EVOLUTION OF THE INTERMETALLIC PHASES IN RECYCLED AlSi9Cu3 CAST ALLOY DURING AGE-HARDENING

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1. Introduction

Using recycled aluminium cast alloys is profitable in many aspects. Requiring only 5% of the energy to produce secondary metal as compared to primary metal and generates only 4% of the green house gas emissions, the recycling of aluminium is therefore beneficial of both environmental and economical point of view [1].

The alloys of the Al-Si-Cu system have become increasingly important in recent years, mainly in the automotive industry that uses recycled aluminium in the form of various motor mounts, pistons, cylinder heads, heat exchangers, air conditioners, transmissions housings, wheels, fenders and so on [2].

Al-Si-Cu systems usually contain a certain amount of Fe, Mn, Mg and Zn that are present either undeliberately, or they are added deliberately to provide special material properties. These elements partly go into solid solution in the matrix and partly form intermetallic particles during solidification:

- **Fe-rich intermetallic phases.** The dominant phase is plate-shaped Al3FeSi (β-needles phase). Al5FeSi needles are more unwanted, because adversely affect mechanical properties, especially ductility. The dele-terious effect of Al5FeSi can be reduced by increasing the cooling rate, superheating the molten metal, or by the addition of a suitable “neutralizer” like Mn, Co, Cr, Ni, V, Mo and Be. The most common addition has been Mn. Excess Mn may reduce Al5FeSi phase and promote formation Fe-rich phases Al5(FeMn)Si2 in form „skeleton like“ or in form „Chinese script“ [3 - 6]. If Mg is also present with Si can form script-like phase - Al5Si6Mg2Fe2.

- **Cu-rich intermetallic phases.** In Al-Si-Cu alloys was detected variously types Cu-rich phases: Al5Cu, Al-Al2Cu-Si and Al5Mg6Cu2Si6 [2, 3]. In unmodified alloys Cu is present primarily as Al5Cu or Al-Al2Cu-Si phase, in modified alloys as Al5Mg6Cu2Si6. The average size of the copper phase decreases upon Sr modification. The Al5Cu phase is often observed to precipitate both in a small blocky shape with microhardness 185 HV 0.01. Al-Al2Cu-Si phase is observed in very fine multi-phase eutectic-like deposits (Fig. 1) with microhardness 280 HV 0.01 [7].

Influence of intermetallic phases to mechanical and fatigue properties depends on size, volume and morphology this phases [3].

Present work is focused on study of the effect of age-hardening on changes in morphology of Cu- and Fe-rich intermetallic phases.

2. Experimental Results

As an experimental material was used recycled AlSi9Cu3 alloy with Al-10.75Si-2.4Cu-0.22Mn-0.9Fe-0.22Mg (wt. %). The melt was not modified or refined. Experimental cast samples were age-hardening, that consist of solution treatment by 515°C with holding time 4 hours, water quenching at 40°C and artificial aging by different temperature 130°C, 150°C, 170°C, 190°C and 210 °C with different holding time 2, 4, 8, 16 and 32 hours. After age-hardening were samples subjected for mechanical test (strength tensile, impact test and Brinell hardness). The alloy and its heat treatment presented in this work is part of a larger project and the microstructural (Si morphology, DAS, Fe-rich phases) and mechanical property details of which have already been published [7,8].

Age-hardening is most commonly heat treatment process used to obtain the optimal combination of strength and ductility in Al-Si-Cu casting. Changes in microstructure include the dissolution of precipitates, the homogenization of the cast structure, such as the minimization of
alloying element segregation, the spheroidization and coarsening of eutectic silicon and the precipitation of finer hardening phase [9]. The precipitation sequence for AlSi9Cu3 alloy is based upon the formation of Al13Cu based precipitates. The sequence is described: $\alpha_{ss} \rightarrow$ GP zones $\rightarrow \theta^\prime \rightarrow \theta$ (Al13Cu).

The phase Al13Cu solidifies in two forms: one massive or blocky (Al13Cu - Fig. 1a) and the other a fine eutectic (Al- Al13Cu –Si - Fig. 1b) formed which depends on the level of Cu, Fe and Sr in the alloy [3, 5].

After artificial aging by temperature 170 °C with holding time 16 hours is this Cu rich phase in form very small globular particles (Fig. 2b).

In AlSi9Cu3 cast alloy are observed Fe-rich intermetallic phases in two form: as platelets Al5FeSi (Fig. 3a) and a compact morphology “Chinese script” (skeleton - like phase) Al15(FeMn)3Si2 (Fig. 3b) [5]. An Al13FeSi phase during age-hardening is shortening, narrowing and dissolving into small needles. Al15(MnFe)3Si2 phase during age-hardening is fragmenting, spheroidizing and segmenting.

After age-hardening by temperature 515 °C and holding time 4 hours (solution treatment) Cu-rich phase is observed in the form coarsened globular particles and these occurs along the black needles, probably Fe-rich Al13FeSi phase (Fig. 2a).

![Fig. 1: Forms of Al13Cu phase in AlSi9Cu3 cast alloy, etch. Dix - Keller](image)

![Fig. 2: Al13Cu phase after age-hardening in AlSi9Cu3 cast alloy, etch. Dix - Keller](image)

![Fig. 3: Forms of Fe-rich phases in AlSi9Cu3 cast alloy, etch. HF](image)

3. Acknowledgements

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4. References