"Take Off" for high-strength aluminium in automotive

Heat treatable alloys from the 7xxx-family have been used in the aerospace industry for many years and due to their extremely high specific strength offer previously undreamt of potential for lightweight construction in the automotive industry.

The aluminium alloys generally employed for sheet applications in the automotive manufacturing area derive from work hardening 5xxx family and heat-treatable 6xxx family. They combine lightweight construction material potential with good formability and weldability, but do not attain the absolute strength of higher strength steel materials. Typical representatives of the 5xxx family are EN AW-5754 and 5182. The best-known representative of the 6xxx family is EN AW-6016. Apart from strain hardening due to forming, the strength of 6xxx alloys is also raised by hardening heat treatment, which as a rule takes place during body paint drying. As the surfaces of the heat-treatable 6xxx alloys are free of Lüders' lines, they are also used in the outer skin area.

Increased strength and hence greater lightweight construction potential due to sheet thickness reduction can be achieved with the high-strength AlZnMgCu-aluminium alloys of the 7xxx family. These alloys have been in extensive, long-term use in aircraft construction for applications that include fuselage structure and the wing sheets, which are subject to severe loads. The higher specific dent resistance of this aluminium alloy as compared to high-strength steel facilitated marked weight reductions in the structural component area. In addition, the high strength in combination with residual elongation of over 10% resulted in superior energy absorption in the case of lateral impact.

As a rule, simple material substitution does not lead to an ideal construction result from either a technical or an economic perspective. An optimum construction solution relates to the entire process chain from the semi to the component assembly. As is the case in other material classes, the task is to achieve an appropriate compromise between strength and the formability needed for component production. Suitable, process-safe joining processes constitute another prerequisite for employment and in addition the material demands relating to vehicle use such as corrosion and fatigue resistance, and crash deformation behavior all have to be fulfilled.

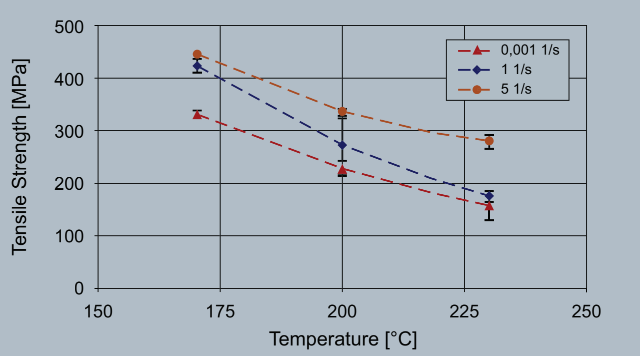

Fig. 1: Tensile strength of AMAG TopForm® UHS as function of temperature and strain rate

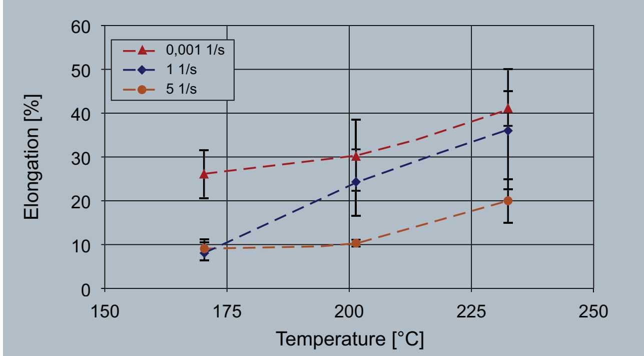

Fig. 2: Elongation of AMAG TopForm® UHS as function of temperature and strain rate

In the high-strength T6 temper the alloys of the 7xxx family demonstrate very limited formability at room temperature. Therefore, in the case of aerospace applications the sheet in this material class is frequently formed in a soft temper. However, this demands highly complex, subsequent heat treatment of the entire component and is thus impractical in view of the general conditions relating to serial, vehicle production.

One promising approach to an improvement in the forming capacity of high-strength 7xxx aluminium alloys is provided by a temperature increase in the warm forming area, below the recrystallization temperature of the materials. In the warm temperature range, the ductility and achievable form changes in the 7xxx alloys already increase markedly at 150°C, while flow stress decreases markedly. AMAG TopForm® UHS is a modification of standard alloy EN AW-7075, optimized for warm forming.

The dependence of the strength of the AMAG TopForm® UHS on the forming temperature and speed is shown in Fig.1. Tensile strength in the warm range falls in line with rising temperature and declining elongation rates. A considerable drop already occurs at 170°C, whereby conversely, elongation at fracture increases as desired (please see Fig. 2).

Fig. 3 shows the forming limit curve diagram for AMAG TopForm® UHS at differing temperatures. The cold formable standard alloy 6016-T4 serves as a reference point and in this diagram the anticipated poor formability of AMAG TopForm® UHS at room temperature is clearly recognizable. However, at 170°C the formability of AMAG TopForm® UHS is already comparable with that of 6016-T4, while at a temperature of 230°C, the formability of AMAG TopForm® UHS is markedly superior to that of the 6016-T4 reference material, in spite of the drastic increase in the strength of the formed component. The anticipated strength of the component derives from the initial strength AMAG TopForm® UHS, which amounts to some 550 MPa, and the strength loss incurred due to the effects of heat during forming and possible paint baking, which may occur at a subsequent point during the production process. These influences are shown in Fig. 4. In the case of suitably rapid process completion, which is also desirable for reasons of productivity, the influence of short-tem heating during forming is virtually negligible. A far greater influence is exerted by paint drying, which with a typical temperature profile of 20 – 30 minutes is completed at 180 – 190°C. This results in a moderate strength loss and the creation of a so-called overaged temper. Depending on the application this may even be regarded as advantageous, in order to enhance other material characteristics such as resistance against tension cracking corrosion.

The strength-elongation diagram (Fig. 5) shows the position of warm formed AMAG TopForm® UHS, as compared with cold-formed aluminium alloys. This makes clear that as a result of forming at moderate temperatures, a combination of geometric complexity and strength can be achieved, which is markedly superior to cold forming.

The question as to the weight saving potential achievable due to the use of high-strength aluminium cannot be answered in general terms, as it is highly dependent upon the construction and the specific demands made on the component. However, if high strength, dent resistance and energy absorption are required in combination with low weight, then AMAG TopForm® UHS is the first choice. In this connection, the advantages of this alloy class such as a high specific yield point and strength with comparatively high residual elongation come to full fruition. Warm forming at moderate temperatures allows major design freedom in tandem with straightforward processing requirements.

The challenge lies in the cost-efficient and process-safe realization of the special further processes required for this alloy class. This is one of the major developments AMAG is concentrating on together with partners from the automotive industry. ■

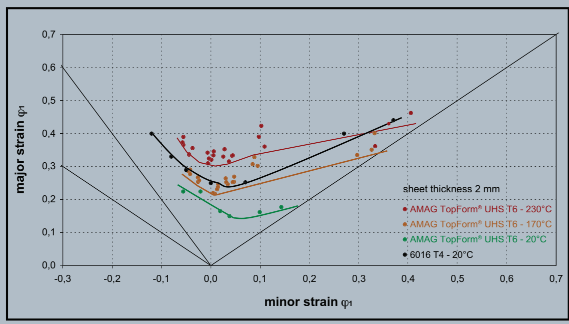

Fig. 3: Temperature-dependent forming limit curve for AMAG TopForm® UHS. The 6016-T4 alloy, which has been optimized for cold forming, serves as a reference. The forming limit curve defines the threshold between achievable forming range and material failure through cracking. Formability of 7075-T6 increases considerably with temperature and at 230°C exceeds cold formability of 6016-T4.

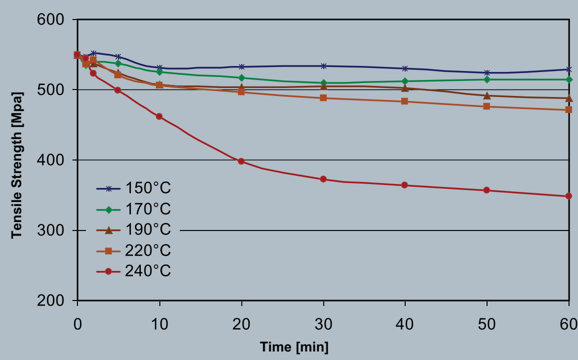

Fig. 4: Overaging heat treatment of AMAG TopForm® UHS

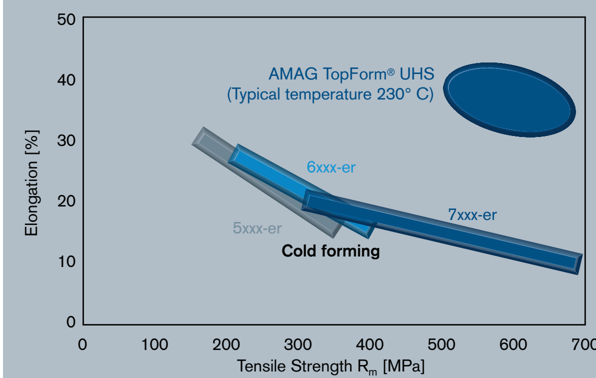

Fig. 5: Tensile strength-elongation-diagram for different classes of aluminium-alloys

Annealing furnaces