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Combination of high Complexity of Additive Manufacturing and excellent mechanical Performance of CFRP

inspire
AG für mechatronische Produktionssysteme und Fertigungstechnik

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Lightweight Structures

The following points are important for lightweight structures:

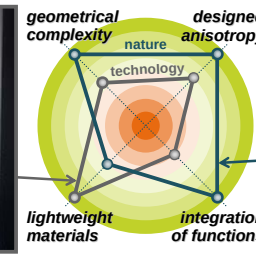
- **lightweight materials**: maximal mechanical material performance per density
- **geometrical complexity**: to place the material where it is most efficient to carry loads
- **designed anisotropy**: to orient the performance of the material according to the loads
- **integration of functions**: integrated additional functions → no extra components needed for these functions

technical & natural structures

Technical lightweight structures are typically made of excellent lightweight materials, like e.g. CFRP.

Natural lightweight structures typically have materials with "average lightweight performance" only. The overall excellent lightweight performance is reached by:

- optimal designed anisotropy
- placement of the material with high geometrical complexity
- integration of many functions



lightweight FRP structures allow high performance race cars with an extraordinary safety level

tree-trunks carry the high loads of the tree tops and can reach an age of several 100 years

Additive Manufacturing

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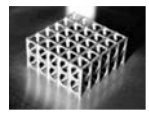
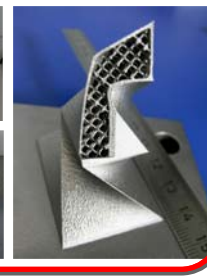


Typically components made by an additive manufacturing process have the following lightweight performance:

- ☺ **lightweight materials**: good
- ☺☺ **geometrical complexity**: excellent
- 😐 **designed anisotropy**: average
- ☺ **integration of functions**: good



Extremely complex structures made of thermoplastic and thermoset polymers, elastomers or metals can be processed by additive manufacturing processes.

CFRP - Carbon Fiber Reinforced Polymers

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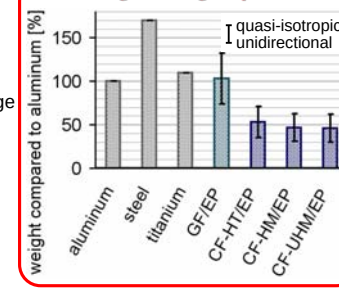
innovative composite structures

Components made of CFRP have good lightweight potential due to the following points:

- ☺☺ **lightweight materials**: excellent
- 😐 **geometrical complexity**: average
- ☺☺ **designed anisotropy**: excellent
- ☺ **integration of functions**: good

CFRP lightweight potential



Combination of Additive Manufacturing & CFRP - Carbon Fiber Reinforced Polymers

The combination of highly complex components made by additive manufacturing with carbon fiber reinforced polymers (CFRP) opens doors to novel lightweight structural designs as well as to new innovative manufacturing process routes.

The outstanding lightweight performance of components made by a carbon fiber reinforced additive manufacturing process is based on the following principles:

☺☺ **lightweight materials**: CFRP with excellent mechanical performance can be applied in the high loaded areas of the components, what results in the highest structural benefits with minimum component weight.

☺☺ **geometrical complexity**: The "complexity for free" of elements made by additive manufacturing processes allows to place the material only where it is needed and especially to support the carbon fiber reinforced areas in a way that these can carry the high loads with maximum efficiency.

☺☺ **designed anisotropy**: The fibers of the CFRP areas of components made by a carbon fiber reinforced additive manufacturing process can exactly be oriented according to the loads.

☺☺ **integration of functions**: The combination of extremely complex shaped elements made by additive manufacturing processes with the good capability of CFRP structures to integrate functional elements and layers leads to an outstanding potential for the integration of functions in components made by a carbon fiber reinforced additive manufacturing process.

A novel processing route has been investigated on combinations of complex elements made of a modified PA12 by a additive manufacturing process and local reinforcements made of carbon fiber reinforced epoxy prepregs:

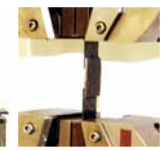
① Lay-up of prepreg layers on a simple tool
② Insertion of complex shaped PA12 elements made by additive manufacturing
③ Lay-up of additional prepreg layers on top of the PA12 elements
④ Curing of prepreg in a standard prepreg process; the high temperature resistance of the modified PA12 allows the complex elements to survive the prepreg curing process without significant deformation

This approach allows to realize novel lightweight design solutions with reinforcement fiber arrangements tailored to load cases that can not be realized with traditional tooling concepts for CFRP components.

Another approach is to reinforce local load introduction areas of CFRP components with polymer or metal elements made by additive manufacturing processes that are connected by form closure and bonding (by the resin of the CFRP).

adhesion of CFRP on PA12

Experimental investigations showed, that during the curing of the prepreg system the epoxy resin is slightly penetrating the rather rough surface of the modified PA12 elements made by an additive manufacturing process. This results, additional to the pure bonding, in a good adhesion between the two materials. In different tests the failure always appeared in the CFRP laminate or in the PA12. That means, that the direct co-bonding of the materials with the epoxy resin of the prepreg is sufficient and no additional bonding film is needed.



more freedom of design

The layer-wise and powder based process allows the production of highly complex geometries. This affect the design process. The product design is not anymore limited through restrictions of the production technology. Almost every design is producible. That means that the product can be designed absolutely function orientated.

complex shapes with simple tooling

The combination of modified PA12 elements made by an additive manufacturing process and carbon fiber epoxy prepregs e.g. allows to manufacture "stand-alone stiffeners" (without special tooling) by an autoclave prepreg process. For the stiffeners as well as for their run-outs lightweight structural designs can chosen, that today can not be realized with traditional tooling concepts for CFRP components.