High-strength and lightweight materials in automotive manufacture

AluReport recently interviewed Dr. Peter Uggowitzer, ETH Zurich and Dr. Helmut Kaufmann, the AMAG COO, regarding the lightweight construction potential of high-strength aluminium alloys and AMAG's intention to play a supportive, pioneering role in the introduction of such sheet materials in the automotive manufacturing sector by means of extensive R&D.

In the course of the debate regarding the role of lightweight construction in the reduction of CO_2 emissions from all types of vehicles, the calls for high-strength aluminium alloys have become increasingly strident. In particular, the automotive industry would appear to be demanding an alternative to high-strength steels and CRP. What is AMAG's position?

Kaufmann: Please allow me to state first that a focus on the strength of a material with regard to its potential for lightweight construction represents a too narrow approach. As a rule, the technical demands made on a component are so complex that it is necessary to select the suitable material for the respective part in coordination with other components throughout the entire lightweight design construction. In this regard, lightweight solutions using aluminium offer excellent prerequisites, as a large number of alloys have become available that can be optimized to suit particular applications. However, to return to your question, high-strength aluminium alloys have existed for a number of years and are employed in aircraft manufacture and sporting equipment, although they have not managed to make the breakthrough into the serial production of cars. AMAG is a high-strength aluminium materials specialist and disposes over several decades of experience in this area. Indeed, the company received its first licence as an aerospace supplier as early as 1979. And now, together with partners from the automotive and automotive supply industries, AMAG intends to play a pioneering role in the introduction of these high-strength materials in vehicle manufacturing.

Dr. Kaufmann mentioned the complex range of demands to which such materials are subject. Prof. Uggowitzer, could you tell us briefly which aluminium alloys are designated as being high-strength and what characteristics must they possess?

Uggowitzer: The European Aluminium Association (EAA) has agreed that alloys with yield strength greater than 300 MPa are to be designated as "high-strength" and those with yield strength in excess of 400 MPa are to be rated as "ultra high-strength". Heat-treatable alloys from the 2xxx (Al-Cu), 6xxx (Al-Mg-Si) and 7xxx (Al-Zn) families are the only ones to surpass this limit, whereby the ultra high-strength alloys derive from among the Al-Zn-Mg-Cu alloys. These facts point to two important pieces of information. Firstly, that such alloys attain their high strength levels following "hardening" in the form of targeted heat treatment. And in fact, the selection of the heat treatment parameters can exert a precise influence on material characteristics. It should also be pointed out that increased strength generally results in a loss of ductility, or in other words, the material becomes more brittle and less amenable to forming at room temperature. In addition, it has been determined that the ultra high-strength alloys contain copper as a major element in increased strength. However, the reverse side of the coin is that this has a negative effect on the corrosion resistance of the alloys.

Let us remain with the topic of corrosion. If this is a problem, why have 2xxx and 7xxx family alloys been employed in the aerospace sector for many years?

Kaufmann: In a nutshell, because progressive, galvanic corrosion requires an electrolyte, which is present on roads wet with deicing salt, but practically non-existent in the air transport sector.

Then what can one do to make alloys containing copper suitable for use in road vehicles?

Uggowitzer: The design strategy is evident and would simply involve the waiving of the use of copper as an alloy. However, the Al-Zn-Mg alloys would then be subject to stress corrosion cracking. This is caused by the formation of base grain boundary phases and the simultaneous occurrence of so-called precipitate-free zones (PFZs) in the vicinity of the grain boundaries. This can be counteracted by the addition of a few tenths of a per cent of silver, which somewhat upgrades the grain boundary precipitation and halts the formation of PFZs with the result that susceptibility to stress corrosion cracking is significantly reduced. Unfortunately, in view of the high price of silver, in spite of its technical attractiveness, this solution is impossible for economic reasons. Therefore, another approach is required and AMAG has strengths in this area, which may well offer an answer...

What would this look like?

Kaufmann: From a current perspective, we are of the opinion that the most promising approach would involve the application of a cladding on the 7xxx sheet materials. This protective layer with a composition and thickness that precisely match the basic material would prevent corrosion attacks, while preserving the important lightweight construction characteristics of the 7xxx sheet component. AMAG has sufficient in-house, roll cladding expertise and initial tests have already shown that this solution offers great promise of success.

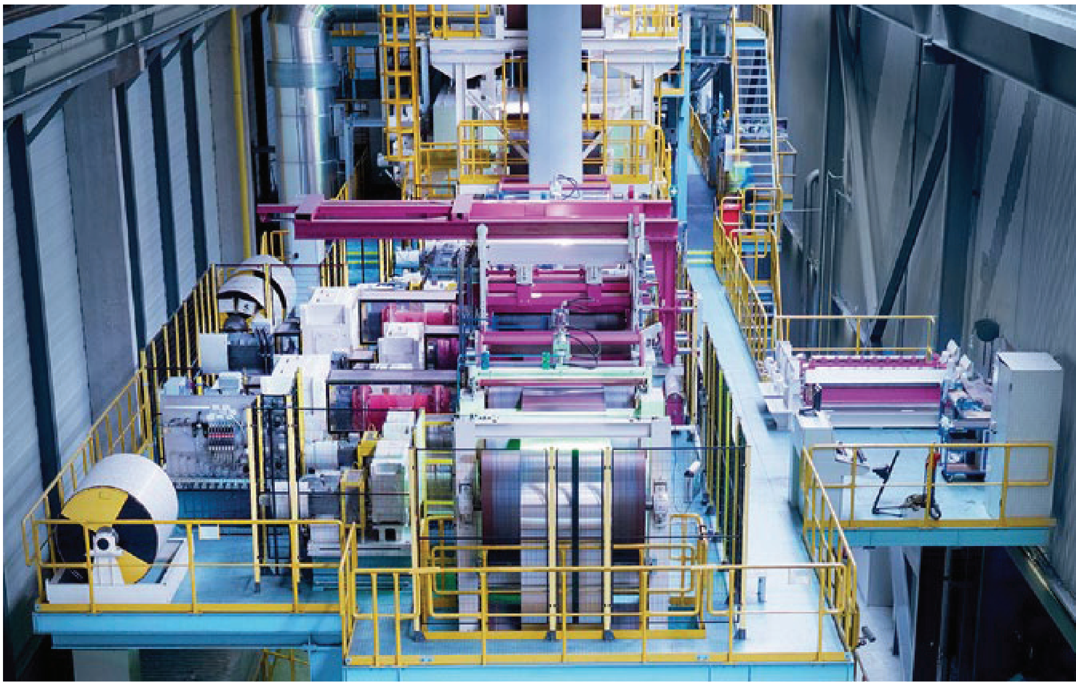
May we now address the important topic of formability. Prof. Uggowitzer, you mentioned that 7xxx alloys are more difficult to form than other aluminium alloys.

Uggowitzer: These alloys are less suitable for forming at room temperature than the 5xxx and 6xxx families usually employed in automotive production. However, there is a relatively straightforward solution, as the 7xxx family alloys already start to demonstrate excellent forming characteristics at 200°C.

Kaufmann: AMAG's solution involved the use of AMAG TopForm® UHS material in combination with warm forming. The sheet made of modified 7075 alloy is only heated briefly and then formed and cooled with the result that only a minimal decline in strength occurs in comparison to that observed with the ultra high- strength T6 temper (please see the article on page 8).

How are the university partners supporting AMAG's development work?

Uggowitzer: If at this juncture I may speak as the chairman of AMAG's advisory scientific committee and on behalf of my colleagues, I can say that this support takes two forms. Firstly, close cooperation



during research projects and secondly via the advisory committee, which scrutinizes closely both the project portfolio and related progress made. I am highly enthusiastic about the targeted nature of the projects and their progress is remarkable. I would therefore like to take this opportunity to express my admiration for the efforts of the team. One must bear in mind that in the last three years alone AMAG has provided over 50 contributions to specialist journals and conferences and I find this achievement most remarkable for an industrial company. In general, these articles and presentations relate to new cast and wrought alloys, innovative heat treatment approaches, optimized formability, high-strength multilayer sheet and new testing techniques for high-strength alloys. This demonstrates clearly AMAG's competence in the field of high-strength alloys.

Our active contribution to projects consists mainly of theoretically backed alloy and process development. However, this can well involve the further development of tools consisting of the computer programs for the simulation of microstructure development and process control in order to optimize heat treatment steps or rolling. In addition, there are the special material testing facilities of the universities, which are needed for comparisons between simulation and practice.

Kaufmann: May I add that the aforementioned computer programs also help us during our customer consulting activities. At the beginning, the fact was mentioned that materials must be selected and modified in accordance with the planned application. The composition of the alloy within a given standard tolerance, the actual forming steps and heat treatment parameters, etc. influence the characteristics of the end product and when the various interconnections are known, can be optimized in a targeted manner.

With its extremely extensive product portfolio, AMAG is generally able to offer customers a suitable solution. And it is not automatically the case that an alloy from the 7xxx is the ideal answer as a structural material in lightweight constructions. For example, AMAG has recently added a series of 6xxx alloys to its range, which as a result of special heat treatment, allows the achievement of far higher strength levels than those possessed following standard T6 treatment. These materials include the 6013 alloy, familiar from the aerospace sector, which could also well be of interest for automotive manufacture due to its list of features, especially after special heat treatment (please see the article on page 7).

Apparently, there are already concrete solutions for enhancing the forming capacity and corrosion resistance of ultra high-strength alloys from the 7xxx family, but what is the situation with regard to joining?

Kaufmann: It is a well-known fact that conventional melt welding processes do not function well for these alloys. However, excellent progress has been achieved recently with spot welding and friction stir welding (FSW) also functions perfectly. Nonetheless, in all probability, gluing will be selected frequently as the bonding method for vehicle structures. This requires suitable surface treatment and AMAG's Development Department is currently investigating the possibilities. As has been announced on several occasions, at the end of the year AMAG will be putting a modern surface passivation line into operation and naturally, the surface issue with regard to the automotive sector will also be dealt with.

High and ultra high-strength aluminium alloys should be employed in lightweight design in order to reduce vehicle emissions of CO_2. However, what is the position with regard to emissions caused during the production of the alloys?

Kaufmann: It is a well-known fact that the AMAG plant in Ranshofen is a leading recycler of aluminium. Using the very latest melting equipment, over 200,000 t of aluminium scrap are recycled annually into high-quality cast and wrought alloys. This involves only 5 per cent of the energy needed for the production of primary aluminium and therefore, emissions of CO_2 are correspondingly lower. Moreover, it is also a pleasing fact that ultra high- strength alloys can be genuinely be seen as recycling-friendly.

Uggowitzer: The optimization of the composition of high-strength aluminium alloys with regard to their suitability for recycling represents an exciting task for research in the coming years. It will demand intensive teamwork between automotive manufacturers, aluminium producers and research bodies and happily we are already on the right road! ■

Prof. Peter J. Uggowitzer

Since May 1996, Prof. Peter J. Uggowitzer has been an ad hominem professor at the Department of Material Sciences of the ETH Zurich, where he heads the laboratory for metal physics and technology. At the beginning of May 2008, Prof. Uggowitzer also became the chairman of AMAG's advisory committee on scientific and technological matters.