Plastics Instead of Metals

Vehicle interiors in the 1960s were dominated by metals (left), whereas today plastics dictate modern design (right)
(photos: Akro-Plastic)

High Performance Polyamides. In comparison to metals high performance polyamides score well on weight, design, functional integration and more cost effective processing techniques. These advantages are particularly demanded for applications within the automobile industry.

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The substitution of metals with plastics is neither new nor unusual. Looking at the interior of automobiles from the 1960s it can be seen that components were almost exclusively made from metal. Metals were not only used for load bearing chassis components, but also for functional elements as well as attractively painted and polished designer surfaces in the interior. Today it is principally plastics that define modern design in the vehicle interior even though metal effects are still used to enhance the vehicle appearance (**Title photo**). Up until now these have been based on coated polymers that require only tiny amounts of metallic raw materials. The use of modern technical polymers however brings with it more than just the substitution of metal. In the case of designer surfaces these also have a protective function and reduce the danger of injury during accidents. When designing components it is important to make use of the full potential of the polymer by for example combining functions, reducing the number of processing steps and incorporating colors as well as corrosion protection.

Translated from Kunststoffe 9/2012, pp. 109–111
Article as PDF-File at www.kunststoffe-international.com; Document Number: PE111150

The choice of material of construction is increasingly being determined by factors such as

- Environmental protection: weight reduction and the use of renewable raw materials,
- Design: freedom of form, implementation of construction concepts and material science,
- Manufacturing process: suitable production processes for the manufacture of the product, precision and simplicity of implementation at mass production scales and
- Cost optimization: reduction of the number of processing steps, energy consumption and tooling costs.

Ecology and Sustainability

It is not only in vehicle construction, but rather in numerous other industrial sectors that weight reduction is a current topic. High performance polyamides such →

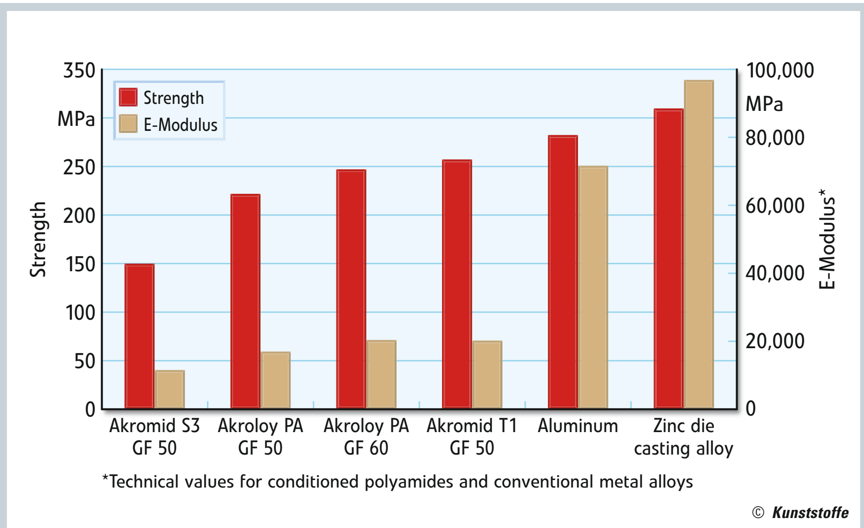

Fig 1. Comparison of the strength and E-modulus of high performance polyamides and die casting alloys

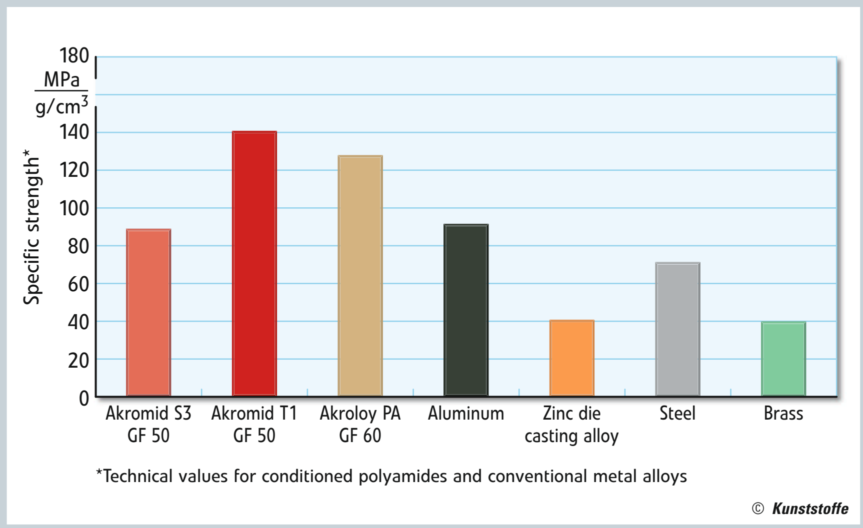

Fig 2. Strength data normalized for density of high performance polyamides compared to metal alloys

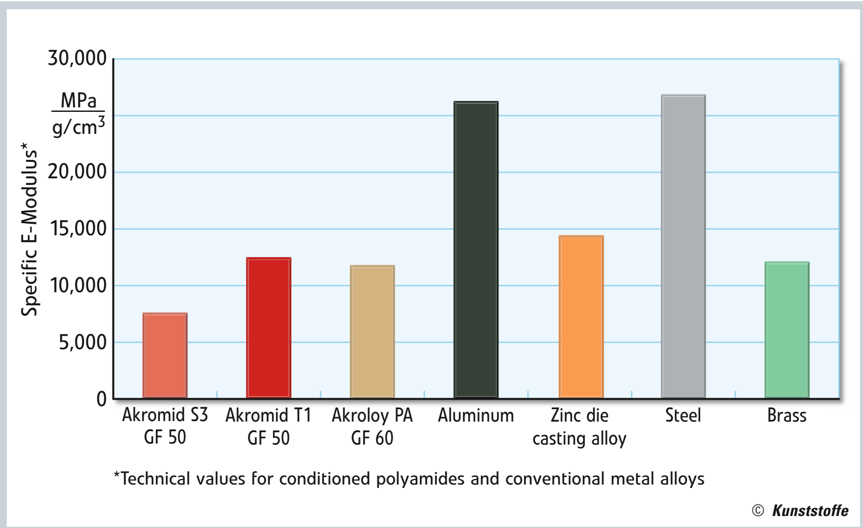

Fig 3. E-Moduli normalized for density of high performance polyamides in comparison to metal alloys

as Akroloy PA GF 60, a PA66 blend with a partially aromatic content, or Akromid T1 GF 50 (PPA), both products from Akro-Plastic GmbH, Niederzissen, Germany, can match practically all the strength properties of die casting alloys at a considerably lower weight **(Fig. 1)**. After compensating for the differences in density of the various materials it can be seen from their strength data and E-modulus that in the final analysis the real question is how much strength at what wall thickness and type of construction is required **(Figs. 2 and 3)**. Through a ribbed construction of the polymer part and external surfaces the sectional modulus can be increased and the strength of a component previously manufactured in metal achieved.

Modern design principles derived from bionics [1] are concerned with strengthening areas which are loaded (the principle of stress equalization) and the reduction of material in areas that are either not or only lightly loaded. Using this principle, components with reduced weight but full loading capacity can be made from plastics.

Ecology however also means sustainability which can be achieved through the use of renewable raw materials. New high performance polymers based on PA 610 such as for example Akromid S, are equally of interest for metal substitution due to their chemical resistance and low water uptake. This material is synthesized from sebacic acid (castor oil). In this way 70 % of the carbon content is provided by renewable raw materials using a process that does not compete with the production of food. The CO_2 savings achieved are between 40 and 60 %.

Glass fiber reinforcement of PA 610 allows high strengths to be achieved that due to low water uptake remain at a high level during service. This means components made from PA 610 have significantly more stable properties than parts made from standard PA6 and PA66.

Design and Engineering

The term "design" should not be understood as merely a reference to the external shape. Design is the implementation of an engineered solution for a part or the complete end application. Alongside knowledge of the precise boundary conditions, systematically engineering a component also requires the necessary understanding of the properties of the material from which the part is going to be made. The assumption that metal alloys are fundamentally better than polymers is still widespread. This does not however apply to zinc die casting alloys.

If a component is permanently loaded at a room temperature of 23 °C with 100 MPa, conventional zinc die casting alloys such as Zamak 5 begin to creep badly after 100 h and fail completely after 1,000 h. Akroloy PA GF 50 which is extremely strong particularly at service temperatures of up to +80 °C exhibits a stretching of just 50 % compared to original data and even lower values can be achieved with Akromid T1 GF50 **(Fig. 4)**. If the influence of a raised environmental temperature of +80 °C is also considered, the material strength of zinc die castings is reduced by 45 % more than a blend

Additional Process Steps	Plastic Injection Molding	Metal Die Casting
Corrosion Protection	Inherent	Protective coating has to be applied
Coloring	Inherent	Requires painting
Post processing	Very little / only in exceptional cases	Flash removal and post-molding milling of any holes
Threads	Molded in (for highly loaded threads insert placed in the mold and over-molded)	Additional process step
Surface texturing	Molded in	Additional post process, e.g. sand blasting

Table 1. Additional process steps can be integrated into injection molding, but not die casting

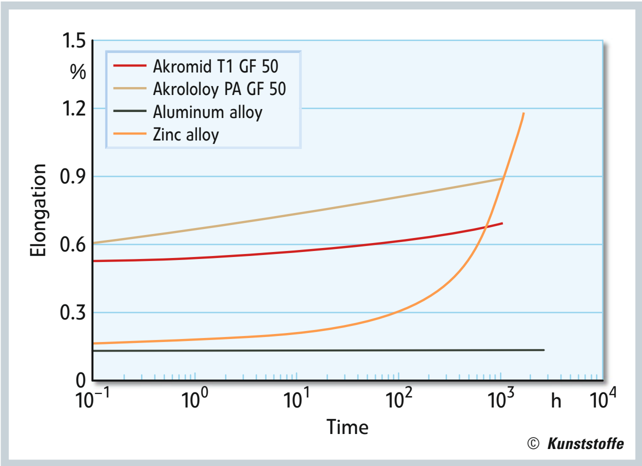

Fig 4. Creep behavior of high performance polyamides in comparison to metal alloys (continuous loading of 100 MPa at 23 °C)

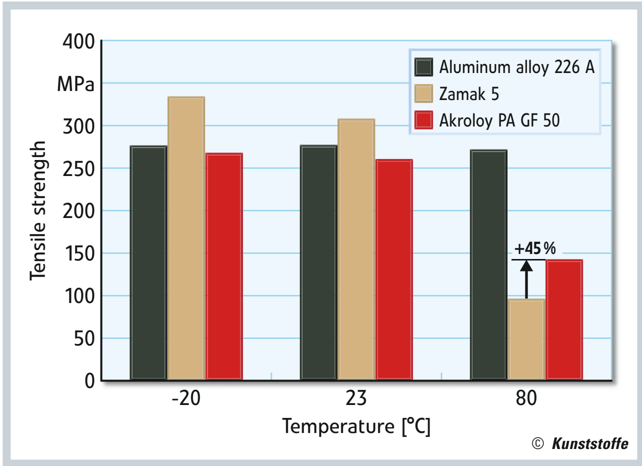

Fig 5. Tensile strength of high performance polyamides in comparison to metal alloys

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of PA (66+6I/6T) with a 50 % loading of glass fiber reinforcement. Only die cast aluminum alloys are unaffected at these temperatures **(Fig. 5)**.

In addition functionality and properties of the component part can be integrated during injection molding **(Table 1)**.

Manufacturing Process and Dimensioning

The shape processes for both injection molding and die casting are subject to conditions that are dictated by the materials used. Due to the very rapid solidification of metals, very high processing temperatures **(Table 2)**, extreme injection speeds (between 0.4 and 6 m/s) and accordingly short injection times of 5 to 60 ms have to be used. Voids are therefore almost unavoidable. With high performance polyamides however during the holding phase and the entire cooling process material to compensate for shrinkage continues to flow, preventing the formation of voids. Thus while technical polymers have lower strengths than metals, their dimensions are much more consistent meaning that in contrast to metal components a factor of safety to allow for voids is not required.

Cost Optimization and Functional Integration

It is particularly in mass production that the advantages of plastic injection molding in comparison to die casting come to the fore. For part counts of more than 700,000 units per annum even when using a polyphthalamide (PPA) with high

Process	Temperature [°C]
Injection molding of technical polyamides	180–345
Zinc die casting	390–450
Magnesium die casting	500–700
Aluminum die casting	600–720
Brass die casting	1,000

Table 2. Comparison between the processing temperatures for plastic injection molding and metal die casting

glass fiber reinforcement levels (e.g. Akromid T1 GF 50) up to 3 tools can be saved in comparison to aluminum die casting since due to the processing conditions these experience substantially more wear. By integrating functions and properties during the production process **(see Table 1)**, additional process steps (inserts, etc.), and assembly operations can be saved.

Alongside the significantly lower investment costs for the machine park it is also the substantially reduced energy consumption that stems from the lower processing temperatures and energy savings in the machines themselves that is a decisive argument in favor of plastic injection molding from both a financial as well as an environmental perspective. ■

REFERENCES

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