Recycled Cast Alloys for Automotive Structural Components

Until recently, recycled cast alloys were neglected for use in crash-relevant automotive structural components as these alloys were considered to be too brittle, particularly because of their higher contents of iron and other tramp elements. Already in the past five years, AMAG carried out several investigations of AlSi9Cu3 alloy to demonstrate that this is a prejudice and not universally applicable but rather that remarkably good elongation values can be achieved even with increased iron contents if the proper alloy composition is chosen [1–3]. Based on that knowledge, in particular of the interaction between alloying elements, it was just logical to extend the work to other alloys in the Al-Si-Mg system, focusing on the resource-saving production of modern automobiles.

Following an analysis of CO_2-emissions of automobiles in service (where lightweight construction has a favorable effect), automotive manufacturers are increasingly investigating also the carbon dioxide emissions produced during automotive manufacture, attempting to reduce these emissions according to a comprehensive approach.
AUDI AG and AMAG are jointly addressing this issue by developing recycled cast alloys for structural components, which so far have been made from primary cast alloys [4]. With respect to the mechanical properties, this fast-growing components segment especially calls for high elongation values to absorb as much energy as possible in case of a crash. To date, this demand has been met by using low-porous castings manufactured by vacuum-assisted pressure die casting processes, as well as by using mainly primary, heat-treatable aluminium alloys.

Automobiles are becoming more efficient and emit less and less CO_2 in service, so it is essential to take into account the expenditure of energy during manufacture. Ideally, emissions from an electric vehicle in service will be very low as it is powered by renewable energies, whereas more greenhouse gases are produced during its manufacture compared to a similar vehicle that is powered by an internal combustion engine [5].

Accordingly, a next logical step in automotive manufacture is to use components made from recycled material. The terms "scrap", "recycling" and "recycled material content" are defined in detail in standard EN ISO 14021:2001 [6]. AMAG calculates the scrap portions of its alloys (= recycled material content) in strict compliance with this standard.

Apart from the iron content mentioned above, recycled alloys contain other tramp elements that are bound to occur in scrap processing. Cu and Zn, as well as elements such as Bi, Cr, Ni, Sb and Sn, must be taken into account because they may have an adverse impact on the desired alloy properties. Therefore, it is essential to define the upper limits of these elements on the basis of metallurgical knowledge and joint discussion with the user in such a manner as to not lose the desired properties of the alloy and to not prevent, through unnecessary restrictions, a high scrap charge rate being applied.

It is not only the scrap portion that is defined by the quantity of admissible trace elements, but

Tolerance acc. specification and its expansions			
	acc. EN 1706	**Cu, Fe, Zn**	**Cu, Fe, Zn + Tramp elements**
Primary ingot	> 60	< 30	< 10
Alloying elements	10	10	10
Scraps	< 30	> 60	> 80

Table 1: Charge rates of ingots, alloying elements and scraps as a function of the specification. Values at defined charge (scrap availability) rounded to 5 %; as of Dezember 2012.

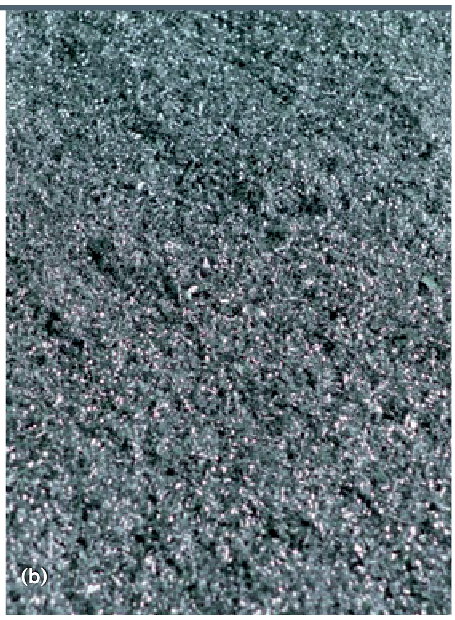


Fig. 1: Examples of scrap charge in recycled alloys: a) Clean, pressed foil and sheet packs sorted by type, with defined compositions. b) Aluminium chips contaminated by oil or emulsion from machining, partly mixed with other materials.

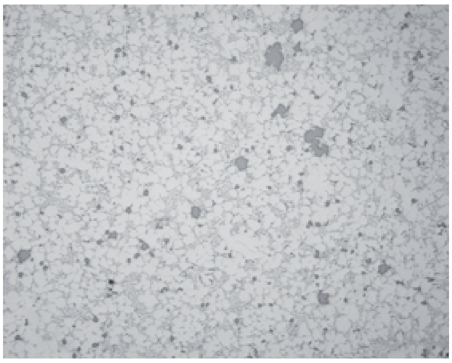
also the type of input material. Table 1 shows the possible starting material in the production of structural cast alloy EN AC-43500 according to DIN EN 1706:2010 [7], the starting material used in case of tolerance extension for iron, copper and zinc (however, with low contents of trace elements, similar to a primary alloy) and that used with a jointly defined tolerance for trace elements as a function of the elements, in a range where no adverse impact on the performance of the alloy is observed yet.

To ensure the desired scrap charge rate for a standard-production component, it is important to estimate the envisaged annual output and to define the time frame for production. These factors must be known to guarantee the type, quality, quantity and availability of the required scrap (Fig. 1).

To experimentally verify variations of alloys that were theoretically optimized by computer simulation, real recycled alloys were produced, cast into plates using a die casting machine (Bühler Evolution 120, 1200t closing force) in a series-production environment, and subsequently heat-treated.

The encouraging results of the tests promise that recycling-friendly structural cast alloys can be processed in series if appropriate process parameters are selected and the required crystalline structure is obtained. In addition to the secondary precipitates, also primary precipitates in the microstructure are to be considered because from a certain size, the latter have an adverse impact, particularly on the elongation values, for example, in the microstructure of an Al-Si-Mg alloy with different iron and manganese contents (Figs. 2a and 2b) [8].
The tests confirm that the use of recycled cast alloys with high scrap charge rates in automotive structural applications is technically feasible, but calls for sophisticated scrap logistics and scrap availability for industrially significant quantities. Even demanding body parts can be manufactured from these alloys, provided the alloy supplier, the casting expert and the designer (automotive manufacturer) closely cooperate.

Recycled alloys contribute to lightening the ecological backpack as early as at the stage of manufacturing a component, in particular with respect to greenhouse emissions [8]. However, it is clear that the challenge of huge growth in the volumes of cast and wrought alloys in automotive construction cannot be met solely by recycled alloys, but it is absolutely necessary to use primary metal. The proportion of recycled alloys in structural castings, however, can be substantially increased when this alloy development is successfully completed. ■



(a)

(b)

Fig. 2 a: Microsection of a pressure die cast plate with coarse primary Al-Fe-Mn phases.

Fig. 2 b: Microsection of a pressure die cast plate with small, finely and uniformly distributed primary Al-Fe-Mn phases. This promising alloy has an optimum Fe/Mn ratio and was cast with adjusted process parameters suitable for series production.

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