

The course of the peritectic transformation in the Al-rich Al-Fe-Mn-Si alloys

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Abstract : In this work an analysis of the course of the peritetic transformation $L+Al_3Fe \rightarrow \alpha-AlMnFeSi$ in Al-Fe-Mn-Si alloys containing an increasing Mn content (0-2%) has been presented. The particular steps of the solidification of the examined alloys by peritectic transformation: 1) primary phase precipitation from liquid alloy: $L \rightarrow L_1+Al_3Fe$, 2) peritectic reaction: $L+Al_3Fe \rightarrow \alpha-AlMnFeSi$, 3) peritectic transformation: $Al_3Fe \rightarrow \alpha-AlMnFeSi \leftarrow L_1$, 4) nucleation and growth of the equilibrium phase in liquid: $L \rightarrow L_2 + \alpha-AlMnFeSi$, have been identified and described. The distribution of the transition metals Fe and Mn in the intermetallic phases has been estimated by means of the EDS microanalysis. Composition gradient in the secondary $\alpha-AlMnFeSi$ phase was analysed as a result of the local transport of the alloy components during the precipitation sequence. It was stated that Mn atoms involved mechanism of the analysed peritetic transformation. The formulated equation $\Delta x_{\alpha}^2 / t = K(Mn, \Delta Mn)$ for isothermal conditions of the analysed transformation has represented a good agreement to the experimental data in the range of the low Mn content ($Mn \leq 1\%$).

Keywords: Peritectic transformation; Al alloys; Intermetallic phase; Fe; Mn

1. INTRODUCTION

The cubic $\alpha-AlFeMnSi$ phase in the cast Al-Si alloys ($Si > 5\%$), can arise as a product of the direct precipitation from the liquid alloys in form of either pre-dendrite or pre-eutectic precipitates [1-3]:



In alloys of lower Si content, as 3xxx or 6xxx series, the phase $\alpha-AlMnFeSi$ has been a product of the peritectic transformations [4-8]:



The rate of peritectic transformation and its ability to go to completion depend on form of the equilibrium diagram and kinetic factors [9-10]. The small gaps between the primary and secondary phases and between the secondary phase and liquid have promoted the tendency of

the transformation to be finished. The composition gradient inside the secondary phase envelope was also regarded as a factor favouring the transformation progress [9,10].

The general formula describing kinetics of peritectic transformation under isothermal conditions can be expressed according to a power relationship [10]:

$$\Delta x_\alpha = t^n \text{ K} \quad (4)$$

where: Δx_α - thickness of the secondary phase layer, t - time of the process, n - empirical constant, for binary systems equal 0.35-0.57, K - constant depending on alloy composition, diffusivity of components and processes at interfaces.

In the present work an analysis of the effect of the Mn content as one of the factors affecting course of peritectic transformation: $L + Al_3Fe \rightarrow \alpha-AlMnFeSi$ in Al-Fe-Mn-Si alloys during continuous cooling and under isothermal conditions will be carried out.

2. MATERIAL FOR EXAMINATIONS AND EXPERIMENTAL

The examined alloys were produced from pure components and melted in the induction furnace (under Ar protective atmosphere) and poured into graphite moulds. Chemical composition of the examined alloys was: F1-3.2Si, 0.03Mn, 11.25Fe, F2-2.7Si, 0.28Mn, 11.10Fe, F3-3.5Si, 1.28Mn, 10.48 Fe, F4-3.0Si, 2.07Mn, 11.10 Fe (wt%, Al.-bal.) Specimens of the alloys were heated till 900°C and then annealed at temperature just below of that established previously for the peritectic transformation [8] by 30, 120 and 240 min. The microstructure of the alloys was examined on the metallographic microsections polished and chemically etched with a reagent: 1mlHF+100mlH₂O dist. The microscopic observations were carried out by means of the LM Neophot 32. Chemical composition of the phase components present in the alloys was estimated by means of the X-ray microanalyser EDS, LINK ISIS 300, combined with the SEM STEREOSCAN 420, using the standardless method.

3. RESULTS OF EXAMINATIONS AND DISCUSSION

3.1. Microscopic observations

The microstructure of the examined alloys is shown in Figure 1 a-b. It is visible that an increase in the Mn content in the examined alloy has resulted in the change of morphology of the $\alpha-AlMnFeSi$ phase particles.

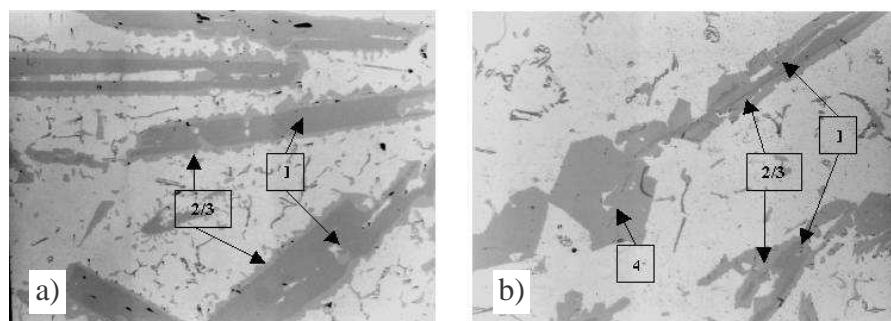


Figure 1. Microstructure of the examined alloy, microsections etched with 1%HF, LM; a) F3 alloy, 200x, b) F4 alloy, 200x.

In the alloys containing only a small addition of Mn (F1, F2, F3) three processes:

{1} $L \rightarrow L_1 + Al_3Fe$ (Fig.1a-b) and {2,3} $L_1 + Al_3Fe \rightarrow \alpha-AlMnFeSi$ (Fig.1a-b) have occurred.

Successive addition of Mn has led, after an envelope of the secondary phase was formed, to start of the nucleation and successive growth of the faceted particles at interface $L_2 / \alpha-AlMnFeSi$. In the F4 alloy, containing 2% Mn, the new particles of the $\alpha-AlMnFeSi$ phase have nucleated and then have grown directly in the liquid without any contact with primary $Al_3Fe(Mn)$ phase (Fig. 1b, process 4th).

3.2. Results of the EDS microanalysis

Difference in the distribution of transition metals expressed as value of Fe/Mn ratio in both primary and secondary phases due to Mn contents was present in Table 1.

Table 1.

Distribution of the transition metals in the phases: primary Al_3Fe and secondary $\alpha-AlFeMnSi$

| Alloy designation | Fe/Mn | | Δc_{α}^{Mn} |
|-------------------|------------------|-----------------------------|--------------------------|
| | primary Al_3Fe | secondary $\alpha-AlFeMnSi$ | |
| F1 | - | - | - |
| F2 | 85 | 33 | 0.28 |
| F3 | 9 | 2 | 0.6 |
| F4 | 4 | 1 | 3.7 |

One can see that with an increase in the Mn content (in a range 0-2%), the tendency to replace Fe with Mn in the crystal lattice of the secondary $\alpha-AlFeMnSi$ phase has augmented (from 3% to 50% of all positions occupied by atoms of transition metals, respectively). However, the atoms of Mn were also systematically built in the crystal lattice of the primary Al_3Fe phase (from 1% to 25%). In the alloys of the low Mn content (< 2%wt), the Mn concentration augmented in the layers precipitated in succession as the solidification process advanced. In the alloy of the higher Mn content (>2%) in the successive layers of the $\alpha-AlFeMnSi$ phase formed peritectically smaller and smaller concentration of this element was registered (Fig.4). The shape of the Mn composition gradient could be recognized to be a result of a competition of two processes: classical peritectic mechanisms ($L + Al_3Fe \rightarrow \alpha-AlMnFeSi$ $Al_3Fe \rightarrow \alpha-AlMnFeSi \leftarrow L_2$) and an individual nucleation and growth of the equilibrium $\alpha-AlMnFeSi$ phase.

3.3. Analysis of the peritectic transformation course during isothermal annealing

The general kinetic formula for isothermal conditions has been adapted for the experiment carried out in this work in form of equation (5):

$$\Delta x_{\alpha}^m / t = K (Mn, \Delta Mn) \quad (5)$$

where: Δx_{α} - increase in the thickness of secondary phase, t - annealing time below transformation temperature, m - constant estimated empirically, , Mn - %Mn in alloy, ΔMn - difference in Mn concentration in centre of primary phase and at $\alpha-AlMnFeSi/\alpha-Al$ interface.

The value of K calculated was used to estimate the value of Δx_{α} depending on the annealing time and Mn content in the alloy (Figs.2 a,b). Comparison of the measured value Δx and that calculated has given rather good consistence in the range of the low Mn concentrations at the short time of annealing when the short range diffusion has determined the solid phase formation.

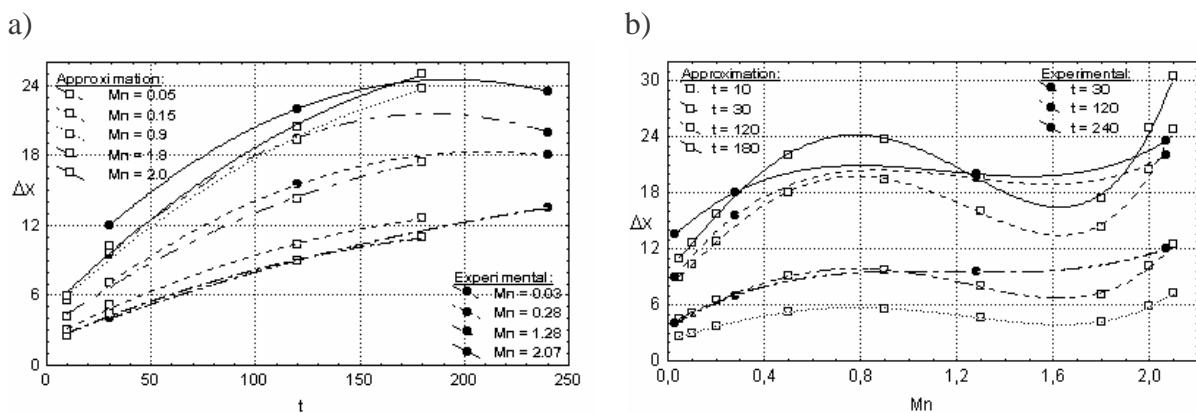


Figure 2. The increase in thickness of the peritectic phase α -AlFeMnSi, a/ Δx_α vs isothermal annealing time t ; b/ Δx_α vs Mn content in alloy.

4. SUMMARY CONCLUSIONS

- Secondary phase α -AlMnFeSi in the examined Al.-Fe-Mn-Si alloys can form by the peritectic solidification in the sequence of the separate and distinct processes:
- In the layer of the secondary phase α -AlMnFeSi a concentration gradient of the Fe, Mn and Si was noticed as affected by the local transport of component during solidification course. The change of the Mn distribution can be considered to be a result of the activation of the individual growth of the secondary phase particles.
- It was stated that Mn atoms involved course of the analysed peritetic transformation. The formulated equation: $\Delta x_\alpha^2 / t = K(Mn, \Delta Mn)$ has represented a good agreement to the experimental data in a range of low Mn content ($Mn \leq 1\%$) for the isothermal conditions.

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