive, Mobility and Materials Research

7.6 Die Ruderwerkstatt GmbH

7.7 TU Darmstadt – Chair of Paper Technology and Mechanical Process Engineering (PMV)

7.8 Evonik Resource Efficiency GmbH

7.9 EDAG Engineering GmbH

7.10 MeFeX GmbH

7.11 FINOBA Automotive GmbH

7.12 University of Kassel – Institute of Materials Engineering

7.13 TU Darmstadt – Chair of Lightweight Construction and Design (KLuB)

7.14 Frankfurt Research Institute (Ffin)

7.15 University of Applied Sciences Darmstadt – Institute of Plastics Engineering Darmstadt (ikd) Materials and Plastics

7.16 University of Applied Sciences Darmstadt – Institute of Plastics Engineering Darmstadt (ikd)

7.17 University of Applied Sciences Darmstadt – Department of Mechanical Engineering and Plastics Engineering

7.18 FkL Ingenieurbüro Schumacher

7.19 University of Kassel – Institute of Materials Engineering

7.20 Fraunhofer LBF Department of Structurally Durable and Function-Integrated Lightweight Design

7.21 ICM-Composites GmbH & Co. KG

7.22 Kargon GmbH

7.23 Carbon-Drive GmbH

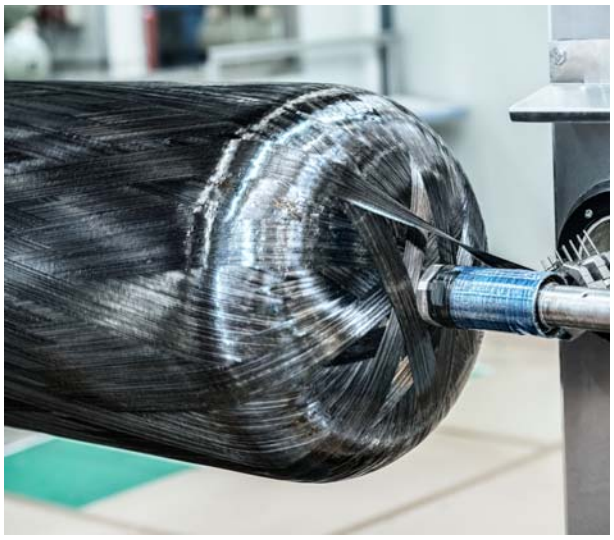
7.1 HEXAGON XPERION GMBH: THE SIMULATED TANK

Optimised design reduces the amount of material required for hydrogen tanks

With the aid of computer simulations, Hexagon xperion develops lightweight design tanks for hydrogen motor vehicles.

Ensuring our future energy supply, noticeably reducing carbon dioxide emissions and using renewable energy are the key challenges facing sustainable mobility. Ranges of up to 600 km are promised when using hydrogen fuel cells in electric vehicles.
The ability to store hydrogen is one of the key technologies here.

Storing hydrogen as a compressed gas under high pressure (up to 700 bar) is currently the most mature technology for market entry. However, one of the main barriers to market entry is the high price of the pressure vessels, which is dictated to 75 per cent by the high material costs for the carbon fibre-reinforced composite materials. Innovative concepts to help improve the design, enable future high-volume production of pressure vessels and to minimise their overall costs are urgently needed before large-scale production can commence.



Winding of a Type 4 high pressure vessel from Hexagon xperion for hydrogen applications

Optimisation in an early phase

Within the scope of the cooperation project 3DSIM, the Kassel-based lightweight design specialist Hexagon xperion GmbH has joined forces with Opel AG and TU Darmstadt to develop a computer-based simulation method to optimise the production of hydrogen high-pressure vessels at an early stage of development. The simulation tool calculates the entire production process for a 700 bar type 4 hydrogen high-pressure vessel, thus helping to cut the amount of material required.

During the winding process, carbon fibre rovings (bundle of parallel arranged continuous filaments) are soaked in resin and then placed on the vessel surface according to previously calculated patterns. These patterns already need to be calculated during the development phase to guarantee the most detailed simulation possible of the vessel under load. Production-dependent parameters can therefore be considered when developing the actual design.

Intermediate fibre fractures under load

In addition to production simulation, a second focus was placed on the mapping of the non-linear material performance of the fibre-plastic composite. Intermediate fibre fractures occur at a relatively early stage under load. However, these levels of degradation do not lead to failure of the vessel structure, as the load-bearing fibres remain undamaged. These degradation mechanisms do, nonetheless, influence the rigidity of the individual layers and should be taken into consideration to allow an exact prediction of stress distribution.

„3DSIM allows us to design our lightweight design tanks efficiently for further, customer-specific requirements and to produce them cost effectively."

Dr. Michael Kleschinski, CEO of Hexagon xperion

To this end, a subroutine was developed that maps the deterioration process as a simulation. By considering the production process and improving mapping of the material performance, the project partners have been able to reduce the amount of expensive carbon fibres significantly through optimised vessel designs.

Installation of 700 bar hydrogen high-pressure tanks in the Opel HydroGen4 (source: Opel)

The design and production know-how for the lightweight design vessels is provided by Hexagon xperion. The company can employ the simulation tool for a multitude of applications and adapt it to the needs of its customers. The company aims to save future development costs through computer-aided simulation and to take forward the commercialisation of alternative drive technologies in fuel cell and natural gas motor vehicles.

Contact

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HEXAGON xperion ENERGY & ENVIRONMENT

Project

This project (HA project no.: 301/11-46) was funded as part of Hessen ModellProjekte as an SME model and pilot project (MPP) using funds from the State of Hessen and the European Union (European Regional Development Fund (ERDF)).

HESSEN Ministry of Economics, Energy, Transport and Regional Development, State of Hessen

EUROPEAN UNION Investing in our Future European Regional Development Fund

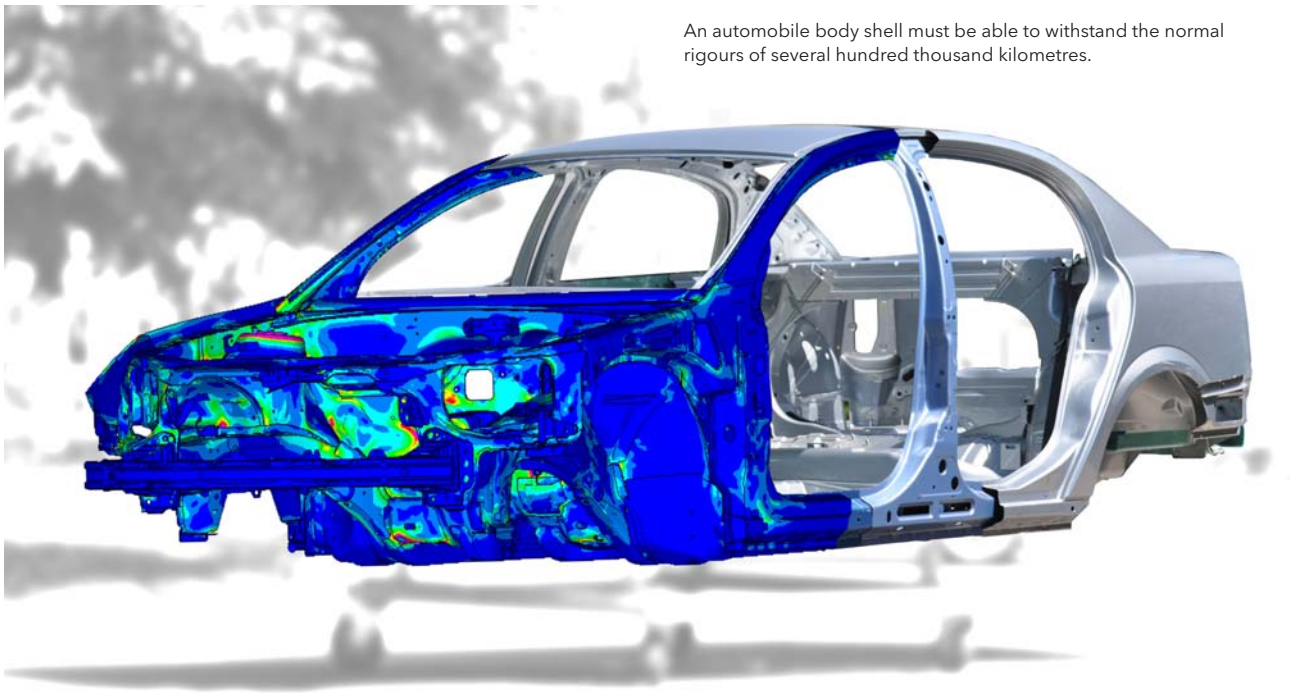
7.2 TH MITTELHESSEN UNIVERSITY OF APPLIED SCIENCES:

Fast and simple preliminary design of automobile structures

The new design method BFast allows small and medium-sized automotive suppliers to make statements about the durability of their lightweight structures during the early stages of development.

The Competence Centre for Automotive, Mobility and Materials Research at TH Mittelhessen University of Applied Sciences has developed the new design method BFast in collaboration with LINDE + WIEMANN from Dillenburg, the engineering firm Huß und Feickert from Liederbach, BÜRCKENMEYER from Stadtallendorf and Opel Automobile from Rüsselsheim. It enables the fast and simple preliminary designing of automotive lightweight structures in terms of their structural durability.

The issue of lightweight design is of critical importance in automotive technology. Saving materials, weight and energy without having to make any concessions regarding functionality, economic viability or safety is the top priority in every situation. Lightweight design is inevitably in danger of using up all its reserves, gradually pushing a structure's limits of durability to their breaking point. This ultimately leads to a growing demand for sustainable structural durability. It ensures that a car can travel several hundred thousand kilometres in a lifetime without suffering catastrophic component failure.



An automobile body shell must be able to withstand the normal rigours of several hundred thousand kilometres.

„TH Mittelhessen University of Applied Sciences consolidates its lightweight design research activities at the Competence Centre for Automotive, Mobility and Materials Research."

Prof. Dr.-Ing. Udo Jung, Department of Mechanical Engineering, Mechatronics, Material Sciences, TH Mittelhessen University of Applied Sciences

Reducing load time series

Computer-based life cycle simulation is a highly effective way of guaranteeing this. It is, however, quite demanding in terms of time and costs: Cyclic material data (Wöhler curves) for all the applied materials are just as important as extensive load time series, which describe the constantly changing loads when driving. The research project TH Mittelhessen University of Applied Sciences has managed to reduce these complex load time series down to a few equivalent static loads that result in comparable damage to the component with more frequent repetition.

Equivalent static loads represent driving manoeuvres that have a serious and damaging effect on a vehicle, such as slamming on the brakes, driving too fast around a tight bend or hitting a pothole. Equivalent static loads can be seen as snapshots in time at which a load impacts a certain structural element of the vehicle.

Major carmakers measure load time series on in-house test tracks. This effort is not financially viable for small and medium-sized enterprises. Nonetheless, suppliers are expected to present technically mature lightweight design concepts. It is for this exact purpose that BFast provides a fast, simple and cost-effective preliminary designing method.

Bfast allows small and medium-sized suppliers to make statements about the durability of lightweight automotive structures during the early stages of development on the basis of finite element analyses. It eliminates the need for test runs or materials testing in advance.

Contact

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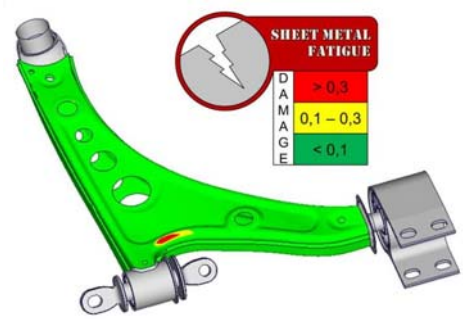


Design method BFast allows you to forecast a crack in a component (highlighted yellow-red) using a computer simulation.

Project

This project (HA project no.: 311/12-01) was funded as part of LOEWE – State Initiative for the Development of Scientific and Economic Excellence, third funding line: SME joint projects.

7.3 FRAUNHOFER LBF: RE-INVENTION OF THE WHEEL

Aircraft wheels made of fibre composites

Development engineers in Darmstadt are working on an aircraft wheel made of fibre-reinforced plastic. Lightweight design is helping to make aviation more environmentally sustainable.

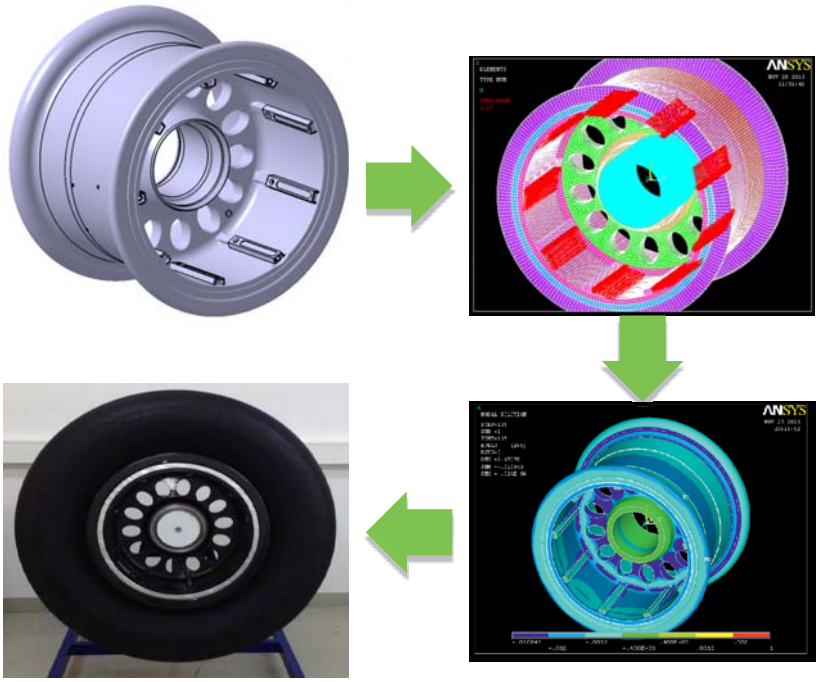
As aviation emissions are responsible for a significant amount of CO_2 emissions in the transportation sector, the aviation industry is interested in minimising emissions in the long term and making the industry more environmentally friendly. To achieve this goal, it has now given itself the ambitious target of reducing CO_2 emissions by 50 per cent by 2050.

The key is developing new technologies and methods that enhance fuel efficiency. Within this development, priority is given to lightweight design. Today, development engineers increasingly employ composites to ensure future generations of aircraft are lighter.

Main landing gear wheel subjected to cyclic load

In cooperation with the Hessen-based company Röder Präzision, experts from Fraunhofer Institute for Structural Durability and System Reliability LBF in Darmstadt have investigated how an aircraft wheel made of fibre-reinforced plastic can be produced. Additional support was provided by Lufthansa AG and the State of Hessen.

The feasibility study focussed on developing a main landing gear wheel under real-world operational cyclic loads. Based on the average number of start and landing cycles and general airfield and runway conditions, the project employed a set of stress factors that included all the loads experienced by an aircraft through landing impact, braking, rolling and curves. Using this set of stress factors, the development engineers dimensioned the wheel with the aid of LBF®.WheelStrength, a specially



From the idea to the prototype: An aircraft wheel made of fibre-reinforced plastic

„Every kilogramme counts when it comes to aircraft. A significant reduction in weight can be obtained for aircraft by using fibre composites."

Dipl.-Ing. M. Eng. Conchin Contell Asins, Fraunhofer-Institute for Structural Durability and System Reliability LBF, Department of Structurally Durable and Function-Integrated Lightweight Design

developed software that uses 3D models of wheels and wheel hubs, plus other details, to detect and highlight potential safety risks through virtual stress tests.

The results showed that this kind of wheel with a potential for light construction does in fact appear possible – the starting signal for a new research project.

Further development through EU JTI Clean Sky 2

An initial wheel was designed and a prototype produced to demonstrate the possibilities offered and to highlight the challenges facing manufacturers. The European aviation research project Clean Sky 2 picked up on these results and developed them further.

The goal is to improve the wheel's design in terms of its load capacity, to optimise its topology and to uncover innovative solutions for local reinforcement of the structure. Clean Sky 2 has set itself the target of maximising the potential of lightweight design.

Contact

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Fraunhofer LBF

Project

This project (HA project no.: 376/13-15) was funded as part of LOEWE – State Initiative for the Development of Scientific and Economic Excellence, third funding line: SME joint projects.

HESSEN Ministry of Economics, Energy, Transport and Regional Development, State of Hessen

LOEWE Exzellente Forschung für Hessens Zukunft

7.4 COMPOSCIENCE GMBH: MODIFIED SANDWICH COMPOSITE

Crash-optimised, hybrid bending beams for the automotive industry

A team of development engineers from compoScience GmbH in Darmstadt has successfully eliminated the brittle fracture properties of composite beams in structures with a high degree of bending stress. This is particularly interesting for the automotive industry.

For the past decade, compoScience GmbH has been developing lightweight design solutions from composites and collaborates with the automotive industry, among others.

Aside from good static strength and rigidity, automotive structural components must provide outstanding crash properties. This includes high energy absorption capacity and unproblematic failure behaviour. In this respect, composites are initially significantly inferior to metal materials due to their lower ultimate strength and elongation at break. Composite beams fail at several individual points and with a low level of energy absorption, especially at structures with a high degree of bending stress.

This fact combined with the, until now, relatively unpredictable numerical failure behaviour of the inhomogeneous material is the reason why this material group is not a mainstay of automotive structures. Another reason is the increased production costs of composites.

"quasi-tough" failure behaviour

As part of a funded joint project with Opel, Evonik and the University of Applied Sciences Darmstadt, the team of development engineers from compoScience GmbH were able to modify the material performance of a sandwich composite, thereby guaranteeing successive, "quasi-tough" failure behaviour instead of the normal brittle fracture properties. The bending beams are manufactured using a so-called CohyBA procedure: They no longer break due to brittleness but expand locally under load and fail under high energy absorption.

In contrast to previous common practice, the CohyBA structural elements are not produced by joining together cut-to-size pieces in a tool to create a finished component. Instead, the fibres are wound around a foam core fully automatically and endlessly and then coated in-line with resin and hardened. Various failure mechanisms occur under crash load conditions, with each failure mechanism guaranteeing higher energy absorption.

It is essential that the reinforcement laminate does not fail as a whole, but, similar to a Chinese finger trap, is radially constricted, thus compressing the foam below.

This design is ideal for by side crash affected components such as door sills and the side impact beams integrated in the door. These elements can be manufactured cost effectively using the pull-press-process developed by Evonik.

Aircraft seat in the future?

The joint project additionally focussed on the poor "predictability" of this new material class. Extensive material testing was initially carried out in order to describe the complex material behaviour numerically.

In the end, it was possible to use several material models to realistically map and extensively examine the "quasi-ductile" material behaviour that is atypical for composites, using several material models. These material models are only used in compoScience GmbH's commercial application for crash calculations.

In the future, the CohyBA principle is also to be used in other industries. The team of development engineers is currently testing other areas of application. At present, a feasibility study is investigating the application of crash-optimised bending beams in the structure of aircraft seats.

„As a development service provider for composite applications, lightweight design is our bread and butter. Funded projects allow us to investigate new technologies and processes and to continually expand our product portfolio."

Dr.-Ing. Martin Fleischhauer, Managing Partner
of compoScience GmbH

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The CohyBA team of development engineers with a composite side skirt prototype

Project

This project (HA project no.: 476/15-18) was funded as part of LOEWE – State Initiative for the Development of Scientific and Economic Excellence, third funding line: SME joint projects.

7.5 COMPETENCE CENTRE FOR AUTOMOTIVE, MOBILITY AND MATERIALS RESEARCH: OPTIMISED RIVETING

Joining ultra-high-strength steels in the automotive sector

A research group at the Competence Centre AutoM, TH Mittelhessen University of Applied Sciences, is currently busy working on joining ultra-high-strength, thermo-formed steel components with the aid of semi-hollow rivets. The respective joints achieve strength levels of up to 2000 N per square millimetre and are intended for applications in automotive architecture.

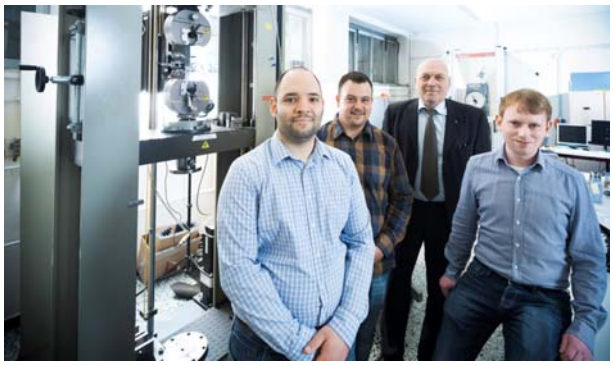
New mixed material concepts are highly appealing to the automotive industry. They help to save lots of weight yet guarantee adequate rigidity to enhance accident safety. This would make current and future car bodies lighter and at the same time safer. This is the aim of the research group at the Friedberg campus which is made up of Opel Automobile GmbH, Stanley Engineered Fastening-Tucker, LINDE + WIEMANN, the B+T Group and Holzapfel Metallveredelung GmbH.

The development of joining methods for ultra-high-strength steels with a mixed material design, for example aluminium, is essential for carmakers to realise light-weight designs. This is necessary since the joining methods that have been predominant so far, such as resistance spot welding, cannot be applied with material combinations of this kind.

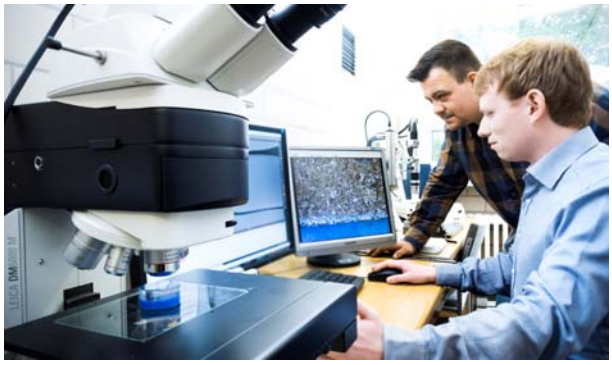
The project is funded by HA Hessen Agentur GmbH as part of Hessen ModellProjekte. Its objective is to optimise semi-hollow riveting procedures for future applications, for instance for door modules. The development portfolio assesses optimised semi-hollow riveted and adhesive joints as well as a hybrid joining solution, although the latter combines both joining variants. The generated samples and demonstrators are examined under quasi-static, dynamic and complex loading conditions.

Research partners work in close collaboration

The high level of strength provided by hot-formed press hardening steels (PHS) demands development of optimised riveting technology. Supported by extensive simulations and joining tests, the research partner "Stanley Engineered Fastening" from Giessen managed to provide an appropriate technology.



Research group of THM (from left to right): Dipl.-Ing. Sascha Roth, B.Eng. Rene Glück, Prof. Dr.-Ing. Heinrich Friederich, B.Eng. Maximilian Stähling



Testing joints with a light-optical microscope at the metallography laboratory of THM
(Photos: HA Hessen Agentur GmbH – Jan Michael Hosan)

In parallel with this effort, the coating specialists at Holzapfel Metallveredelung GmbH from Herborn developed a special adhesive joint. It combines the plate structures in such a way that crevice and contact

„The further development of joining technologies is indispensable in order to utilise the potentials of new lightweight materials for multi-material construction."

Prof. Dr.-Ing. Heinrich Friederich, Competence Centre AutoM,
TH Mittelhessen University of Applied Sciences

corrosion is pretty much impossible in the overlapping joint.

The series of tests for determining superimposed corrosive-mechanical stress are ideal for mapping the sensitivity of ultra-high-strength PHS plates in martensitic state regarding hydrogen-induced stress corrosion cracking. Investigations focus predominantly on an uncritical stress limit.

The project is planned to run until March 2018. The respective results will be presented at conferences on joining technology and be featured in relevant publications. The results to date give reason to believe that the automotive industry will implement the findings in both pre-production batches and large production runs. To do so, they need to be tested on vehicle structures in test bench and field experiments.

Testing of quasi-static failure loads of the specimens

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THM TECHNISCHE HOCHSCHULE MITTELHESSEN

AutoM Kompetenzzentrum für Automotive, Mobilität und Materialforschung

Project

This project (HA project no.: 481/15-23) was funded as part of LOEWE – State Initiative for the Development of Scientific and Economic Excellence, third funding line: SME joint projects.

HESSEN Ministry of Economics, Energy, Transport and Regional Development, State of Hessen

LOEWE Exzellente Forschung für Hessens Zukunft

7.6 DIE RUDERWERKSTATT GMBH: ROWING BOAT WITH A HONEYCOMB CORE

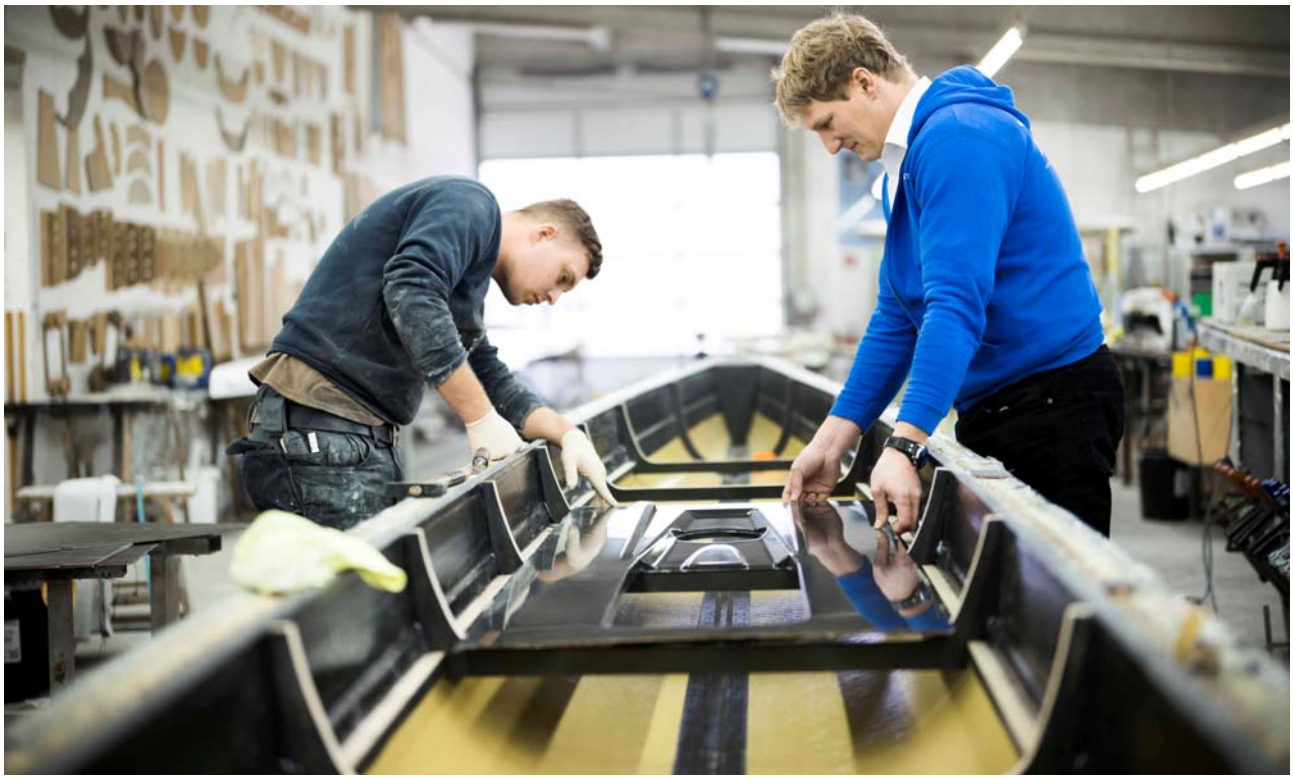
Modular cockpits with fibre composite structure

Above all else, rowing boats need to be lightweight. An innovative structure solution conceived by Die Ruderwerkstatt GmbH from Wetzlar has made the cockpit 25 per cent lighter.

Die Ruderwerkstatt GmbH produces rowing boats with innovative lightweight design based on carbon-fibre reinforced composites. In addition, the company is a sales partner of Ruderwerkstatt Filippi, which provides, among other things, rowing boats to Germany's national rowing team at Olympic Games. More than 400 medals have been won at World Championships and Olympic Games over the past twenty years by athletes in Filippi rowing boats.

The workshop is additionally well-equipped to carry out rowing boat repairs and maintenance work. From single scull to coxed eight, the Wetzlar-based company produces all standard 'C' type rowing boats.

Besides the actual characteristics of the hull, the weight of the boat is paramount in rowing, and the hull, despite its lightweight, must display a high tolerance to damage and be very strong. The 'C' type rowing boats are constructed using vacuum-bagged carbon fibre-reinforced composites and aramid in epoxy resin. Aramid honeycomb is additionally applied as the lightweight core material.



Fitting a modular cockpit in a 'C' type fours
(Image: HA Hessen Agentur GmbH – Jan Michael Hosan)

„Thanks to support received, we have not only been able to significantly improve our product and procedures but have also enhanced our digital expertise."

Daniel Riechmann, Managing Director of Ruderwerkstatt GmbH

Reducing the overall weight by 10 per cent

For the past two years, Die Ruderwerkstadt GmbH has been redesigning the seats in its boats, thereby making them more ergonomic and safer. Moreover, the company continues to develop its production procedures to reduce the weight of the cockpit significantly. It is supported in its work by a LOEWE funding project of Hessen Agentur in cooperation with the Institute of Materials Engineering at the University of Kassel.

By the end of the project in November 2017, the company had developed a digitally-crafted cockpit consisting of aramid honeycomb with carbon-fibre reinforcement. The weight of the component had been reduced by roughly 25 per cent, meaning a 'C' type fours is actually about 6 kilogrammes lighter. This corresponds to an almost 10 per cent reduction of the overall weight.

Boat building is and remains a popular craft. Digitisation and the thus related optimisation of production processes is, nevertheless, a key issue. Besides the positive impact on the product, the funding project of Hessen Agentur has helped to sharpen the company's awareness for this important topic. One of the many good things to come out of this will be the digital makeover of the boat's shape in order to further enhance its performance characteristics.

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WERNER KAHL DIE RUDERWERKSTATT

Visually inspecting a carbon-reinforced surface
(Image: HA Hessen Agentur GmbH – Jan Michael Hosan)

Project

This project (HA project no.: 498/16-10) was funded as part of LOEWE – State Initiative for the Development of Scientific and Economic Excellence, third funding line: SME joint projects.

HESSEN Ministry of Economics, Energy, Transport and Regional Development, State of Hessen

LOEWE Exzellente Forschung für Hessens Zukunft

7.7 TU DARMSTADT: BUILDING WITH PAPER

Semi-finished products made of paper and paper-based composites

Researchers from universities and universities of applied sciences in Hessen are working together to turn paper into the building material of the future.

Natural materials such as wood or paper have been used in the building industry for thousands of years and still play an important role in modern building and interior construction.

Paper is a renewable and natural raw material that offers excellent potential for sustainable and environmentally-sound applications in the building industry. In addition to the ecological advantages, paper boasts very good strength properties and is relatively easy to functionalise chemically. However, in contrast to well established building materials, like timber, paper does not offer underlying scientific principles, such as design and calculation approaches, to gain a foothold in the building sector. This should change in the future.

The opportunities provided by paper

To this end, the State of Hessen actively supports the research project "BAMP! – Building with Paper". The aim of the LOEWE project is to investigate the advantages and possible use of paper in building applications and to help establish a new technology field for "Building with Paper" in Hessen.

Cross structure for connecting paper sleeves for framework structures

The participating scientists are experts in the fields of architecture, building sciences, chemistry and mechanical engineering and come from the University of Applied Sciences Darmstadt (h_da), TH Mittelhessen University of Applied Sciences (THM) and TU Darmstadt (TUD). BAMP! is split into seven sub-projects that range from material and semi-finished product development to components, assemblies and buildings.

	tensile strength	elastic modulus	density	specific tensile strength	specific elastic modulus	thermal conductivity
unit	MPa	GPa	g/cm³	MPa/(g/cm³)	GPa/(g/cm³)	
concrete	2.5	30	2.2	1	13.6	
structural steel ST52	510	210	7.85	65	26.8	
timber (spruce)	100	11	0.6	166	18	
paper	70-90	10	0.7	100	14.3	
paper composites	130-260	11-22	1.2	108-216	9.2-18.4	

Mechanical properties of selected building materials

„Paper is sustainable. Lightweight design with paper is opening up new markets for the paper industry."

Prof. Dr.-Ing. Samuel Schabel, TU Darmstadt,
Chair of Paper Technology and Mechanical Process Engineering

For instance, in sub-project 3, the Faculty of Mechanical and Plastics Engineering at the University of Applied Sciences Darmstadt is involved with the production and optimisation of semi-finished paper products and paper-based composite materials. The objective here is the optimisation of semi-finished products with regard to the fulfilment of requirements in the building sector and their further processing to complex components. In this respect, the development engineers pay particular attention to mechanical properties like component stiffness and strength.

Sandwich structures made of reinforced paper

One of the ways to reinforce paper is to integrate continuous fibres made of paper or natural materials such as jute or flax. These reinforcing fibres can be used locally as paper yarns or paper cords along the previously identified load paths or as two-dimensional textiles as woven fabrics.

The reinforced plate-shaped semi-finished products can be applied to produce sandwich structures based on the application-specific requirements. In addition, individual layers can be provided with special properties such as, for example, protection against water and hail.

BAMP! has already had initial success: The researchers have developed demonstrators for various application areas, including 1:1 models made of paper materials. They are intended to serve as the initial basis for the joint research process. They have also managed to produce the first semi-finished products.

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TECHNISCHE UNIVERSITÄT DARMSTADT

BAMP! Bauen mit Papier

Sandwich structure made of flax-fibre reinforced paper

Project

LOEWE Focus BAMP! / Building with Paper
TU Darmstadt (leadership), University of Applied Sciences Darmstadt, TH Mittelhessen University of Applied Sciences

HESSEN Ministry of Economics, Energy, Transport and Regional Development, State of Hessen

LOEWE Exzellente Forschung für Hessens Zukunft

7.8 EVONIK RESOURCE EFFICIENCY GMBH: AS LIGHT AS YOU LIKE

FEM calculation of fibre composite components

Today, lightweight design solutions are in demand in an array of application areas. Nonetheless, "lightweight at any cost" is not usually desirable. In fact, it is generally about finding the right balance between production costs, process reliability and component weight.

To guarantee the necessary mechanical properties, components that were previously made of just one material, usually metal, are now being replaced by sandwich structures. They consist of a core and two thin cover layers made of fibre composites or other materials with a high level of tensile strength. If the core material applied is lightweight, the finished component offers high mechanical performance while being much lighter than the fully fibre-based version.

The core material has a strong impact on the performance of sandwich structures. Aside from the mechanical performance, it should be possible to produce both the sandwich core and the entire sandwich component economically. Until now, polymer hard foams for sandwich components were predominantly manufactured in blocks and then formed into the desired shape in a further processing step, usually by CNC milling. The high degree of manual forming and the relatively high wastage mean that manufacturing costs for large-scale production are too high. This is what led Evonik to develop a new in-mould foaming process (IMF) for its rigid foam in order to manufacture complex geometries. For ROHACELL® Triple F, PMI granules in the desired density are foamed into a finished foam core in a mould.

Body in white in hybrid design

„Our goal is to achieve optimised material utilisation through FEM simulations, thereby making the development process more efficient."

Dr. Arnim Kraatz, Evonik Resource Efficiency GmbH

Metallic parts, for example threaded inserts, can be directly integrated during the foaming process. ROHACELL® Triple F is compatible with conventional resins such as epoxy resin. Thermoplastic materials can also be set directly in the mould as a cover layer.

Thanks to its excellent mechanical properties, even at higher temperatures, this foam can be used in high-pressure RTM or wet-pressing processes for the quick and efficient production of sandwich components with light foam cores for the automotive industry, for example, in car bodies, chassis and mounted parts, for commercial volumes of 1,000 to 50,000 parts a year. Large-scale production of the first sandwich components with ROHACELL Triple F cores commenced in 2015.

Thanks to ROHACELL® Triple F, high-performance CFRP standard parts can be produced economically using the in-mould foaming process, such as the back shelf of the Audi R8 Spyder.

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EVONIK
KRAFT FÜR NEUES

Strut brace with ROHACELL® Triple F foam core

7.9 EDAG ENGINEERING GMBH: ULTRA LIGHT AND ULTRA SAFE

A bonnet hinge with active bonnet function

EDAG Engineering GmbH has developed LightHinge+, an engine bonnet hinge that combines lightweight design and pedestrian protection. This was made possible by additive manufacturing.

EDAG is an independent engineering services provider to the global automotive industry. The company serves leading carmakers and automotive suppliers. EDAG offers complementary engineering services in the fields of Vehicle Engineering, Electrics/Electronics and Production Solutions.

For the LightHinge+ project, EDAG joined forces with voestalpine Additive Manufacturing Center and Simufact Engineering to demonstrate the benefits and potential of additive manufacturing technologies in automotive production. LightHinge+ is an engine bonnet hinge manufactured using a powder-bed based, metal additive approach. It combines ultra-lightweight design and active bonnet function for pedestrian protection and can be produced in small batches.

50 per cent weight advantage

Engine bonnet hinge systems are very complex because of the high demands on safety and functionality. EDAG optimised the topology of the component structure to achieve a weight advantage. Using bionic principles, a 50 per cent weight advantage over the metal reference was attained.

The topology optimisation uses the actual loads to calculate the minimal material requirements of the hinge. The resulting geometries require a high proportion of support structures, which could then be reduced to a minimum in the project.

In the additive manufacturing process, the concentrated heat input with high heating and cooling rates causes distortion and residual stresses in the component. A non-distortion-compensated hinge can thus deviate by one to two millimetres from the CAD model.

Ultimate function integration: Additively manufactured breakaway structure instead of complex metal joint kinematics for the active bonnet function

„Additive manufacturing is set to overtake rapid prototyping and rapid tooling and to add a new dimension to traditional production processes and structural design possibilities."

Dr.-Ing. Martin Hillebrecht, Head of Competence Centre/Innovation
at EDAG Engineering GmbH

With Simufact Additive, the actual printing process and the subsequent process steps can be simulated and thus distortions and residual stresses predicted.

On the basis of the simulated distortion, the component geometry was negatively deformed so as to minimise the shape deviations of the printed hinges to the target geometry.

Highest level of precision in the first production batch

The simulation of the build process has contributed significantly to the improved design, protection and distortion optimisation of the additively manufactured hinge. In the end, economical, resource-saving production with low rework was achieved. The hinge is thus as good as ready for use after the laser additive manufacturing process.

A key feature of the LightHinge+ is the integration of an active bonnet function. If a pedestrian collides with the vehicle, a pyrotechnic actuator is triggered. The impact of the pedestrian is thus cushioned by the resulting free space. The result is complex hinge kinematics. Instead, special breakaway structures are integrated in LightHinge+. In the event of a crash, an additional joint is released through the action of force thus lifting the engine bonnet.

This function integration through experience-based, non-automatable vehicle engineering reduces the number of components to a minimum and helps the assembly lose much of its original weight.

This concept enables EDAG to initiate further co-operation with high-end carmakers looking for a tool-free, variant-intensive production of complex products.

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LightHinge+: Tool-free production of variant-intensive ultra-lightweight hinges. Nineteen components (metal, 1,450 g) are reduced to just six (AM, 720 g).

7.10 MEFEX GMBH: SOLVING DESIGN PROBLEMS

Services for projects with fibre-reinforced plastics

MeFeX GmbH from Weiterstadt helps answer specific questions that arise for companies working in the area of fibre-reinforced plastics (FRP). To do so, the enterprise employs a pool of selected experts.

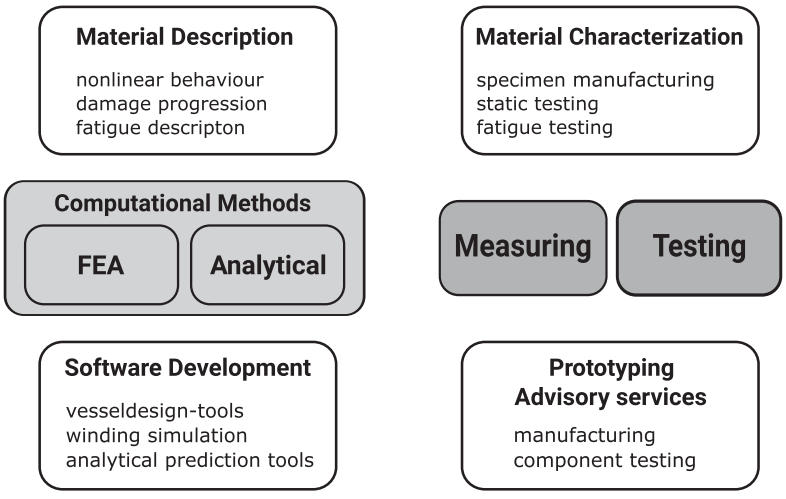
Lightweight design is playing an ever more decisive role in many sectors. Besides other materials, composites can be used to meet lightweight design targets. Design engineers can determine the production characteristics of fibre-reinforced plastics to a greater extent than with metal materials. Furthermore, their material performance is significantly more complex.

To justify the higher material costs, development engineers must make effective use of the advantages offered by the material. This is guaranteed by a comprehensive design process which combines material properties, production influences and special FRP design options.

Complex material performance

The core strength of MeFeX GmbH lies in its focus on composite-specific planning and design, specimen production, materials testing and prototype construction.

For calculations using analytics and the finite element method, the enterprise offers solutions that accurately map the complex, non-linear performance of the material. In addition to the static failure analysis of FRP components, the experts offer advice on how to determine fatigue strengths.



Range of services of MeFeX GmbH

„The highest quality of lightweight design is always achieved when considering the individually manufactured material and the entire design process."

Dr.-Ing. Daniela Feldten, Managing Director of MeFeX GmbH

Fibre-reinforced high pressure vessels

MeFeX GmbH utilises its methods to, among other things, calculate fibre-reinforced high pressure vessels. Using a production simulation program, the company calculates fibre distribution in the component. Connected analytical and numerical calculation methods ensure detailed mapping of the material's complex failure process and differentiation between critical and tolerable damage.

FRP high pressure vessels can be calculated thanks to a characteristic value identification system tailored exactly to the production process. This enables much lighter and less expensive vessels that offer the same amount of safety.

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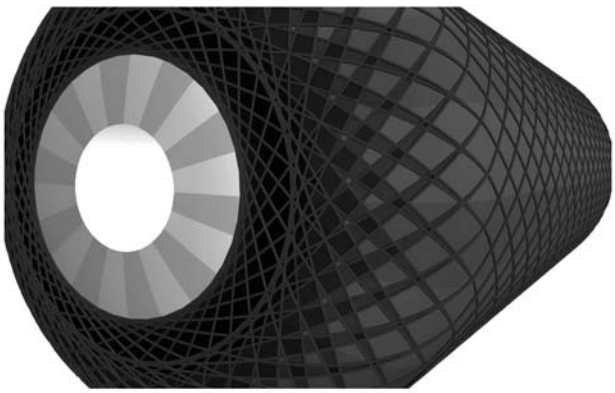
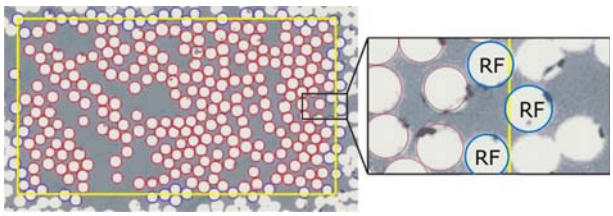


Using a newly developed virtual winding simulation of vessel production, it is possible to calculate all fibre positions precisely. This data then forms the basis for further analytical and numerical calculations of the vessel.



The volume per cent of fibre must be determined during testing to calculate a fibre-reinforced plastic component. In contrast to determining combustion loss, local determination is possible with the aid of an optical procedure.

7.11 FINOBA AUTOMOTIVE: THE POST-CASTING STEPS

Processing aluminium and magnesium cast lightweight components

FINOBA Automotive GmbH is facilitating the construction of lighter, more fuel-efficient vehicles due to its complete processing capability for lightweight components.

Lightweight design is a central future topic of the automotive industry. Irrespective of the engine size, a vehicle's weight has a significant impact on energy consumption and range. Significant potential weight savings at relatively low costs are promised by lightweight metals such as aluminium or magnesium.

In contrast to steel components, die-cast aluminium strut domes at the front axle help save roughly 20 kilogrammes per vehicle. Since larger components offer even greater potential weight savings, the range of applications for die-cast components has grown continuously in recent years. Today, it incorporates almost all the assemblies in the area of structural, chassis and drive components.

A dozen processing steps

Die-cast aluminium or magnesium components require intensive finishing prior to being installed. In the relevant sectors, cast aluminium components do have the same material properties as steel but need, to be heat treated: Aluminium components obtain their required mechanical properties in a two-stage process consisting of solution heat treatment and artificial ageing.

Washing and pickling passivation is another example of the way die-castings are processed. The component's homogeneous surface finish enables its subsequent connection to other components to create a finished vehicle. In many cases, up to a dozen processing steps are necessary in the fully automatic process chain before the component is finished. The processing of structural components, i.e. chassis parts and underbody components, is particularly challenging and complex.

Europe's largest continuous heat treatment system for structural components in Baunatal near Kassel

Washing and pickling passivation system

„Complete processing after casting ensures manufacturers can take the next step in automotive lightweight design."

Dipl.-Ing. Guido Barde, Chairman of the Management Board
at FINOBA Automotive

Turning cast blanks into finished parts

FINOBA Automotive GmbH undertakes large-scale contract processing for the complete process chain after casting. The company turns cast blanks into finished parts and supplies them straight to customer assembly lines. Complete processing from a single source and under one roof reduces the number of quality interferences and the logistical efforts for FINOBA's customers, including Audi, Porsche, BMW and Daimler. The company has continued to grow in recent years and now employs about 650 people at four sites in Germany. Two years ago, it installed and commissioned Europe's largest continuous heat treatment system for structural components at its headquarters in Baunatal near Kassel.

Module and system suppliers

FINOBA is currently investing €20m in its Kassel site, where the company processes the latest three and four-cylinder engine generation for petrol and hybrid vehicles of the Volkswagen Group: A total of more than 600,000 units per year over a period of eight years. The processing specialists now want to become module and system suppliers. As a pioneer in the processing of lightweight cast parts, FINOBA is confident of achieving this target. The rapid development of die-cast technology and the increasing complexity of component processing mean the company has to keep coming up with increasingly complex system solutions.

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FINOBA AUTOMOTIVE
We treat parts

Processing of a strut dome for the Audi Q7

7.12 INSTITUTE FOR MATERIALS ENGINEERING UNIVERSITY OF KASSEL: TOO DIFFERENT?

Plastic-metal hybrid components for complex applications

At the University of Kassel, researchers are working on components that combine metal and plastic. However, the coefficients of thermal expansion of the two materials are throwing up some challenges.

The Department of Thermoplastic Lightweight Materials at the Chair of Plastics Technology of the University of Kassel develops processes and applications based on the premise of reducing weight, saving resources and using energy more efficiently.

Research currently being undertaken there focuses on thermoplastic materials which, together with metal semi-finished products, serve as the composite partners for hybrid systems. Multi-material design attempts to reduce a component's weight and to increase its viability by combining the advantages of several materials, while the respective disadvantages of the materials compensate each other. When combined, both help to unlock weight and cost benefits.

It has, nonetheless, not yet been possible to use hybrid technology for some challenging areas of application for lightweight design as the materials simply behave too differently. The large difference in the coefficients of thermal expansion for metal and plastic is a particular challenge. As a result, hybrid components have only been used to a limited extent in thermally critical areas and in areas contaminated with corrosive media, such as water, which demand greater impermeability.

Up to 30 per cent reduction in weight

The researchers at the Chair of Plastics Technology want to expand the scope of application of hybrid components also to these areas. Through the use of permanently sealed plastic-metal hybrid components, they hope to reduce the weight of highly stressed, media-conducting automotive components that are manufactured using a large-scale production suitable joining method during the injection moulding process. This approach is based on preliminary investigations which showed that standard hybrid components are no longer impermeable after coming into contact with media and temperature.

The standard gearbox cover demonstrates the lightweight potential of plastic-metal hybrid components for highly stressed, media-conducting automotive components.

The researchers took a closer look at hybrid components manufactured with and without adhesive agents, as well as the influence of surfaces structured using selective laser melting (SLM). They were able to show that mechanical bonding with SLM-structured surfaces actually enhances the mechanical strength. However, none of the measures improves impermeability after combined temperature-media exposition.

„The local substitution of metal materials through plastic inserts in low load environments can lead to significant weight reductions."

Prof. Dr.-Ing. Hans-Peter Heim, Institute of Materials Engineering, University of Kassel

To guarantee impermeability, the researchers want to prevent that components dissolve at the boundary layer. The next step should see the development of a flexible intermediate layer. This will then compensate the levels of stress generated by thermal expansion.

The potential of this type of connection is substantiated by a standard gearbox cover: A consistent component design is expected to offer reductions in weight of between 15 and 30 per cent for enclosure-like structures.

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Hybrid specimens for impermeability testing

7.13 TU DARMSTADT: HONEYCOMBS, LATTICES AND CELL CORES

Cellular structures in additive manufacturing

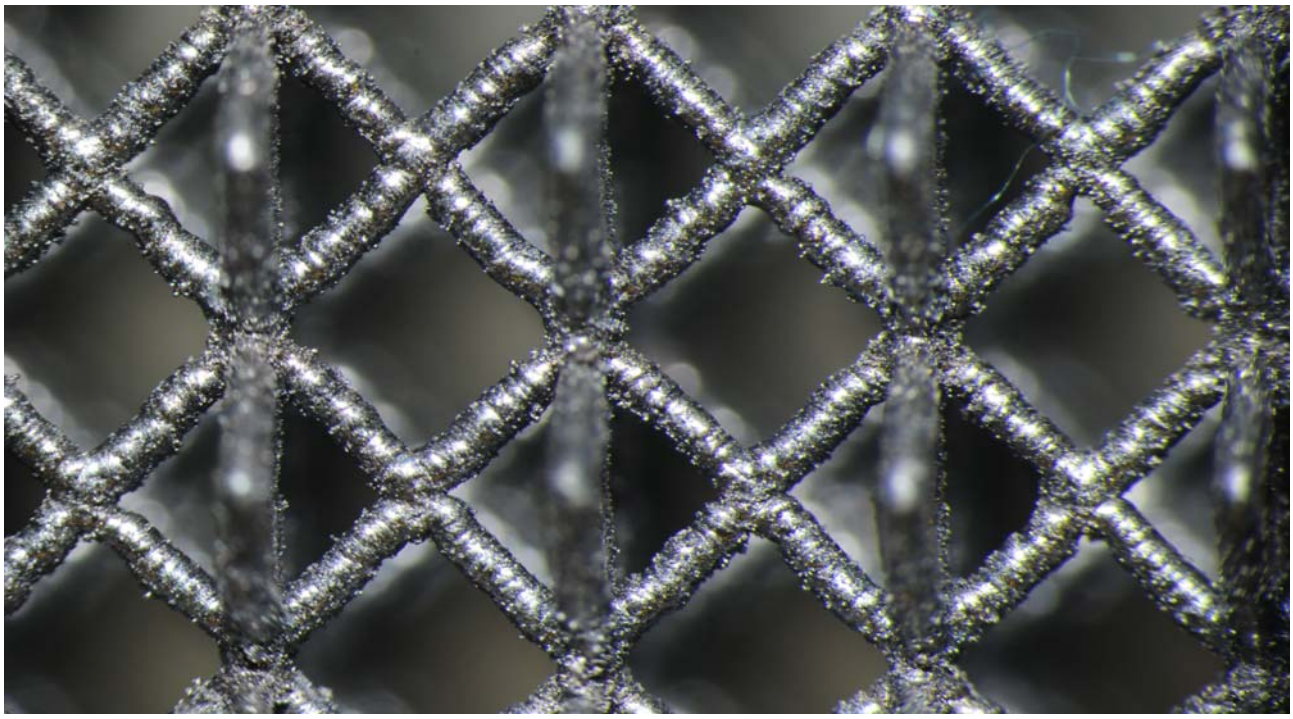
In the future, engineers should be able to specifically implement cellular structures when constructing lightweight components. The Institute of Lightweight Design and Construction at the Technical University of Darmstadt is working on planning and design rules to maximise the lightweight potential of additive manufacturing.

Selective laser melting is an additive method which utilises a laser to fully melt and fuse metallic powders. In theory, this enables the generation of complex structures. However, in reality, there are numerous limitations and rules that have to be considered.

Additive manufacturing engineers often turn to nature for inspiration. When it comes to lightweight design, the human thigh-bone is an ideal prototype for a load and environment-adapted structure: The optimisation of bone structures occurs not only on the macro-level but also on the meso and micro-level. By incorporating this principle, additive manufacturing has special potential for lightweight design.

Predicting mechanical performance

Knowledge about the mechanical performance of additively manufactured structures of various scaling properties is required though. In this context, the image on the right shows simple tensile specimens with varying component layout.
The Institute of Lightweight Design and Construction develops and validates calculation methods to predict



Side view of an additively manufactured lattice structure made of AlSi10Mg

„Engineers will be able to make full use of the lightweight potential of additive manufacturing when optimising structures both globally and locally."

Prof. Dr.-Ing. habil. Christian Mittelstedt, Head of the Institute of Lightweight Design and Construction, Technical University of Darmstadt

mechanical performance and to assess the lightweight design quality of a cellular structure. This requires increments to characterise the real mechanical performance.

Tensile specimens made of AlSi10Mg with varying component layout

The aim is to ensure design engineers can use cellular structures to meet mechanical load-bearing demands or to compensate manufacturing-related restrictions. Cellular structures can be three-dimensional lattices as well as two-dimensional cell cores, for instance honeycomb cores. The image right exemplifies a construction platform with lattice structures whose mechanical properties need to be investigated.
The high number of possible orientations in the construction space results in an array of applications for lightweight structure integration. This applies in particular to two-dimensional structures. Investigations into manufacturing-related challenges, such as powder adherence, which can be seen in the image right, need to be done.

The methods of structure selection for predicting the mechanical performance of cellular structures and for optimising multi-targeting and multi-scaling are published regularly by the institute and can be used for design purposes.

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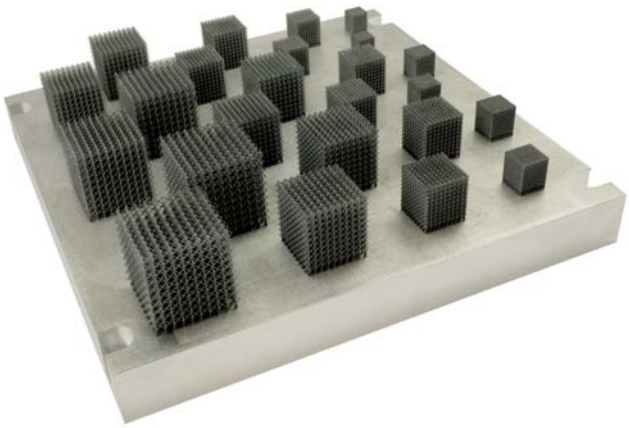
KLuB Konstruktiver Leichtbau und Bauweisen



Construction platform with lattice structures of varying cell widths

7.14 FRANKFURT RESEARCH INSTITUTE (FFin): BUILDING WITH FABRICS AND FOAMS

Foamed 3D fabrics for lightweight design in architecture

At the Frankfurt Research Institute (FFin), Professor Claudia Lüling and her colleagues are busy working on building elements made of 3D fabrics which, if required, can be filled with foam.

The FFin is part of Department 1 at the Frankfurt University of Applied Sciences. The academic work of the faculty focuses on sustainable architecture and civil engineering: From planning, design and the actual structure to the digital management of spatial processes. A main objective of the research work is fabric-based lightweight design and the field of FabricFoam©.
The respective contacts are Prof. Dipl.-Ing. Claudia Lüling (architecture), Prof. Dr.-Ing. Agnes Weilandt (structural engineering) and Prof. Dr.-Ing. Petra Rucker-Gramm (building physics).

FabricFoam© deals with foamed materials in combination with three-dimensional fabric techniques, for example spacer fabrics. They consist of two outer layers that are kept apart by pole fibres, thus, forming individually configurable hollow spaces. Their local definable material and fibre geometry offers undreamed-of possibilities. Depending on the arrangement of the fabric layers and in combination with other materials, spacer fabrics can assume the integrative functions of an outer wall element.

Self-supporting and insulating building elements

Together with lightweight insulating and construction foams, spacer fabrics can be transformed into a tension and pressure-resistant material composite that also provides insulating properties. This distinguishes it quite clearly from traditional, solely tensile-loaded membrane structures without added thermal characteristics.

This results in prefabricated, self-supporting and insulating building elements in which the fabric determines the surface structure and the outer appearance as the lost formwork.

Partially foamed spacer fabrics for lightweight applications in architecture (Image: Tobias Etzer)

„Our goal is: 'Architecture fully fashioned' – fabric-based lightweight design with building elements that adapt to climatic and spatial conditions."

Prof. Dipl.-Ing. Claudia Lüling, Professor of Planning and Design at Frankfurt University of Applied Sciences

Initial results have been achieved by the "3dTEX - Fabric Lightweight Wall Element" project of the "Zukunft Bau" research initiative: This has led to single-layered fabric lightweight wall elements consisting of foamed and plastically-deformed spacer fabrics as well as two-layered planar spacer fabric which, when foamed, provides an integrated rear ventilation level in addition to the support and insulation layer. It was also possible to demonstrate that combining fabric technologies with foaming methods has a high potential for gradient material.

Foldable and energizing

A second project deals with reversible foldable spacer fabrics for sun protection elements: "ReFaTex – Reversible Foldable, Energizing, 3D Fabrics in Architecture" was funded by the innovation fund "Research" and completed in March 2018. It focused on the fabrication of ultra-lightweight yet robust elements for the opening range that can be additionally folded and, if required, are adaptive. They may be produced opaque or translucent and with or without insulation.

Depending on the insulating standard and stability, they can be structurally and partially reinforced with foam. The spacer fabric guarantees translucency and folding capability, and it is worth noting that additional mechanical hinges are not required for folding. This promises robust and low-maintenance products that reduce energy loss through the building shell significantly but, when unfolded, permit high diffuse solar irradiation.

Future projects intend to investigate, among other things, material combinations of similar fabric and foam materials in order to develop a structurally-differentiated and easy-to-recycle mono-material. The overarching objective is "architecture fully fashioned": Geometrically complex, fabric-based building elements that are easy to assemble and utilise light and heat conductive or temperature-amplitude-attenuating materials.

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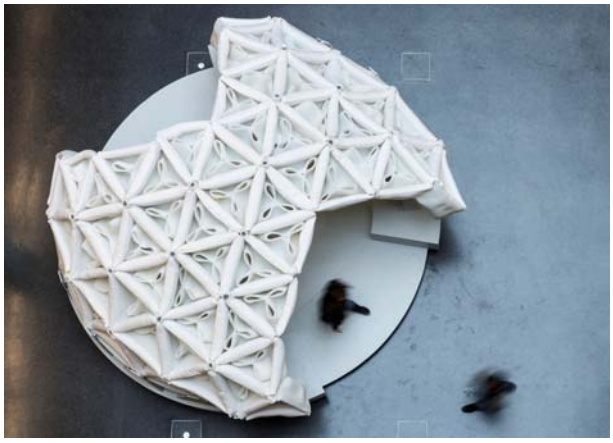


The Spacer Fabric Pavilion constructed using foamed 3D fabrics (Image: Christoph Lison)

Project

This project was funded by the Zukunft Bau research initiative of the Federal Institute for Research on Building, Urban Affairs and Spatial Development.

7.15 UNIVERSITY OF APPPLIED SCIENCES DARMSTADT: RELIABLE SIMULATIONS

Predicting the performance of lightweight materials more accurately

Researchers from the Institute of Plastics Engineering in Darmstadt have been working with a company to accurately predict the performance of load-bearing lightweight materials.

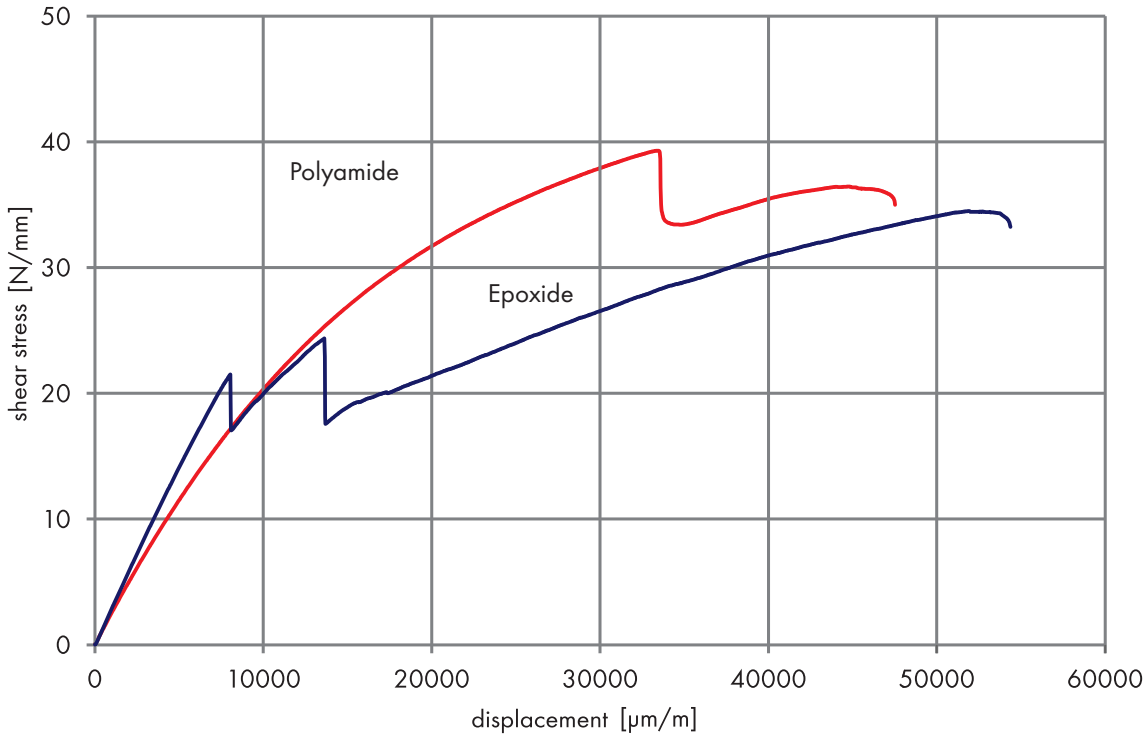
The automotive industry simulates the impact of varying loads on component performance in order to predict component properties. However, the results of such simulations are only as good as the material models and data applied. This applies, in particular, to the fibre-reinforced plastics used in lightweight design.

The department of Materials and Plastics at the Institute of Plastics Engineering in Darmstadt hopes to improve the accuracy of prediction methods in this field.

This involves mapping and evaluating relevant load and performance testing.
Using an accredited test laboratory, the members of staff determine characteristic values based on material selection standards and injection moulding simulations. Several universal testing machines with temperature chambers and specimen clamping fixtures for tension, compression, bending and shearing tests, for example a shear frame to standard DIN SPEC 4885, are available to judge the material data for the structure simulations.

A drop tower for impact penetration tests

Using a shear frame of this kind as part of the LOEWE project CohyBA, the researchers in Darmstadt worked



Shear stress via shear rate for carbon fibre-reinforced composites in an epoxy or polyamide matrix

„Lightweight design is increasingly helping to shape future sustainable development."

Prof. Dr.-Ing. Martin Moneke, University of Applied Sciences Darmstadt,
Institute of Plastics Engineering Darmstadt

closely with the local company CompoScience to examine, among other things, shear stress as a function of shear rate for carbon fibre-reinforced composites in an epoxy and polyamide matrix. CompoScience developed a corresponding simulation procedure for which the material specialists supplied reliable material data.

Using a shear frame to standard DIN SPEC 4885, researchers from the Institute of Plastics Engineering in Darmstadt examined shear stress as a function of shear rate for carbon fibre-reinforced composites.

Another example of load-specific testing is a drop tower for impact penetration tests that has been modified to enable dynamic three-point bending tests.

Furthermore, they developed the prototype of a component test in which components can be loaded with very low weights of below one kilogramme and high speeds of up to eight metres per second. Measured values are logged using optical measuring techniques, also based on digital image correlation methods.

These are all ways and approaches to provide reproducible and specific material data for a reliable simulation.

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Projekt

This project (HA project no.: 476/15-18) was funded as part of LOEWE – State Initiative for the Development of Scientific and Economic Excellence, third funding line: SME joint projects.

HESSEN Ministry of Economics, Energy, Transport and Regional Development, State of Hessen

LOEWE
Exzellente Forschung für Hessens Zukunft

7.16 INSTITUTE OF PLASTICS ENGINEERING DARMSTADT: LIGHTER ON THE CLIMATE

Lightweight design for cars through the structural optimisation of injection-moulded parts

The Institute of Plastics Engineering Darmstadt assesses the capability of production processes for lightweight design in automotive engineering. The objective is to reduce CO_2 emissions.

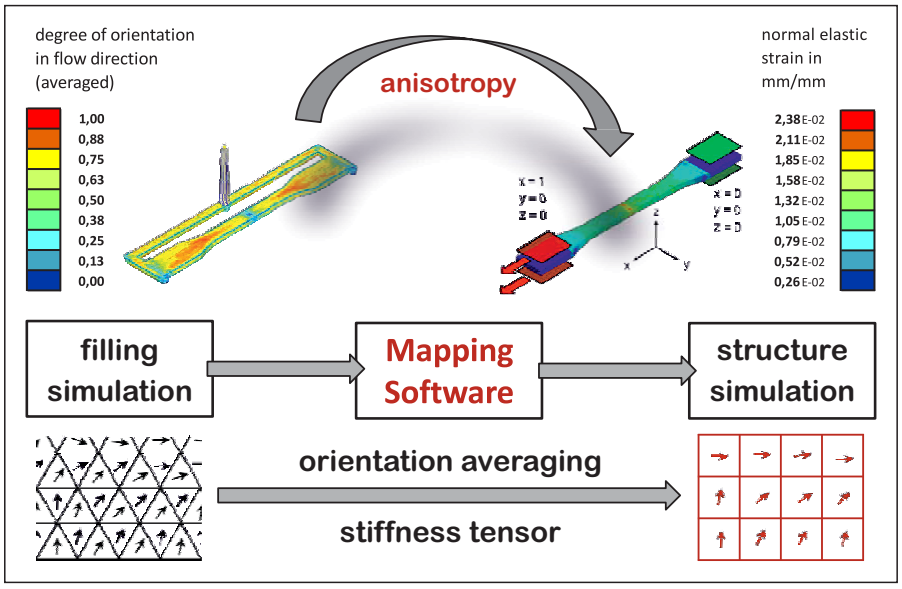
Carbon dioxide (CO_2) is driving climate change and it is therefore increasingly important to significantly reduce its emissions. In the European Union, road traffic is responsible for 23 per cent of CO_2 emissions. The Institute of Plastics Engineering Darmstadt, in cooperation with the automotive industry, conducts many research projects that deal with this topic.

The vehicle construction industry is helping to cut CO_2 levels by, first and foremost, reducing the weight of cars. This is especially efficient in injection moulding procedures where development engineers combine innovative production processes with integrative simulation. A holistic approach is always taken and advocated here.

Foaming and gas injection

The researchers examine production processes such as the foaming of plastics, gas injection techniques or hybrid injection moulding to assess their capability for lightweight design in automotive engineering.

In combination with structural analysis and process technologies, integrative simulation enables the targeted optimisation of topologies. Today, simulation contributes to the development of new moulded part geometries which are weight-optimised to give the best performance for each load case.



Simulation technology: The integrative approach

„Through the targeted combination of innovative procedures and materials, structure-optimised moulded parts can open up new potentials for light-weight design."

Prof. Dr. Thomas Schröder, Institute of Plastics Engineering Darmstadt

The Institute of Plastics Engineering Darmstadt implements the finite element method for structural analyses and utilises the respective results to optimise component topology. The researchers conduct tests for light-weight moulded parts and produce specimens for comparative measurements. In an initial step, the simulated results are compared with real measurement results and the models equipped accordingly. As the results show, the simulated results are very similar to the measured values. The applied methods include additive manufacturing.

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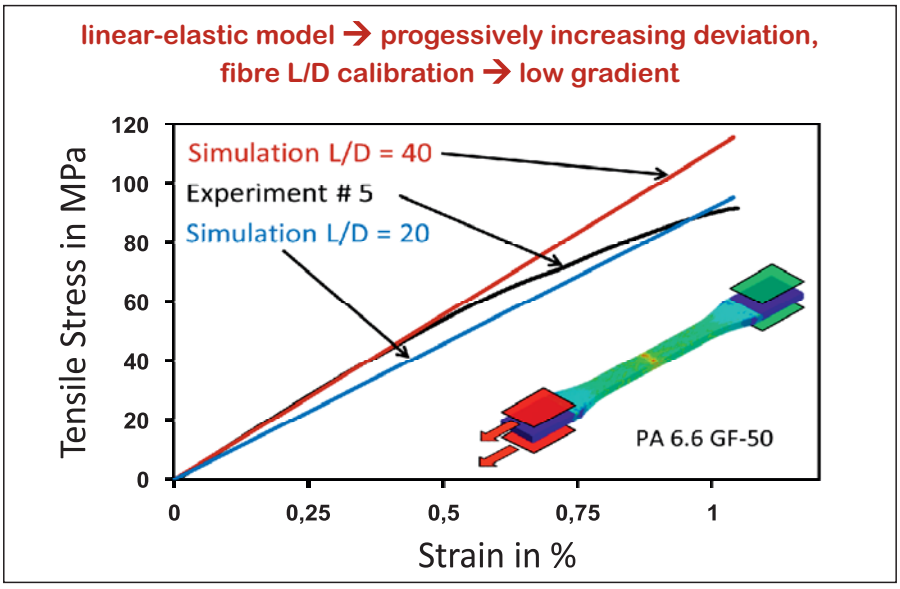

Tensile stress-strain diagram: Comparison of simulation with the experiment

7.17 UNIVERSITY OF APPPLIED SCIENCES DARMSTADT: HOLISTIC ASSESSMENT

Structurally durable and function integrated lightweight design

EU JTI CleanSky wing demonstrator with a shape variable front edge in a wind tunnel

EU Enlight FRP control arm – approx. 35 per cent lighter than the standard steel cross arm

Car wheel with integrated electric motor

„Material-compatible, intelligent lightweight design presupposes experimentally verified material data for the modelling and design process, while taking both recycling aspects and production and assembly requirements into account."

Prof. Dr.-Ing. Andreas Büter, Faculty of Mechanical and Plastics Engineering, h_da University of Applied Sciences Darmstadt

The lightweight design experts from Darmstadt evaluate andContact optimise lightweight structures in terms of stability and structural durability.

In the Department of Structurally Durable and Function-Integrated Lightweight Construction at the Fraunhofer Institute for Structural Durability and System Reliability LBF and at the University of Applied Sciences in Darmstadt, components made of fibre-reinforced and unreinforced plastics are analysed from a holistic perspective, taking the material, design, production and application into account.
The employees examine and optimise their properties and life-cycle and consider real, application-specific operational loads and ambient conditions.

The lightweight design experts combine this test with the influences of temperature, moisture and media, such as fuel and hydraulic fluids. Based on experimental experience, the department develops models for the mathematical assessment of service life in relation to the finite element method.

The structural durability findings are applied by the experts to, among other things, develop integrated structural health monitoring systems (SHM) or for lightweight design with function integration.

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7.18 FkL INGENIEURBÜRO SCHUMACHER: AS LIGHT AS YOU LIKE

FEM calculation of fibre composite components

FEM calculation of a GRP blade for a wind turbine
(Photo: zentilia / iStock, modified FkL Ingenieurbüro Schumacher)

„Our goal is to achieve optimised material utilisation through FEM simulations, thereby making the development process more efficient."

Jana Schumacher, Managing Director of FkL Ingenieurbüro Schumacher

A young engineering firm uses state-of-the-art finite element methods to support ideas aimed at reducing weight.

FkL Ingenieurbüro Schumacher specialises in fibre composites and lightweight design. The company based in Weiterstadt helps its clients bring their product ideas to life using carbon or other fibre-reinforced plastics (FRP).

The engineers offer, among other things, material-compliant geometry design, draping simulation with deduction of pre-cut parts, accurate calculation of fibre composite components using finite element software Ansys ACP and the optimisation of laminate in relation to stress, rigidity, weight and costs.

Various modes of fracture

When calculating components made of fibre-reinforced plastics, the firm faces a number of challenges. For instance, laminate fails in various modes of fracture depending on the fibre direction and the actual load. Furthermore, the material parameters are often scattered in all directions and depend on the production processes. In addition, the load applications are critical for lightweight structures at their limit of operational range.

For its clients, the engineering firm develops material-compliant geometries for a desired component and provides a design using state-of-the-art finite element methods. One of the advantages of FEM calculation is that less prototype-based test series are necessary. This cuts costs when developing complex components and speeds up the development process.

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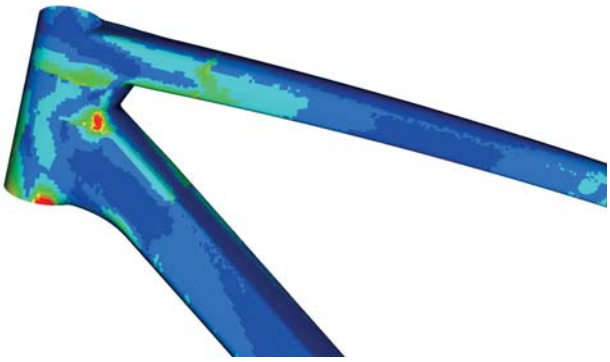


Inter fibre failure effort in the CFRP laminate of a bicycle frame
(Image: FkL Ingenieurbüro Schumacher)

7.19 INSTITUTE FOR MATERIALS ENGINEERING UNIVERSITY OF KASSEL: CLOSER TO THE MAXIMUM LOAD

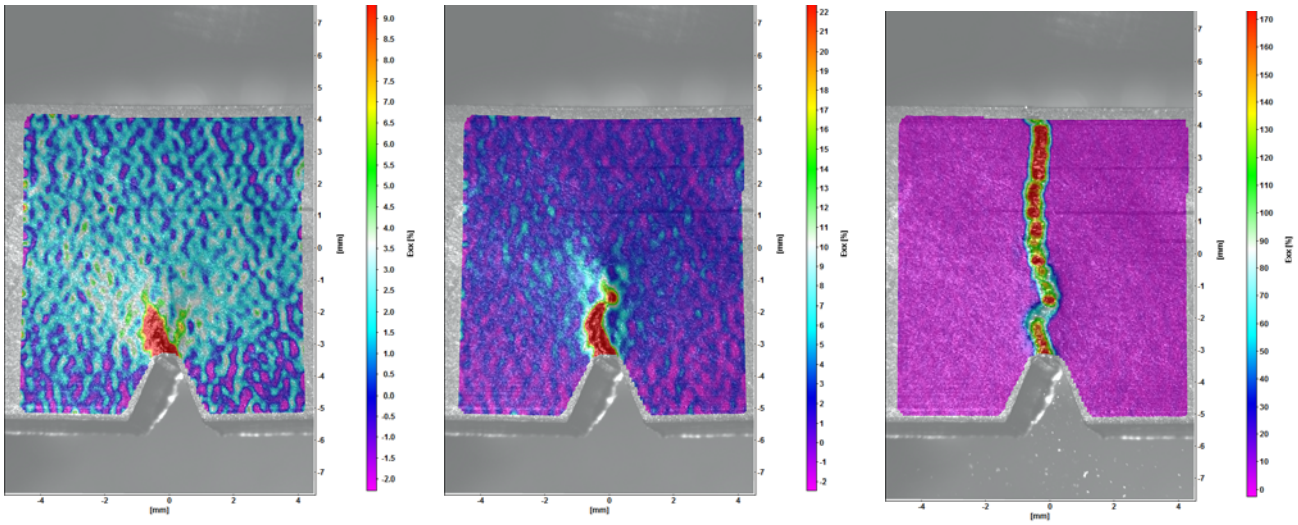
Characterising heterogeneous lightweight materials

Researchers at the University of Kassel are currently investigating the main failure mechanisms of lightweight structures, thereby enabling future components to be designed closer to maximum load capacities.

How can lightweight materials be made safer and more reliable in the future? To achieve this goal, the Department of Heterogeneous Materials at the Institute for Materials Engineering of the University of Kassel examines polymer materials whose structural character demonstrates a degree of heterogeneity.

The material portfolio comprises all lightweight materials. These include foamed, self-reinforced or filled and graded polymers as well as hybrid materials, primarily plastic-metal hybrid structures. The focus is, however, not just on special lightweight applications. In fact, the objective is to investigate and develop various approaches for interpreting and better understanding the failure mechanisms at material level. Spatially resolved analysis methods, such as the in-situ detection of stress step-ups through REM, CT or light microscopy, are taken into account along with the assessment of edge effects and the mechanisms of initiation for crack formations.
Also included in this are cyclic-dynamic load scenarios or crash-relevant specifications as well as ageing stability with and without media impact.

These activities contribute significantly to the design of lightweight materials. The Department of Heterogeneous Materials hopes to enhance and expand the range of knowledge that exists about these materials while focusing, in particular, on high and long-term loads. Moreover, the researchers want to make the investigated materials safer. The objective is to design future products as close to maximum load capacities as possible, thereby boosting the potentials and increasing the efficiency of lightweight design.



Crack growth at a notched specimen made of PA66-GF35

„Lightweight design is a key technology. To drive it forward, it is essential to gain a real understanding of lightweight materials so as to design future products as close to maximum load capacities as possible."

Prof. Dr.-Ing. Angela Ries, Institute of Materials Engineering,
University of Kassel

Cyclic-dynamic material testing of
short fibre-reinforced plastic

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Heterogene Werkstoffe
Prof. Dr.-Ing. Angela Ries

7.20 FRAUNHOFER LBF: EVERY KILO COUNTS

Effective mobility through lightweight design

Fraunhofer LBF is helping to cement the future of lightweight design in the mobility industry: The institute proves the reliability of CFRP components in aircraft construction and develops, for instance, primary components for electric cars.

Design engineers are increasingly turning to carbon fibre-reinforced plastic components (CFRP) to reduce the weight of aircraft further. Proving the reliability of these components during flight is crucial. Thanks to an innovative structural monitoring system for the aircraft fuselage, the Fraunhofer LBF, together with two other Fraunhofer Institutes, has now proven the reliability of CFRP components in aircraft construction.

As part of the European aeronautical research project Clean Sky, the scientists have developed a measurement concept that has been installed and tested on an aircraft fuselage. Using optical measuring fibres and piezo sensors, the researchers were able to determine the real loads at high altitudes while monitoring the structure. Based on these results, components can now be optimised, thereby saving weight. Furthermore, these lightweight components can also be used longer.

Systematic lightweight design

Resource productivity and resource efficiency are key elements of a sustainability strategy for products along the path from manufacturing to use and disposal. Weight is often crucial, particularly for the operating phase. For example, major driving resistances of a motor vehicle, and therefore its fuel consumption, depend directly on its mass. Lightweight design is becoming a specific development goal.

Efficient lightweight solutions include many aspects: The development and processing of materials, design and construction technologies, manufacturing and joining technologies, assessment and verification methods which also have to be economical solutions. The implementation of reliable lightweight solutions requires extensive expertise and systemic understanding. Knowledge of relevant loading conditions and frequencies is essential for design optimisation: Fraunhofer LBF scientists determine this load data using computational and measurement methods. For engineering products, particularly for safety-relevant components, lightweight design is not conceivable without structural durability.

The Fraunhofer LBF's concept vehicle, featuring a 10 kWh LFP battery and an integrated battery management system

„Intelligent lightweight solutions must also work reliably in safety-critical components."

Prof. Dr.-Ing. Tobias Melz, Director of the Fraunhofer Institute for Structural Durability and System Reliability LBF

As light as possible

Steel and cast iron, non-ferrous metals and sintered materials, but also polymer and fibre-reinforced composite materials are thoroughly investigated in Fraunhofer LBF accredited laboratories. Statistical methods and state-of-the-art non-destructive test procedures – including computer tomography – make the results reliable and accurate. A systematic view of lightweight design helps to realise products that are as light as possible and fulfil their function safely and reliably for the product's intended service life. Or components with integrated sensors, actuators and functional elements which report maintenance and service needs, or actively intervene in the structural performance.

Strength, durability and vibration performance define boundary conditions and application limits for many lightweight solutions: Fraunhofer LBF helps customers with conceptual issues, with development and subsequent testing and validation.

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Fraunhofer LBF

Ground test in the laboratory: A special measurement setup detects the cyclic internal pressure load on an aircraft fuselage simulated by inflation. (Image: ©Leonardo)

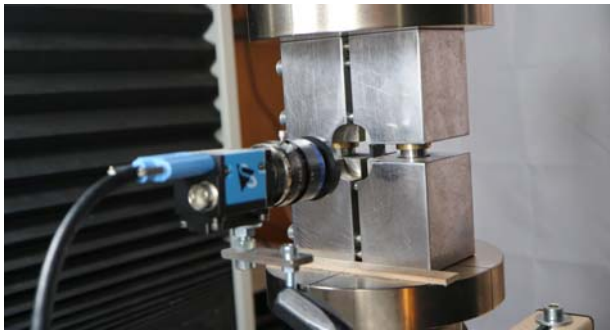
7.21 ICM-COMPOSITES GMBH & CO. KG: FLYING FIBRES

In-situ strength levels of fibre composites

The engineering firm ICM-Composites based in Weiterstadt is involved in the aviation research programme of the Federal Ministry for Economic Affairs and Energy. The aim of the experts for fibre composites is to make lightweight aircraft even safer and more efficient.

A decisive factor for the success of a lightweight design project is how and from which fibre composites a component is manufactured. Therefore, later component manufacturing should already be considered in the initial design sheets.

Bend test at the in-house developed, customer-specific special test stand



Fibre-parallel pressure test with optical strain measurement using DIC (Digital Image Correlation)

The engineers at ICM-Composites are well aware of this fact. The lightweight design experts from Weiterstadt have more than 30 years of experience in working with fibre composites. They assist their clients with their projects through detailed calculations, prototyping, process development and component testing.

The firm has its own technology centre for fibre composites and a test laboratory for measuring and testing. Components developed at a computer can thus be implemented and tested within a short space of time. Thanks to this working method, the engineers are able to detect possible problems for practical component manufacture at an early stage and eliminate them without delay.

Only possible with fibre composites

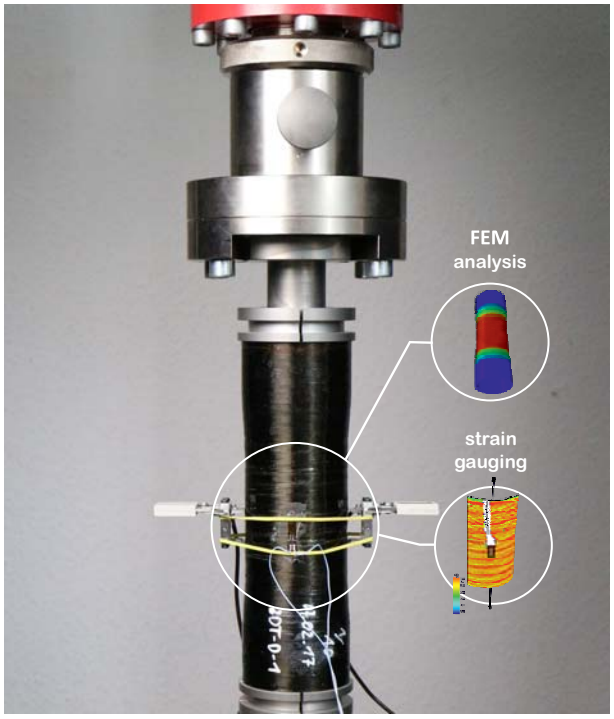
Less weight and flexible shape are often the first arguments in favour of using fibre composite structures. But there are more: For instance, fibre composites actually enable the precisely adjustable rigidity of rotor blade structures or certain force-displacement curves of spring elements. No other material would be able to achieve the desired properties.

„The possibilities and potentials of fibre composite structures are always fascinating."

Benedict Krowarz, Development Engineer at
ICM-Composites GmbH & Co. KG

As part of the aviation research programme (LuFo) of the Federal Ministry for Economic Affairs and Energy (BMWi), ICM-Composites is currently determining the in-situ strength levels of fibre composite layers in real structural laminate. This is particularly beneficial for the further development of lightweight aircraft. Thanks to the generated knowledge, they should glide through the air even more safely and efficiently in the future.

The next step for ICM is to equip its technology centre and test laboratory with a servo-hydraulic fatigue test stand. The engineers can thus investigate the, as yet, under-explored aspects of the structural durability of fibre-reinforced composites. This should help to adapt the fibre composite components even better to subsequent stress factors.



Strength and rigidity determination at wound or infiltrated tube samples with regard to tension, pressure and torsion

Contact

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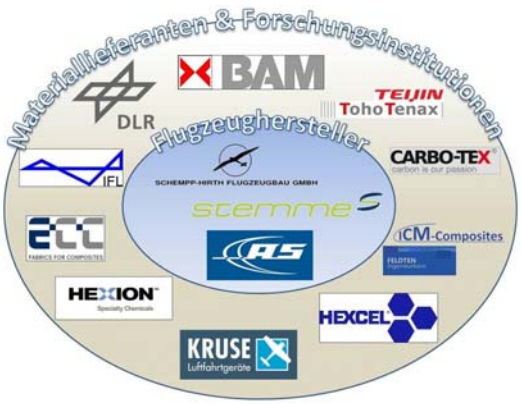


Project

LuFo project GeAviBoo (General Aviation Booster):
Fibre composite testing at ICM
for lightweight aircraft construction

7.22 KARGON GMBH: LIGHTWEIGHT CARGO BIKES

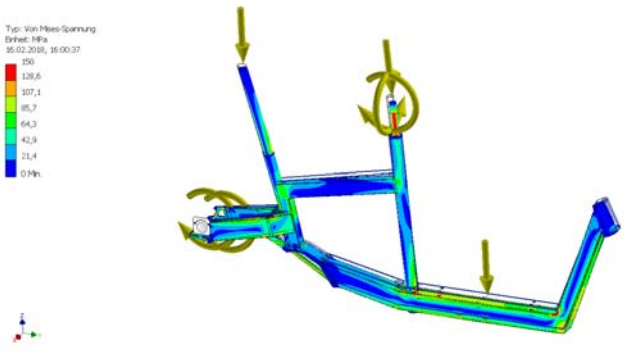
Lightweight design makes cargo bikes more user friendly

The young company Kargon, based in Weiterstadt, develops cargo bikes that are characterised by their manoeuvrability and lightweight. This is achieved through special concepts for the frame and steering.

Standard cargo bikes quite often have a total weight of more than 40 kilogrammes. Many people have difficulty handling this amount of weight appropriately in everyday situations. Kargon from Weiterstadt wants to change this. The young company develops cargo bikes with and without an electric drive that are both light and manoeuvrable.

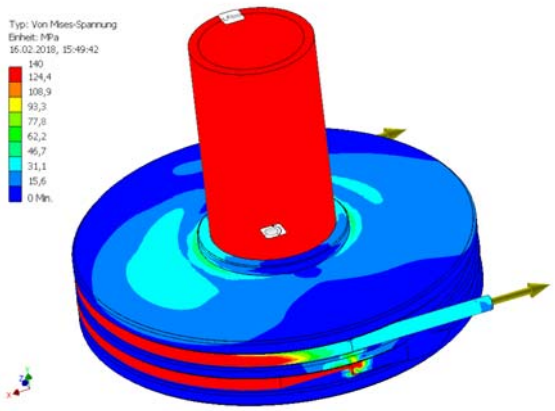
Lightweight design for frame and steering

To keep the weight of its cargo bikes as low as possible, Kargon counts on structural lightweight design. Starting with the frame of the transport bike, featuring a single-arm design with a central torsion and bending beam. Due to detailed analysis using the finite element method, Kargon has optimised this design while taking into account lightweight design aspects. Despite an overall payload of 160 kilogrammes, the company managed to keep the dead weight of the cargo bike frame below seven kilogrammes.



Cargo bike frame

For the steering, the company has developed its own concept targeted at lightness and manoeuvrability. The steering utilises a cable pull that enables a steering angle of more than 90 degrees. This helps the rider, when manoeuvring in difficult or tight spaces, for example at the entrance to a supermarket. Furthermore, the steering system can be mounted on any suspension fork.



Rear guide pulley

Above all safety

Lightweight is also trump when it comes to the actual load: The modular loading concept of the bike frame features five universal attachment points at which a rattle-free, 120-litre transportation box can be attached. The loading box consists of an aluminium bracket with pre-tensioned truck tarpaulin and weighs just a few kilogrammes. Alternatively, customers can also attach their own solutions.

To guarantee the safety of its cargo bikes in every possible situation, Kargon has laboratory examined and tested all the materials and components thoroughly. The company carries out all the tests at calibrated test machines from Zwick Roell at its fully air-conditioned and certified test laboratory.

„We manufacture a large part of the bike components, such as the main frame, and our transportation solutions in-house. This is the only way can we make sure that our high quality and reliability demands are met."

Andreas Muth-Hegener, Co-Founder of Kargon GmbH

Kargon is currently occupied with the further development of its cargo bikes and adding new functions to them. Further loading concepts and an optional automatic gear system should, for example, be integrated. The development engineers are also thinking about the possibility of a new model series.

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KARGON
CARGOBIKE MANUFACTORY

The cargo bike from Kargon GmbH based in Weiterstadt

7.23 CARBON-DRIVE GMBH: THE MOTOR SPINDLE OF TOMORROW

Fibre composite solutions in mechanical engineering

The physical limits of steel have been largely exhausted in the machine tool industry. Carbon-Drive GmbH opens up a new path into the future with its full carbon motor spindles.

Carbon-Drive GmbH from Weiterstadt is the world's first manufacturer of full carbon motor spindles for the machine tool industry. The company has its roots in the Institute of Lightweight Design and Construction at the Technical University of Darmstadt headed by Prof. Dr.-Ing. Schürmann.

The motor spindle is the key component of each machine tool and thus decisive for its productivity.

It is the core of each state-of-the-art machine tool and has a great impact on the machine's productivity and quality. The motor spindle consists of an electrically driven shaft with integrated tool interface that machines the workpiece via rotation. At one-minute intervals, the shaft is accelerated up to 60,000 rpm and then braked again.

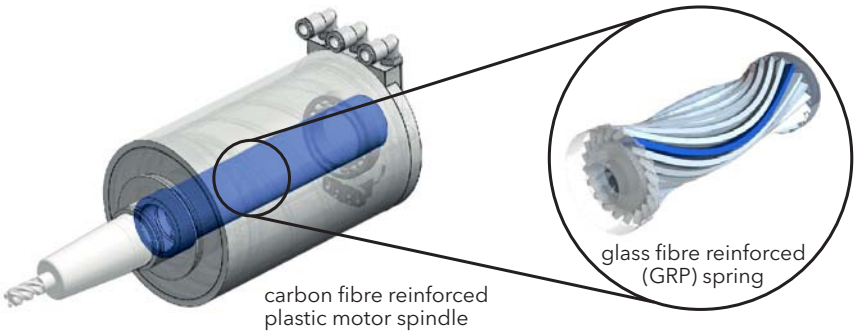
- 70 % lighter
- 95 % more precise
- 50 % faster
- higher life expectancy

The significance of motor spindles for German industry is demonstrated by a normal passenger car that consists of roughly 10,000 individual parts. The vast majority of these parts requires their own machine tool equipped with one or several motor spindles for production. The efficiency of component manufacturing depends, for instance, on the performance of the motor spindles. In this context, the market trend in the machine tool industry has been clear for decades: Greater productivity with the greatest possible precision, dynamics and surface quality.

The physical limits of steel

In the meantime, however, all highly accelerated and loaded components have been vastly exploited so that the physical limits of steel have been reached. The currently followed approach of compensating the negative effects of steel through expensive additional components only works to a limited extent and has, up to now, only been affordable for niche applications.

Complex cooling circuits are, for example, integrated into the spindle shaft to compensate the thermal longitudinal growth of the shaft, thus improving the repeatability of the spindle. This is, in particular, crucial for high precision applications that demand strict dimensional accuracy and small tolerance fields as well as good surface qualities.



Schematic illustration of a motor spindle, including GFRP spring assembly for clamping tools

„In many other industries, such as the aerospace and automotive sector, CFRP is already a well-established feature. CFRP also has the potential to initiate the next technology leap in the machine tool industry."

Dr.-Ing. Martin Klimach, Managing Director of Carbon-Drive GmbH

Legal and social requirements formore sustainability and increased resource efficiency additionally aggravate this problem: The machines should not only become more productive and precise but at the same time consume less energy. Therefore, Carbon-Drive GmbH counts on full carbon motor spindles.

Clear advantages over steel

The company offers the full process chain from design and manufacture to quality assurance of the fibre-reinforced plastics (FRP). The product portfolio ranges from simple components such as novel glass fibre springs for tensioning tools and ultra-precise carbon spindle shafts to complete functional units like full carbon motor spindles.

Carbon exhibits a high specific rigidity. It is very light and has no thermal expansion due to the correct fibre angle. This offers clear advantages compared to conventional steel and has an immediate effect on the machine tools.

Firstly, spindle nose growth reduced by 90 per cent results in the highest possible precision and minimises the reject rate. Secondly, the use of carbon reduces the mass by 50 per cent which in turn cuts energy consumption and saves costs. Thirdly, carbon increases all acceleration processes by 50 per cent and thus shortens warm-up times. The machines are therefore sooner ready for operation, thus increasing productivity. The aim of Carbon-Drive is to ring in a new era of technology in milling technology through the application of carbon and to establish itself as the leading manufacturer of fibre-reinforced plastic spindles and adjoining components for the machine tool industry.

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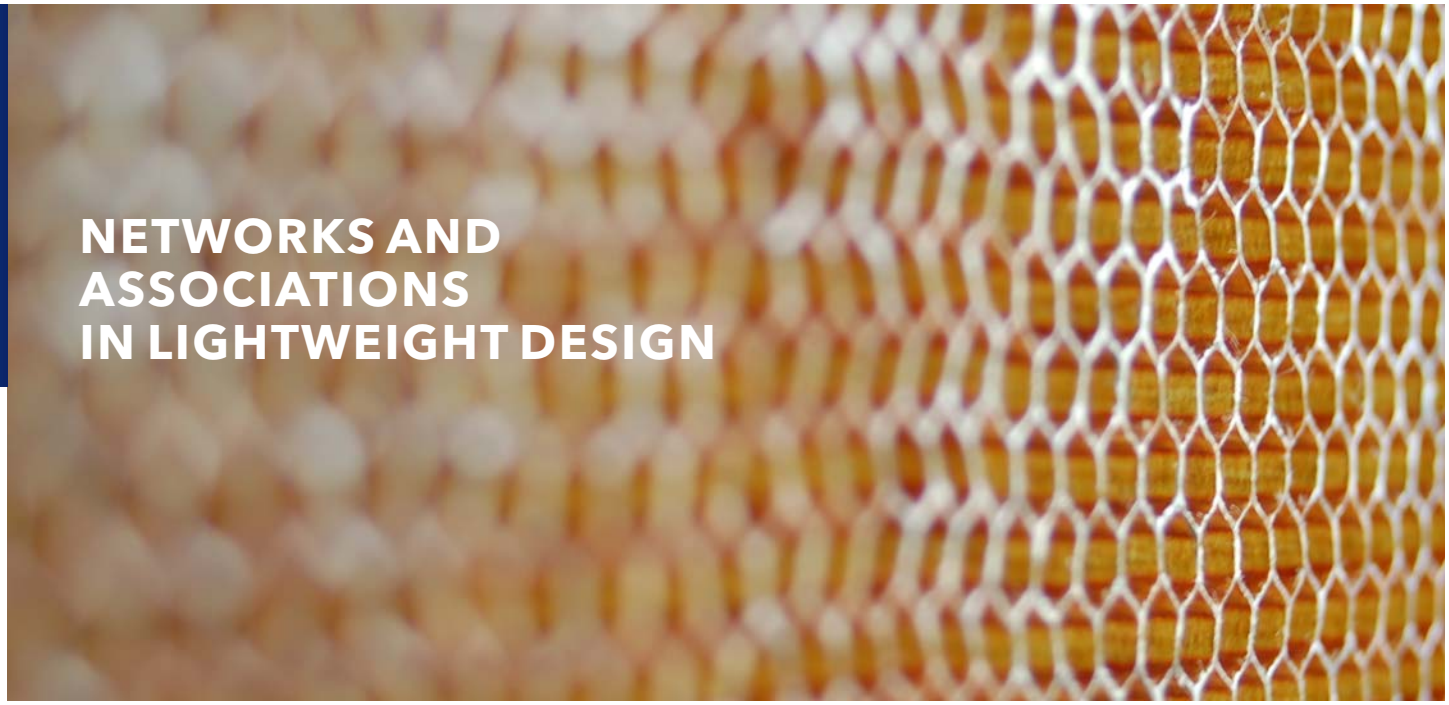
Carbon-Drive

Carbon-Drive received the Innovation Award in the Drive Technology category at EMO 2017 (the world's leading metalworking trade fair).



8 NETWORKS AND ASSOCIATIONS IN LIGHTWEIGHT DESIGN

8.1 REGIONAL NETWORKS

Bauindustrieverband Hessen-Thüringen e.V.

Lightweight design contributes greatly towards resource efficiency, especially in the construction sector. In contrast to other industries, the construction industry is already a highly innovative market and not only in the traditional timber and dry construction sector, with innovations in brickwork or carbon concrete technology, but also in the development of new lightweight composite techniques. When taking into account the lightweight design patents compared to the entire patent activity of the sector, the construction industry is at the forefront of innovation, followed by the transportation sector. This seems quite logical considering the advantages. With constant or even optimised functions, weight is reduced and less material and energy required. Architecturally, new designs with very light and delicate structures are already implemented today. The same applies to very wide structures or mobile or temporary buildings.

The construction industry associations provide support to a wide range of initiatives in this context. Among others, Hauptverband der Deutschen Bauindustrie is active in the advisory board of the Lightweighting Initiative of BMWi and in the programme committee of Carbon- und Textilbetontage.

Further information:
www.bauindustrie-mitte.de

BAUINDUSTRIEVERBAND
HESSEN-THÜRINGEN e.V.

Bionik-Netzwerk Hessen

In bionics, nature delivers the ideas for the development of technical products and methods. Bionik-Netzwerk Hessen was initiated in 2012 by the Hessian Ministry of Economics as an interdisciplinary network of biology and technology. The administrative office of Bionik-Netzwerk Hessen is based at Hessen Trade & Invest GmbH.

Through the offered activities, it enables interdisciplinary exchange between engineers, technicians, biologists, product designers and entrepreneurs from various industries. The exchange of knowledge and the development of joint projects are the key objectives of the network. The main areas are lightweight design, robotics and surfaces.

Bionik-Netzwerk Hessen offers the organisational framework for this and supports stakeholders through advice and accompanying measures, such as events or the provision of information. The network assists with the initiation of bionic research and development projects, provides information and establishes contacts.

The network's well-known event series "Bionik im Betrieb" (Bionics in Operation) is aimed at companies, scientists and politicians and is planned and organised by the coordination office.

Further information:
www.bionik-hessen.de

Bionik-Netzwerk
HESSEN

Competence Center Aerospace Kassel-Calden (CCA)

The civil aviation industry and air transport industry have been on the rise for many years – and this trend is set to continue. Both sectors place high requirements on established and new players: Increasingly complex and globalised development and production processes and high cost pressure characterise the market and technology environment. Besides technological excellence, the ability to collaborate, in particular, becomes a key factor to permanently taking part in the booming aircraft construction and air traffic sector. The increased application of new lightweight design methods and materials is also the main focus here, always pursuing the objective of reducing fuel consumption and negative environmental effects.

Against this backdrop, 50 companies and research institutes have now joined forces in the Competence Center Aerospace Kassel Calden – in short: CCA – with the aim of pooling, strengthening and marketing their skills and resources. Proactive action and fair collaboration, based on spatial proximity and content congruency, are the factors for success.

As a professional networking, marketing and innovation platform in the target fields "aviation technology" and "airport technology", the CCA and its members have made a name for themselves within the local region as well as further afield. This foundation must be developed and translated into market success and technological advances.

We look forward to your cooperation!

Further information:
www.cca-kassel.de

CCA
Competence Center Aerospace
Kassel Calden

Photos: Thomas Ott, Mühltal

Holzbau Cluster Hessen (pro holzbau hessen)

Residential construction in Hessen is one of the most important target markets of Holzbau Cluster Hessen. The industry offers immense potential for development, particularly due to the ever increasing demand for urban buildings on small plots and the redevelopment of existing buildings. The raw material timber is characterised by excellent technological, ecological and energetic possibilities and thus contributes greatly to achieving the federal state's climate protection goals.

A special advantage of timber construction is the option of large-scale prefabrication of the components at the factory. This way, timber buildings can be constructed in a very short space of time and with minimum impact on local residents. Another argument in favour of using timber for construction and development is climate neutrality and the low energy consumption of timber as a raw and building material.

By integrating the three main dimensions ecology, economy and socio-culture, timber construction already meets all the requirements for sustainable building today. The recycling of timber, in particular, perfectly supports the function of timber as a carbon store.

Within the timber network, Holzbau Cluster Hessen has positioned itself as the mediator between companies, research institutes, service providers and other recycling institutions, as well as customers and communal institutions. The declared target of the timber construction cluster is the optimisation of communication and collaboration between companies and institutions with regard to sustainability and resource conservation.

Further information:
www.holzbau-cluster-hessen.com

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Kompetenznetz Adaptronik e.V.

The technology network was founded in Darmstadt in 2007 on the initiative of Fraunhofer LBF as the regional network Rhein-Main Adaptronik e.V.. And this is where the coordination office is still located today. The member organisations of the network are in the meantime at home throughout Germany. These include small and medium-sized enterprises as well as large industrial groups. Added to this are universities, universities of applied sciences and research institutes.

The association offers a large range of competencies, from adaptronics, materials and materials technology, sensors and actuators to prototyping and testing technology - along the path from fundamental research to application.

The aim of the association is to network players from business and science at different positions along the value-added chain and thus to develop and tap the further potentials of "smart" structures and systems. This also concerns, in particular, function integration and lightweight design through active structural measures. The service portfolio of Kompetenznetz Adaptronik e.V. primarily addresses the target markets automotive, mechanical and system engineering, aerospace as well as automation and special machinery construction.

The association provides a platform to its members for the trustful exchange of experiences and the implementation of joint projects.

Further information:
www.kompetenznetz-adaptronik.de

KOMPETENZNETZ Adaptronik

KCN – Kunststoff Cluster Nordhessen

Kunststoff Cluster Nordhessen offers interested parties, institutions and persons a basis for exchanging information, problems and experiences in almost all aspects of the plastics value-added chain. The collaborative development or further development of methods, machines and plastic products is the network's self-declared goal.

Organisationally, the cluster is integrated in the association Innovationszentrum Kunststofftechnik e.V. and covers, last but not least due to its proximity to the specialist field of plastics engineering at the University of Kassel and thanks to many years of trustful relationships with other research institutions, a wide range of expertise in the area of plastics and lightweight design. The focus is on so-called multi-material systems, especially plastic/plastic and plastic/metal hybrids.

As part of various event formats and activities, the cluster management offers players space for intensive technical-scientific exchange and promotes networking actively. The development and support of cooperation projects are the key focal areas of the cluster management's activities.

Further information:
www.kunststoffe-nordhessen.de

KUNSTSTOFF CLUSTER NORDHESSEN

INNOVATIONSZENTRUM KUNSTSTOFFTECHNIK e.V.

8.2 NATIONAL ASSOCIATIONS

C³ – Carbon Concrete Composite e. V.

Together with more than 160 partners from companies, research and associations, the C³ project develops the novel composite made from carbon fibres and high-performance concrete – carbon concrete.
www.bauen-neu-denken.de

Materials

Carbon Composites e.V.

Carbon Composites e.V. (CCeV) is a group of companies and research institutions that covers the entire value added chain of high-performance fibre-reinforced composites in Germany, Austria and Switzerland.
www.carbon-composites.de

Materials

CFK Valley e.V.

The association CFK Valley e.V. is a leading global competence network of the fibre composite industry with roughly 120 regional, national and international members.
www.cfk-valley.com

Materials

Composites Germany

The four strong organisations for composites AVK, CFK-Valley, CCeV and VDMA have joined forces in a trade organisation to promote the future topics of high-performance composites and automated production techniques in and for Germany.
www.composites-germany.org

Materials

Forschungskuratorium Textil e.V.

Forschungskuratorium Textil e.V. provides access to pre-competitive research results of the textile industry.
This also includes numerous aspects of lightweight design.
www.textilforschung.de

Methods / Knowledge

GKV/TecPart - Verband Technische Kunststoff-Produkte e.V.

GKV/TecPart is the lobby for manufacturers, recyclers and compounders of technical plastic products in the public sector, politics and (inter)national bodies.
www.tecpart.de

Materials

Fraunhofer Lightweight Design Alliance

The Fraunhofer Lightweight Design Alliance brings together the expertise of 18 Fraunhofer institutes with the goal of supporting the application-oriented development of innovative lightweight design solutions.
www.leichtbau.fraunhofer.de

Methods / Design principles

igeL – Interessengemeinschaft Leichtbau e. V.

igeL is a network of industry, teaching and research focussing on furniture/interior finishing as well as mobile spaces.
www.igel-ev.net

Methods / Materials

Fraunhofer MATERIALS

The Fraunhofer group MATERIALS integrates the expertise of 16 institutes and provides a broad skills base for material science. The group is a member of the Lightweighting Initiative.
www.materials.fraunhofer.de

Materials

Industrieverband Veredlung - Garne - Gewebe - Technische Textilien e.V.

IVGT is Germany's biggest textile trade association. Numerous technical textiles are suitable for lightweight design and are manufactured by our members.
www.ivgt.de

Materials

Gesamtverband der Aluminiumindustrie e.V. (GDA)

GDA, based in Düsseldorf, is an association of more than 100 aluminium companies that produce raw aluminium or aluminium products, also as composites with other materials.
www.aluinfo.de

Materials

Industrievereinigung Verstärkte Kunststoffe e. V. (AVK)

AVK is the oldest interest group of the plastics industry in Germany. With approximately 240 member companies, AVK is one of the largest associations in the field of reinforced plastics or composites in Europe.
www.avk-tv.de

Materials

Lightweight Forging Initiative

An international collaboration of steel manufacturers and forging companies to analyse the lightweight design potential of forged steel components in the powertrain, chassis and gear mechanism of, for example, hybrid vehicles and heavy commercial vehicles.
www.massiverLEICHTBAU.de
www.lightweightforging.com

massiverLEICHTBAU

Machines

VDMA Working Group Hybrid Lightweight Technologies

The working group currently has 205 members and promotes exchange between mechanical and system engineering processes for the production of hybrid lightweight components and user industries, suppliers and research.
www.lightweight.vdma.org

VDMA
Arbeitsgemeinschaft Hybride Leichtbau Technologien

Machines

Interest group for the technical processing, application and marketing of basalt fibres

A network of business and research experts who promote efficient use of the potentials for application provided by basalt fibres and explore their opportunities for technical application.
www.bafanet.com

BASALTFASERNETZWERK

Materials

Verband der Chemischen Industrie e.V.

The VCI is a political interest group that additionally uses its trade and regional associations and its expert committees to share its expertise on material research and innovative materials within numerous networks.
www.vci.de

VERBAND DER CHEMISCHEN INDUSTRIE e.V.
WIR GESTALTEN ZUKUNFT.
VCI

Materials

MS Multi Mat – Microsystems Based on Multifunctional Hybrid Materials

The network provides its members with support for the exchange of knowledge and when applying for research funding for the development of microsystem products, e.g. sensory systems for fibre composites.
www.msmultimat.de

µS Multi Mat
Kooperationsnetzwerk

Materials

VERBAND FÜR SCHIFFBAU UND MEERESTECHNIK e. V.

VSM is the political and commercial representative of interests of the German maritime industry. It represents, directly and indirectly, more than 550 companies and research institutes.
www.vsm.de

VSM
VERBAND FÜR SCHIFFBAU UND MEERESTECHNIK E.V.

Methods / Design principles

PlasticsEurope Deutschland e.V. – Association of Plastics Manufacturers

Plastic plays a key role in alternative drive systems and cutting-edge mobility. The know-how of plastics manufacturers contributes greatly to the development of innovative lightweight solutions.
www.plasticseurope.de

PlasticsEurope
Der Verband der Kunststofferzeuger

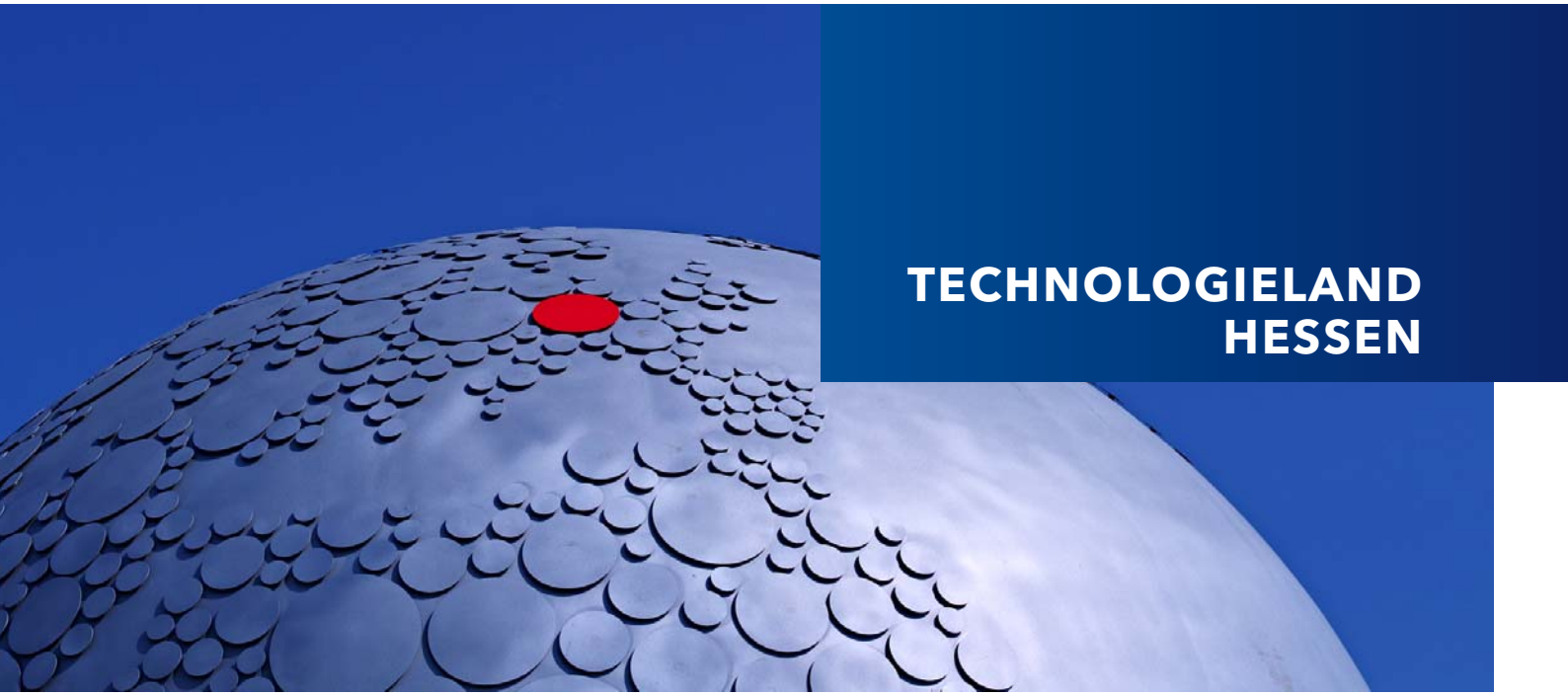
Materials

wdk Wirtschaftsverband der deutschen Kautschukindustrie e.V.

The Association of the German Rubber Industry is the political and commercial representative of the rubber and elastomer sector as a key economic factor in Hessen.
www.wdk.de

wdk

Materials



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Under the brand name "Technologieland Hessen", Hessen Trade & Invest GmbH combines technological innovations and promotes the development, application and marketing of relevant future and key technologies in Hessen on behalf of the Hessian Ministry of Economics.

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- Optical technology/Photonics

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You may also be interested in these publications:

- Kompetenzatlas Bionik in Hessen, 2nd revised edition, November 2015
- Additive Fertigung: Der Weg zur individualisierten Produktion, 1st edition, April 2015
- Mit Ecodesign zu einer ressourcenschonenden Wirtschaft, 1st edition, October 2015
- Ressourceneffizienz in Hessen Praxisbeispiele und Fördermöglichkeiten, 1st edition, April 2017

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