EDAG INSIGHTS
ADDITIVE MANUFACTURING

Visionary outlook for what might well be the next industrial revolution in automotive development and production. From the prototype and low-volume series through to the series in the automotive industry.

EDAG’s and experts’ viewpoints.
EDAG INSIGHTS CONTENTS

4 The 3D print revolution has begun

5 Additive manufacturing makes it possible:
Applying the systems found in nature - without compromise

8 Our hypothesis:
Additive manufacturing is ready for the next step

10 Overview
Additive manufacturing processes

12 Technology assessment and roadmap

13 The EDAG roadmap:
The evolution of additive manufacturing in the course of the next decades

14 Additive manufacturing:
Its impact on automobile production

17 EDAG demonstrator:
Laser additive manufacturing of ultra-light,
multi-functional components using the example of power electronics

18 Outlook with EDAG:
What we would like to offer

19 Publishing information
THE 3D PRINT REVOLUTION HAS BEGUN.

After consumer printers for €1,000 have flooded the market, industrial applications will follow. Generative manufacturing processes or additive manufacturing will leave rapid prototyping behind, adding a new dimension to the classical manufacturing methods and helping to define the path to lightweight design 2.0. The transfer of successful technologies from industries not (yet) involved in the automotive sector leads to new partnerships within the value chain, and to product innovations which will help to secure the technological leadership of the European locations.

ADDITIVE MANUFACTURING

Everyone is talking about “3D printing”. Additive manufacturing has long been in use in the automotive and aerospace industries and in medical technology. Above all, small spare parts and prototypes can be produced quickly, and without the use of tools.

Despite the large number of conceivable processes on the market, the general principle is the same: the material is built up layer by layer, without the use of tools, and only a 3D data model must be available as input data. This method opens up enormous freedoms in development and design which, due to restrictions in production on account of the classical primary forming, reshaping and machining manufacturing processes (in accordance with DIN 8580) were previously not accessible.

Additive manufacturing therefore opens the way to new solutions in terms of function-oriented lightweight construction:

- Considerable increase in material efficiency and resource efficiency
- Considerable increase in economic viability of complex products
- Considerable reduction in damage to the environment
ADDITIVE MANUFACTURING MAKES IT POSSIBLE: APPLYING THE SYSTEMS FOUND IN NATURE - WITHOUT COMPROMISE!
With “EDAG Genesis”, the company’s exhibit at the 2014 Geneva Show, EDAG offered a visionary outlook for what might well be the next industrial revolution in automotive development and production. One Component - One Module - One Body - One Vision

Our exhibit, “EDAG GENESIS” can be seen as a symbol of the new freedoms and challenges that additive manufacturing processes will open up to designers and engineers in development and production. Additive manufacturing will make it possible to come a great deal closer to the construction principles and strategies of nature.

ADDITIVE MANUFACTURING MAKES IT POSSIBLE: APPLYING THE SYSTEMS FOUND IN NATURE - WITHOUT COMPROMISE!

Developed functionally and evolutionarily into optimised structures from which man can learn. And the entire process is tool-free, resource-saving and eco-friendly.

“EDAG GENESIS” is based on the bionic patterns of a turtle, which has a shell that provides protection and cushioning and is part of the animal’s skeleton. The shell is similar to a sandwich component, with fine, inlying bone structures that give the shell its strength and stability. This concept is reflected in the exhibit.
In “EDAG GENESIS”, the skeleton is more of a metaphor; in this case, it is not so much part of a musculoskeletal system, but instead provides extra passenger safety. The framework calls to mind a naturally developed skeletal frame, the form and structure of which should make one thing perfectly clear: these organic structures cannot be produced using conventional tools!

Although the turtle had millions of years to develop accordingly, and, for instance, perfect its “passenger safety system”, man is still theoretically at the very beginning of a possible paradigm shift. The traditional rules of design, with restrictions caused by production, will only play a very minor role in additive manufacturing, and the tried and tested construction methods of nature can also be applied in a genuine series production situation, which was unconceivable in the past.

Now it’s our turn!

Additive manufacturing enables parts to be designed so that they are load-specific, multifunctional and bionic, while ensuring ideal wall thickness and outstanding material properties. Working directly from the data models, tool-free, highly flexible production is possible. Weldable metals and plastics developed to be suitable for specific applications will pave the way to future applications.
OUR HYPOTHESIS: ADDITIVE MANUFACTURING IS READY FOR THE NEXT STEP
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In our position as the world’s leading design engineering company in the automotive industry, EDAG’s core activities include the development of innovative trends and technologies. In view of the enormous potential of additive manufacturing processes, the EDAG team have been looking into the subject, and working in close dialogue with leading technological and scientific experts to develop a roadmap.

Co-creators of the workshop were Prof. Dr.-Ing. Claus Emmelmann (Laser Zentrum Nord, Hamburg), Prof. Dr.-Ing. Jens Günster (BAM Bundesanstalt für Materialprüfung, Berlin), Dr.-Ing. Eric Klemp, Mr. Stefan Peter (DMRC Direct Manufacturing Research Center, Paderborn), Steve Rommel and Mr. Andreas Fischer (Fraunhofer IPA) provided EDAG with their indirect support. We would like to say a special thank you to all of these people for joining in the constructive dialogue and intensive exchange of ideas with our EDAG colleagues, and for the significant contribution they made.

This workshop between the EDAG team and leading authorities from the field of additive manufacturing helped us to select particularly promising processes from the wide portfolio of possible options, to specify relevant influencing factors, to identify booster potential and to formulate technological impact. As a result, 16 hypotheses were set forth, and these form part of these EDAG INSIGHTS. Subsequently, EDAG development, design, lightweight construction and production specialists added the finishing touches to the roadmap, and documented it as an outlook for the future of additive manufacturing. During the think tank, it very quickly became clear that additive manufacturing processes offer considerably greater potential than current ideas, restricted largely to the field of rapid prototyping or 3D printing, suggest.

We anticipate that additive manufacturing processes are ready for the next step, and will revolutionise the classic manufacturing processes and structural design methods. The reason for this assumption are the latest advances in development, which enable extremely complex and highly efficient structures to be represented using this process, which can also implement special functions over and above this. In medical technology, for instance, production already involves high levels of automation and large quantities, in order to be able to make use of the advantages of variant-rich, tool-free production.
OVERVIEW
ADDITIVE MANUFACTURING PROCESSES

The immense potential of additive manufacturing inspired us to define and analyse the current status quo of the latest technologies, and then assess the extent to which it might be possible to use them in vehicle development and production. What processes offer the best prospects for producing structural parts with the requisite product properties in a single production step, without the use of tools?

Possible candidates for the situation analysis of additive manufacturing were technologies such as selective laser melting (SLM), selective laser sintering (SLS), 3D printing (3DP), stereolithography (SLA), and fused deposition modelling (FDM), were examined.

FDM - Fuse Deposition Modeling
- **Principle:** using a nozzle that moves three-dimensionally in an open space, melted thermoplastic polymers are sprayed on layer by layer, and built up to produce a workpiece.
- The inclusion of reinforcing fibres is still currently being researched (3D fibre printer).

SLM - Selective Laser Melting
- **Principle:** electron beam melting: powdered metallic materials are locally laser remelted under inert gas.
- By and large, mechanical properties conform with the basic materials
- Particle sizes are selected subject to layer thickness and surface quality.

SLS - Selective Laser Sintering
- **Principle:** powdered thermoplastic materials are laser sintered layer by layer in an inert gas atmosphere, to produce a workpiece.
- Mechanical properties are below those of injection moulding.

SLA - Stereolithography
- **Principle:** selective polymerisation of fluids by laser (epoxy resins).
- A classic rapid prototyping process since the 1990s
- As a rule, material properties are geared to model building materials.

3DP - 3D Printing
- Any solids imaginable can be bound together layer by layer, using suitable bonding agents
- Subsequent treatment is carried out to define the properties of the workpiece
- Simultaneous printing of plastics in various degrees of hardness and colours
**SLM process**

1. CAD data file
2. Layer information
3. Lowering the construction platform
4. Application of a layer of powder
5. Local fusing of the component geometry
6. Finished component

Source: Direct Manufacturing Research Center, 2014

**FDM process**

1. FDM head
2. Model material
3. Support material
4. Construction platform

Source: Direct Manufacturing Research Center, 2014
**Booster potential**

Besides the SLM process already industrially available today (see diagram on page 11), with its portfolios of weldable metals and plastics, and in addition to 3DP, there is also a refined FDM process that looks as though it might be another promising candidate.

Unlike other technologies, FDM makes it possible for components of almost any size to be produced, as there are no pre-determined space requirements to pose any restrictions. Instead, the structures are generated by robots applying plastic materials layer by layer. Complex structures are built up in an open space, using practically no tools or fixtures. It might even be possible to integrate semi-finished products using this method.

In contrast, metallic SLM already offers the strength, stiffness and energy absorption values generally required in the industry today, and which are essential in a structural application.

The FDM process could, in the future, provide remedial action to improve the structural relevance by the parallel addition of an endless carbon fibre to the production process; this is currently at the research and development stage. One of the central booster potentials of high-performance thermoplastics is their potential for the incorporation of fibre reinforcements to systematically increase strength and stiffness.

It would also provide significant booster potential if there were a possibility of not incorporating fibre reinforcements throughout the component, but depositing them at specific load-relevant positions, where they are really needed. This would mean that fibre-reinforced components can be produced more bionically, at considerably lower cost and using fewer resources: as much reinforcing material as necessary, but as little as possible.

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**TECHNOLOGY ASSESSMENT AND ROADMAP**

The various technologies were summarised in an assessment matrix, put in relation, compared, and assessed using relevant weighting factors:

- How great is the structural relevance today and in the future?
- How wide will the range of materials that can be used be in 2015, 2025, 2035 and 2045?
- How will it be possible to reduce the process times using suitably intelligent automation?
- What effects will this have on the cost?
- What degree of complexity and lot sizes will be involved in producing structural parts in the future?
THE EDAG ROADMAP: 
THE EVOLUTION OF ADDITIVE MANUFACTURING
IN THE COURSE OF THE NEXT DECADES

ROADMAP
ADDITIVE MANUFACTURING

FDM
- Principle: melted thermoplastic materials are laid down and built up layer by layer, using a nozzle that melts the thermoplastic material.
- The inclusion of reinforcing fibres is still currently being researched (3D fibre printer).

SLM
- Principle: electron beam melting: Powdered metallic materials are locally laser remelted under inert gas.
- By and large, mechanical properties conform with the basic materials.
- Particle sizes are selected subject to layer thickness and surface quality.

SLS
- Mechanical properties are inferior to those of injection moulding.

3DP
- Principle: solid materials are bound together layer by layer, using suitable bonding agents.
- Subsequent treatment is carried out to define the properties of the workpiece.
- Simultaneous printing of plastics in various degrees of hardness and colours.

Booster potential FDM
- High performance thermoplastics
- In situ bonding agents
- Portal instead of printer

Booster potential 3DP
- Subsequent treatment processes
- Optimisation of system of bonding agents for solid materials
- In situ bonding agents

Booster potential SLM
- Customised alloys
- Multi-beam/scanner
- Weight – moulding flask

Booster potential FDM
- Biopolymers
- Optimisation of fibre matrix
- Multi-jet

Booster potential SLS
- Fibre reinforcement
- Optimisation of matrix materials
- Integration of semi-finished products
- Multi-beam/scanner
- Scale-up

Booster potential 3DP
- Consumer hype

Booster potential SLA
- Integration of fibres in 2D

Booster potential SLM
- Integration of semi-finished products
- Portal instead of a chamber

ECOLOGICAL PERFORMANCE
STRUCTURAL RELEVANCE
MATERIAL RANGE
PROCESS SPEED
COMPLEXITY
TOLERANCE
PRODUCTION COSTS
COMPONENT SIZE
BATCH SIZE

MATERIAL RANGE
- CoMPlexity
- BAttCh SIzE

ECOLOGICAL PERFORMANCE
- ECoLoGICAL PERFoRMANCE

STRUCTURAL RELEVANCE
- PRoDUCTIoN CoSTS

PRODUCTION COSTS
- PRoCESS SPEED

COMPLEXITY
- CoMPoNENT SIzE
ADDITIVE MANUFACTURING:
ITS IMPACT ON AUTOMOBILE PRODUCTION
ADDITIVE MANUFACTURING: 
ITS IMPACT ON AUTOMOBILE PRODUCTION

The impact it might have on the status quo of vehicle development is immense. The high degree of freedom offered by additive manufacturing processes enables load-specific and multi-functional parts to be designed, while ensuring ideal wall thickness (no over-dimensioning) and outstanding material properties. The one advantage that will prove decisive in moving our society forwards is the CO₂-reduced vehicle body of the future.

We are on the threshold of a possible paradigm shift in product design, as all the familiar restrictions previously linked to production-oriented development are about to become virtually obsolete. Suddenly, it is possible to produce anything!

The new processes enable us to reproduce nature, and bring us one step closer to adapting bionic thought patterns. It will, however, be necessary to introduce our future designers and engineers to these ideas and train them accordingly. It is quite possible that, in the process, we will realise that our present computer-based software for the phases styling, development, design, calculation and production has not yet been brought in line with the new processes.

Apart from new design possibilities, additive manufacturing processes are also a great advantage in production. Making direct use of the 3D data model - which exists anyway in order for a component to be created - permits almost tool-free, extremely flexible and variant-rich production. Further, evolution in the speed and growth of construction volumes in additive manufacturing processes and corresponding automation engineering gives rise to expectations of a 100 to 1000-fold increase in productivity in the next 10 to 20 years. If, however, it is assumed that the 3D design data mentioned will be made available on the Internet, it will not be long before questions on copyright are raised. Similar problems already exist in the music, film and photographic industries.

Combinations of hybrid structures with classical construction methods (sheet and cast metal, fibre composites, etc.) will bring about radical improvements in functional properties and efficiency. The new, bionic design options already mentioned will also help to reduce the weight of plant technology, leading to energy savings in its production and operation. This means that, in the future, components, tools and clamping technology will be weight-optimised, and robots smaller.
From a logistic point of view, then, additive manufacturing processes also have advantages. Future decentralised manufacturing structures will, for instance, bring about a high degree of flexibility and efficiency in product evolution. This will go far beyond the production of spare parts. Suppose, for instance, that components and spare parts were only printed or generated on request or if needed for repairs.

We can only begin to speculate as to what potential for optimisation would result for warehousing and logistics in the future. And as to what contribution this would make towards saving resources, due to cuts in transport costs.

For the vehicle manufacturer, this potential opens up new ways of reacting with far greater tolerance to calls for the low-volume production of high-performance vehicles, model variants and derivatives, facelifts and individual product variants for specific customers.

To sum up, it can also be said that the development process chain, from performance specifications to topological analysis, function development, bionic design and production-oriented design, has not yet been established, and is still very time-consuming. Additive manufacturing processes have not yet been integrated into the established development and manufacturing process chain. However, there is no room here for pessimism. We only have to recall the history of the digital camera or mobile phone. Even though people had serious doubts about both items to begin with, we can nowadays see that these developments and the changed business models they have occasioned have had an enormous impact on everyday life.
EDAG DEMONSTRATOR: LASER ADDITIVE MANUFACTURING OF ULTRA-LIGHT, MULTI-FUNCTIONAL COMPONENTS, USING THE EXAMPLE OF POWER ELECTRONICS

Even though industrial usage of additive manufacturing processing is still in its infancy, the revolutionary advantages with regard to greater freedom in development and tool-free production make this technology a subject for the future. From today’s point of view, it is quite feasible and realistic to assume that it will be possible to produce components in the near future, and modules and assemblies in the next stage. Our great inspiration today is the vision of a full-scale, generatively produced vehicle body made of an affordable, structural high-performance material. According to the Chinese proverb, every journey starts with a single step.

The photo shows the demonstrator of a generatively produced multi-functional housing, taking the example of the power electronics of an electric vehicle built by EDAG and Laser Zentrum Nord as a joint project. Its dimensions, which meet load and technical requirements, permit a weight of 900 g instead of the 1,900 g of the reference construction method in cast metal.

The industry already uses selective laser melting (SLM) to produce functional components with a number of variants directly from the data files, without any tooling. The demonstrator makes in-depth dialogue between potential users and EDAG specialists possible.
OUTLOOK WITH EDAG: WHAT WE WOULD LIKE TO OFFER

We hope that, apart from giving you a degree of insight into the world of additive manufacturing, we have also whetted your appetite and made you keen to find out more. The EDAG GENESIS vehicle body sculpture enabled us to demonstrate and discuss with you whether, and if so how, additive manufacturing processes can influence production in the future.

In order to be able to realise the full potential of these new technologies, however, specialised knowledge on how to consolidate this new production process chain is needed. Knowledge on applicable processes, production-oriented component development and material optimisation. Within the context of EDAG GENESIS experts’ think tank, we were able to identify key authorities. What is more, with EDAG GENESIS, we have given new momentum to bionic design. Our findings will in the future help to derive structural parts from bionic templates, and therefore from the specifications of Nature herself.

As both an integrator of new technologies and the world’s leading independent design engineering company in the automotive industry, we are responsible for promoting the development of new lightweight construction technologies. Consistently questioning the status quo in an attempt to improve the mobility of tomorrow. We do this not for just any old body, but for our customers and clients, namely the leading vehicle manufacturers and suppliers throughout the world. Not for just any old reason, but to advance Germany’s reputation as a high tech location. And last but not least, to turn technology into emotion. We see ourselves as a support team for your vehicle development and lightweight construction projects and are more than happy to offer advice on the exciting, new generative development process chain. We look forward to taking this first step with you.
EDAG INSIGHTS

WANT TO FIND OUT MORE ABOUT ADDITIVE MANUFACTURING? THEN ASK US.

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