Currently, for sheet applications in car body engineering AlMg alloys of the 5xxx series or precipitation hardening AlMgSi alloys of the 6xxx series are used. The focus on lightweight design is still increasing due to legislation and customer requirements for less fuel consumption. Therefore high strength AlZnMg(Cu) alloys of the 7xxx series with tensile strength up to 700 MPa are extensively discussed. The aerospace and sports industry have been benefitting from the utilization of these high strength alloys for decades in terms of significant weight savings and enhanced performance.

However a successful transfer to the automotive industry requires innovative solutions to allow cost-efficient series production. The proposed solution is such that rolling, solution heat treatment and artificial ageing shown in figure 1 are done at the rolling mill, while the components are produced via warmforming at the customer’s site. Warm forming at temperature levels far below those for press hardening steel helps to overcome the moderate formability of 7xxx-alloys at RT.

High strength 7xxx series alloys of the type AlZnMg(Cu) double the yield strength compared to standard 6xxx series automotive alloys. Both alloy families increase their strength significantly by precipitation hardening. In a continuous strip annealing line both alloy types are solution heat treated and quenched to freeze the supersaturated solid solution. Natural ageing at room temperature starts and in contrast to AlMgSi alloys formable for a couple of months the hardening of AlZnMg(Cu) alloys continues. Therefore, AMAG developed a Cu-containing alloy called AMAG TopForm® UHS for replacing press hardened steel in automotive components like B-pillars or side impact beams. It is an AA7075 type alloy (AlZn5,5MgCu) optimized for warm forming in the long-term stable T6 peak age delivery temper. Higher strength compared to Cu-free derivatives combined with controlled solution annealing, quenching and artificial ageing at aircraft certified continuous coil treating lines ensure reproducible constant properties and reduce the investments and processes needed at the car manufacturer.
Warm Forming and Paint Bake Response

Cold forming of artificially aged AA7075 in temper T6 is limited to rather simple geometries, e.g. roll forming with radii according to stringers in the aircraft industry. For complex components warm forming is recommended.

Based on FEM simulation results the parameters for warm forming at a pilot press line were adjusted. The plane 7xxx-blank was heated up to the warm forming temperature within a minute in a simple hydraulic press in direct contact to hot plates. Short process times and a low process temperature of around 200°C are essential to keep the decrease of strength due to overaging as small as possible.

Figure 1: Temperature-time-diagram for high strength 7xxx series alloys
The forming limit curves (FLC) in Figure 2 compare the formability of AMAG TopForm® UHS at different temperatures around 200°C with the standard cold forming procedure of a typical AA6016 automotive alloy in temper T4.

As already mentioned, cold forming of an AA7075 T6 sheet is limited to rather simple geometries. At 170°C the forming limit curve comes close to the AA6016 T4 curve especially for plain strain conditions. A further increase to 230°C improves the formability significantly and even for the stretch-forming path AMAG TopForm® UHS reaches the formability of AA6016 T4 in cold forming.

On a pilot warm forming line a small series of a structural component, similar to a side impact beam of an automotive door was produced at a Tier 1 automotive supplier in co-operation with AMAG (Figure 3). This process proved to be robust with very small variation of mechanical properties after forming and painting.

While a variation of the warm forming temperature leads to different mechanical properties after the press shop, after the additional heat treatment in the paint shop the final material properties are very uniform. Figure 4 compares the tensile and yield strength after warm forming and after an additional heat treatment in the paint shop.

While warm forming at 170°C with just one or two minutes process time has almost no impact on strength, a slight increase to 200°C reduces the strength by some 50 MPa. Typically a common 5-step paint-bake cycle for drying the body-in-white structure, e-coating and curing the various paint layers enables re-aging. About altogether one hour heating with a temperature collective of 125 to 185°C with intermediate cooling to room temperature leads to a yield-strength of 460 MPa.
From the customer's point of view the process starts with well defined and long-term stable properties of AMAG TopForm® UHS sheet. During warm forming in the customer’s press shop and the subsequent paint bake cycle the mechanical properties of the component become uniform on a high level.

Parameter fluctuations of time and temperature during warm forming do not result in fluctuations of the material properties after forming and painting (Figure 4).

It was also observed that the springback after warm forming is low because of the significantly reduced yield strength at forming temperature.

**Joining**

Conventional fusion welding of copper containing 7xxx series is difficult due to the occurrence of solidification cracks. For AMAG TopForm® UHS two modified thermal joining methods were tested on a laboratory scale.

Resistance spot welding trials with the already commercially available Fronius Deltaspot® technology show very promising results. Thereby two cross die parts with a drawing depth of approx. 50 mm, derived from a 2 mm AMAG TopForm® UHS sheet, were produced and joined (Figure 5). Detailed results will be presented in the next AluReport 1/2013.

Additionally, AMAG TopForm® UHS was successfully joined with Friction Stir Spot Welding (FSSW). This is a modification of the well-known FSW process resulting in round joining spots. A process innovation of the company RIFTEC with a segmented rotating tool fills the deepening of the spots leading to a smooth surface. This improved joining method shows promising results for overlap joints of AA7075 sheets.

The aircraft industry has a positive long-term experience with mechanical joining methods (e.g. riveting) of 7xxx series Al-alloys which are also applicable to AMAG TopForm® UHS. Automotive specialties like self piercing rivets or flow drill screws should also work but have to be adapted from low and medium strength aluminium to high strength 7xxx series alloys.

Adhesive bonding is another widely spread joining technology used for aluminium in the aerospace industry. In recent years this type of joining became popular in car manufacturing especially in multimaterial car body designs. Galvanic isolation of materials with different electrochemical potentials and the prevention of crevice corrosion is an important factor for this type of joining. For a sufficient degradation performance of the bond, the surface has to be properly prepared.

Adhesive bonding pre-treatment in the aircraft industry is based on batch wise anodizing procedures for structural parts exhibiting excellent tensile shear strength and fracture pattern. So far, new pre-treatments show comparable good results on a laboratory scale and tests on AMAG’s modern and flexible continuous automotive pre-treatment line will follow soon.

**Customer Benefits**

AMAG TopForm® UHS doubles the strength compared to a standard AA6016 alloy. Therefore a high specific resistance to denting and high specific crash performance make this alloy ideal for the replacement of press hardened steels e.g. in side impact protections or bumper beams. AMAG TopForm® UHS is an AA7075 type alloy (AlZn5,5MgCu) optimized for excellent warm forming behaviour at temperatures between 170 and 230°C.

While time consuming process steps at high temperatures like solution annealing and artificial ageing are done in the rolling mill in an efficient and controlled manner it just takes seconds in the press shop to heat up the blank to a temperature of around 200°C. Furthermore the customer benefits from the fact that there is no requirement of rapid quenching after warm forming.

A reliable and stable heat treatment process at the rolling mill provides long-term stable mechanical delivery properties in T6 temper and offers stable high level properties after press and paint shop within a robust process window. New innovative thermal joining technologies recently introduced to the automotive industry have been successfully tested for this AMAG high strength alloy. Moreover, mechanical methods and hybrid joining in conjunction with adhesive bonding extend the joining portfolio. AMAG TopForm® UHS in combination with tailored pre-treatments fully exploits the strength potential of modern automotive adhesives.