Aluminum Alloy for Additive Manufacturing in Automotive Production

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Currently available materials for additive manufacturing have not been specifically developed for the automotive industry. Particularly for crash-relevant applications only few alloys are available. Against this background, Edag and its partners in the project CustoMat_3D researched a novel aluminum alloy for automotive applications.

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ADDITIVE MANUFACTURING ALLOY FOR SERIES PRODUCTION

New drivetrain technologies, automated driving and the collapse of the market as a result of the coronavirus pandemic are causing major upheavals in the automotive industry. Electrification in particular is further blurring the differences between vehicle categories, making it increasingly difficult to differentiate between luxury and sports cars. Additive manufacturing reveals great potential for resolving this challenge. The use of additive manufacturing makes both lighter and individualized vehicles possible from a technical and an economic point of view. For the standard production of additively manufactured metallic components, however, no alloys capable of meeting all the requirements of the manufacturers are available as yet. This is where the CustoMat_3D project comes in, a project that saw the development of a new aluminum alloy, the corresponding production processes, simulation possibilities and applications. The aim was to find an alloy which would combine good workability, high strength and great durability at a competitive price.

The definition of the alloy was based on these specifications. To these were added specific requirements such as paintability, joining technologies and corrosion properties. It also needed to be possible to atomize the alloy into fine powder, which is melted down in the subsequent process. AlSi10Mg, an alloy already established on the market, was taken as a reference to be improved upon in terms of properties. The alloy system chosen was a silicon-magnesium alloy. Alloys in this series are characterized not just by low corrosion but also by the possibility of carrying out thermal treatments. The weldability essential for processing in selective laser melting was also given. Within the alloy system, five alloys were systematically defined by partner Leibniz IWT and methodically investigated. The powder atomization was carried out in a laboratory at Ecka Granules Germany. A narrow particle size distribution was achieved, ensuring processability.

ADJUSTABLE DUCTILITY AND STRENGTH

The manufacturing process was developed by Fraunhofer IAPT. To this end, test specimens of the alloys were first produced, for which basic mechanical properties such as hardness, tensile strength and pore content were determined. The alloys with the highest potential then passed through a series of tests for different heat treatment strategies, thus enabling the properties to be further developed. It quickly became apparent that an alloy meeting all requirements had been found. It also proved possible to produce either highly ductile or high-strength versions of the alloy by applying adapted heat treatment strategies. In line with the project title, the alloy was named Custalloy. The possible spectrum of properties is shown in **FIGURE 1**. It became clear that both a greater fracture strain and higher strength are possible than with the reference alloys. Very expensive alloy components, such as scandium in the material brand Scalmalloy, can be avoided in the process. The extreme toughness of the material, which is reflected in improved crash performance, should be noted here.

Processing in large series is only possible if the appropriate equipment is available. In order to transfer the process from test facilities with limited space, two project partners, GE Additive and FKM Sintertechnik, carried out corresponding upscale testing, which showed that specially adapted process control is essential if the outstanding properties of the alloy are to remain unaffected. A high level of process understanding has been developed, which will ensure that the components can quickly be implemented in the future. The Concept Laser M2 system types investigated and the Concept Laser X-Line 2000R for particularly large components also ensure that almost all components with dimensions of up to 800 × 400 × 500 mm can be produced by additive manufacturing. Within the available space, either one large or several small components can be produced in one manufacturing step.

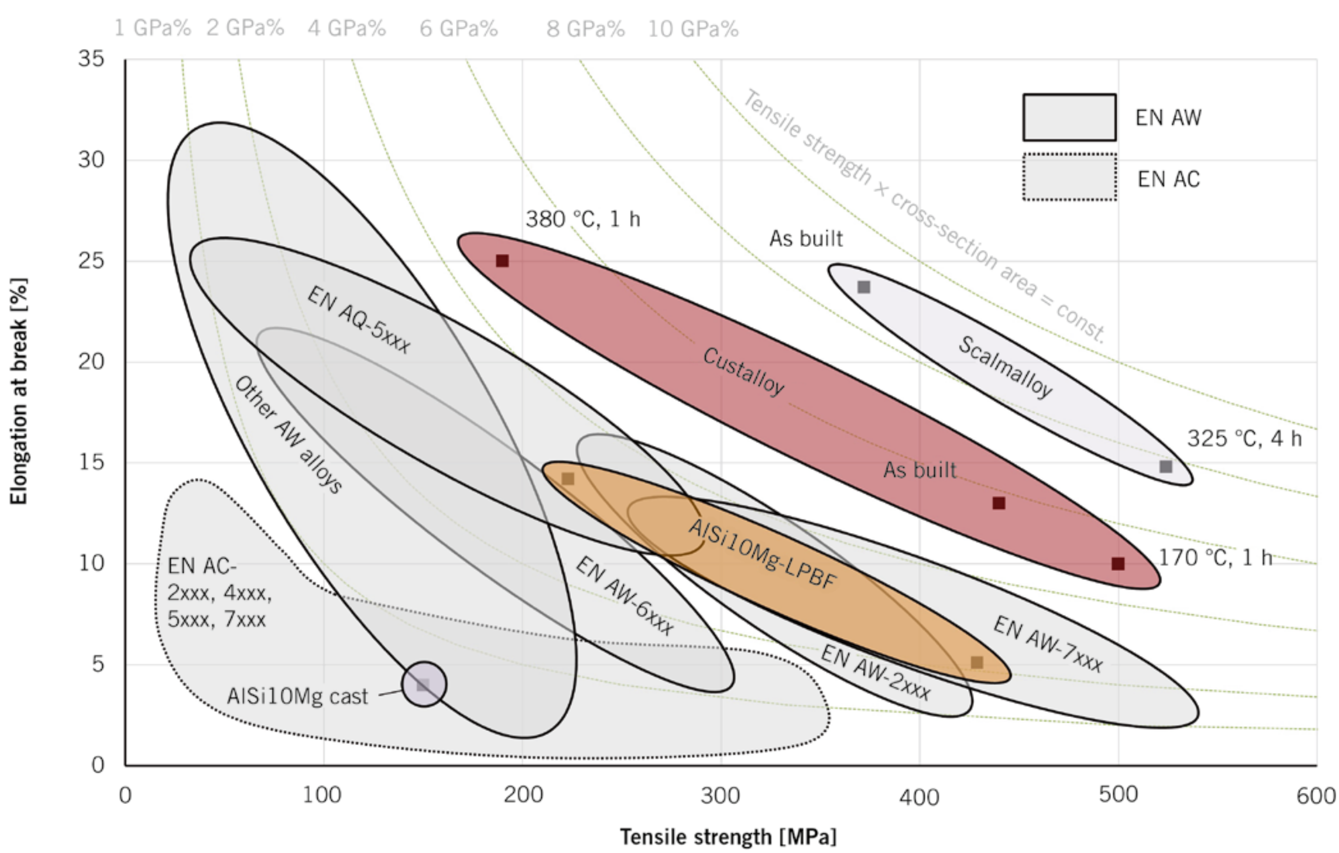

FIGURE 1 Comparison of the new alloy with conventional materials (LPBF: Laser Powder Bed Fusion) (© Leibniz IWT)

LASER WELDING WITH HIGH SEAM QUALITY

Joining technology is of decisive importance in vehicle production. For this reason, a test program that included standard processes such as gluing, riveting and laser welding was developed for the alloy. These procedures produced good results. Even with laser welding – often seen as a challenge – the specialists were able to achieve a high seam quality. Laser metal deposition, a method that can be used to systematically reinforce conventionally manufactured components, was also investigated. This method can be put to great effect with very little effort.

One of the constant challenges in selective laser melting of metals is component distortion. Using this method, the material is fused in individual layers, and cools down at each point under specific conditions. This frequently results in internal stresses, and these can even lead to stress cracks. For this reason, new multi-scale simulations were made possible for the first time ever by Fraunhofer ITWM and Magma Gießereitechnologie in the course of the project. This involved detailed simulation of the melting and cooling processes at microscopic level. The results are transferred to the full component at meso-level, bringing about greater simulation accuracy. Thermal treatment and finishing are also simulated in the process, **FIGURE 2**. Specific solvers capable of handling the high computing input in a short time were used here. Simulation can thus be carried out in much the same time as other processes. In this way, alignment, the positioning of support structures and distortion can be detected before the process even begins.

Based on a vehicle screening Mercedes-Benz and Edag selected complex and highly stressed components, which were to be used as examples in a weight reduction process. The parts chosen were a shock absorber dome currently made of die-cast aluminum, which is shown in the title figure of this article, and a wheel carrier for high-performance vehicles. These components also enable a direct comparison of costs and benefits to be made. Functions such as mounting elements were partially integrated into the component, enabling later assembly steps to be omitted. As the joining sequence has been retained, direct implementation in existing production lines is possible. Special material cards were generated to calculate the strength and stiffness of the components. Altair provided the Optistruct software for structural optimization, which can make weight savings of up to 30 % possible in the demonstrator components. All existing requirements set out in the product specifications were met. The advantage here was that the teams were able to use the requirements of the additive manufacturing process as a basic condition for optimization. The reduction of the support structures in line with the build direction was a major optimization goal.

VEHICLE-SPECIFIC ADAPTIONS

The great advantage of additive manufacturing is that no tools are required. This means that the component can be adapted to meet the requirements of the vehicle concerned. An example of this is the axle load, which varies depending on the type of drive used. With the help of a load level model it was therefore possible to increase secondary weight and cost savings. For lower axle loads, the shock absorber dome is correspondingly lighter, which leads to a further reduction of up to 18 % in component weight. The shock absorber dome examined by Edag consists of two components joined together using the laser welding process that has been developed. In addition to the use of different building directions and the resulting savings in support structures, this also enables the additional weight potential described above to be raised. For joining and reworking on critical connecting elements, a very cost-effective reusable clamping device was created. This can be seen in **FIGURE 3**, during finishing processes. This made accurate adherence to the tolerances that are particularly important for chassis components possible. The shock absorber dome was mounted on an original vehicle body using the usual joining methods, and is now available for demonstration purposes. To conclude, a cost appraisal carried out showed that small to medium production rates of the components pro-

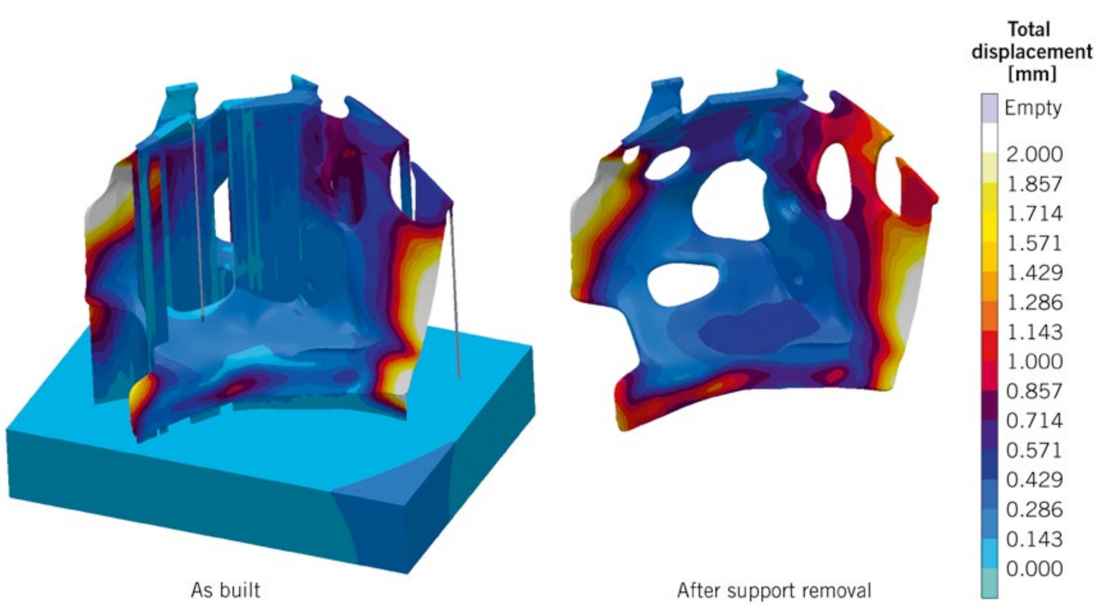

FIGURE 2 Multi-scale simulation of distortion after construction process and finishing treatment using the example of a single shock absorber dome component (© Magma Gießereitechnologie)

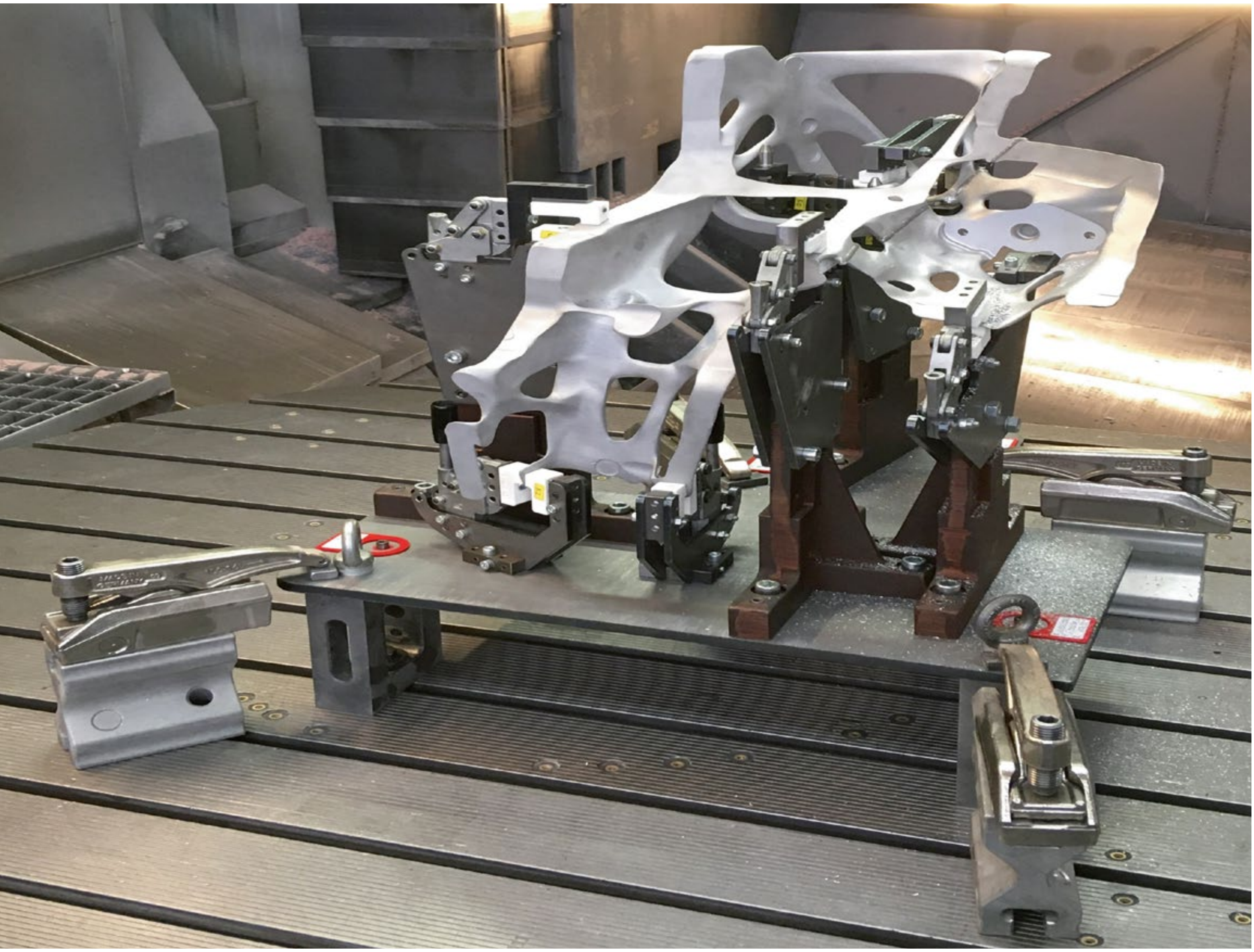

FIGURE 3 Reusable jig for the detailed finishing of connection points (© Edag Group)

duced with the new aluminum alloy are competitive.

CONCLUSION

The result of the project is a complete process chain from the powder, through simulation and process technologies, to ready-to-use components. The basis is the new type of aluminum alloy, which will be available in future under the brand name Custalloy. The results bear out the fact that the new alloy can contribute to the lightweight design of car bodies and is a high-potential basis for series applications.

THANKS

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