Proceedings of the 12th International Conference on
Aluminium Alloys, September 5-9, 2010, Yokohama, Japan

pp. 290-295

Effects of Trace Elements in Al-Fe-alloys on Microstructure and Properties of Rolled Products

Dr. Jochen Hasenclever
Hydro Aluminium Deutschland GmbH , Research and Development Bonn,
Post-Box 2468, D - 53014 Bonn / Germany

The role of trace elements, such as gallium, nickel, vanadium or zinc, in the production process of rolled material was the focus of this investigation.
In lab scale trials Al-Fe-alloys on a pure basis were cast to rolling ingots. Different trace elements and two levels of contents (low / high) were added to the basis alloy Al-Fe 0.35% and processed to rolled material. The influence of trace elements was investigated at final thickness 0.3 mm.
The microstructure feature “constituent particle” is nearly unaffected by trace element additions. Other features, such as solute level or grain size after an O-temper annealing, were strongly influenced by trace elements. The elements vanadium and gallium have a negative influence on the resulting grain size.
The thermal stability of the rolled material is strongly influenced by the trace element vanadium. The thermal stability is increased by the addition of V.
The investigation demonstrates the importance of looking at trace elements in the process chain. The effects depend on processing and quality requirement for the rolled product.

Keywords: AlFe-alloys, recovery, recrystallisation, grain structure, mechanical properties

1. Introduction

It is well known that trace elements may have a strong influence on the microstructure, the recovery and the recrystallisation behaviour of deformed aluminium. [1 – 5]
The role of trace elements, such as gallium, nickel, vanadium or zinc, in the production process of rolled material was the focus of this investigation.

2. Experimental

In lab scale trials Al-Fe-alloys on a pure basis were cast to rolling ingots. The chemical composition of the alloys investigated is given in figure 1. Different trace elements and two levels of contents (low / high) were added to the basis alloy Al-Fe 0.35%. In all alloys the content of other elements was constant and at low level (=basis pure Al) .
The material was produced according to the practice given in figure 2. Starting with a pre-heat treatment, the rolling ingots were hot rolled to 4.5 mm and then cold rolled (without / with inter-mediate annealing) to the final thickness of 0.3 mm.

Composition in wt.%

Si	Fe	Cu	Mn	Mg	Cr	Ti
0.1	0.35	< 0.004	< 0.007	< 0.003	< 0.006	< 0.01
	variants of trace elements					
alloy	**Element**	**content in ppm**				
1_A	Zn, low	20				
1_B	*Zn, high*	*320*				
2_A	Ni, low	25				
2_B	*Ni, high*	*150*				
3_A	V, low	50				
3_B	*V, high*	*370*				
4_A	Ga, low	70				
4_B	*Ga, high*	*230*				

Fig. 1: Composition of Alloys

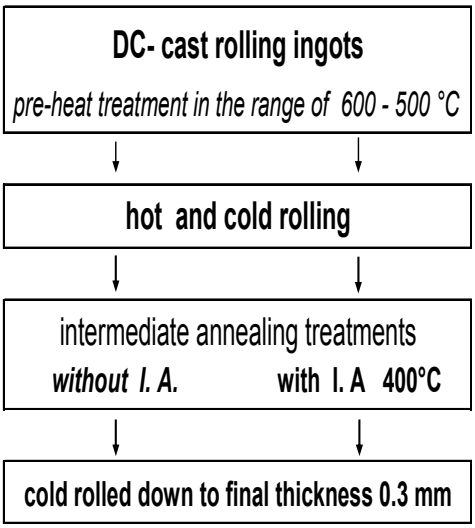


Fig.2: Experimental procedures

At final thickness the strength was determined in the as-rolled condition and after annealing 280°C/ 10 min. by tensile tests. The recrystallisation behaviour and the resulting grain structure after an O-temper annealing at 350°C was checked by light microscopy. Information about the dissolved iron content was obtained by measuring the electrical resistivity at 4.2 K. The content of iron in solid solution was calculated from the resistivity using the factor 3.20 µohmcm/ wt.% Fe.

3. Results

Microstructure

The influence of the trace elements on the constituent particles was investigated by image analysis of light microscope sections. The results revealed that the area of the particles is not affected by the addition of higher contents of trace elements. The number of particles (figure 3) shows only a small change by higher trace element content. The most prominent effect is found for the trace element vanadium.
On the other hand it seems that the trace element gallium, regardless of the amount, has the tendency to generate a lower number of particles in the as-cast structure.

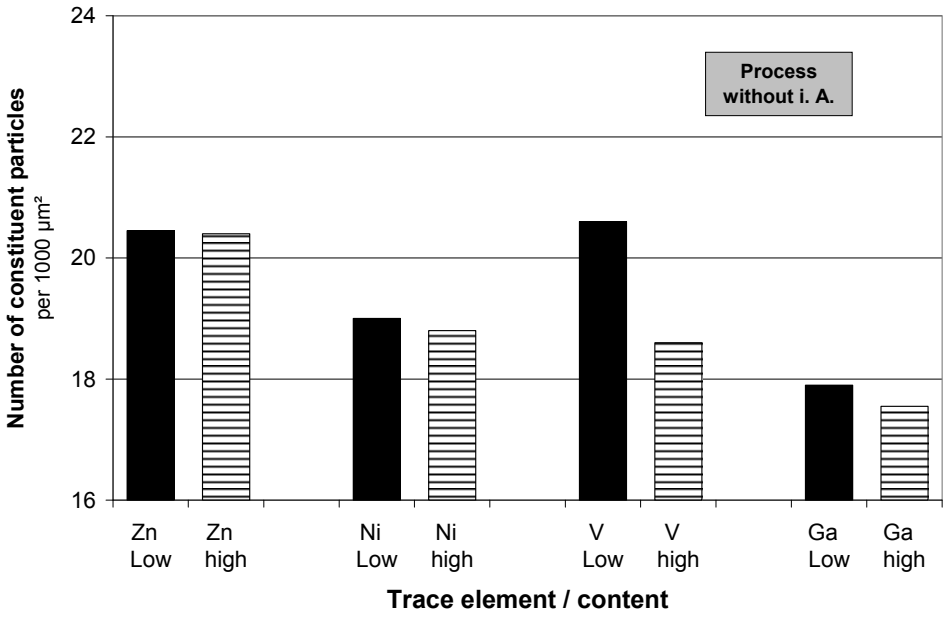


Fig.3: Influence of trace elements on the number of constituent particles

The addition of trace elements on the solute level at final thickness in the as-rolled condition was checked by electrical resistivity measurements at 4.2 K. The content of iron in solid solution was calculated from the resistivity values (figure 4).

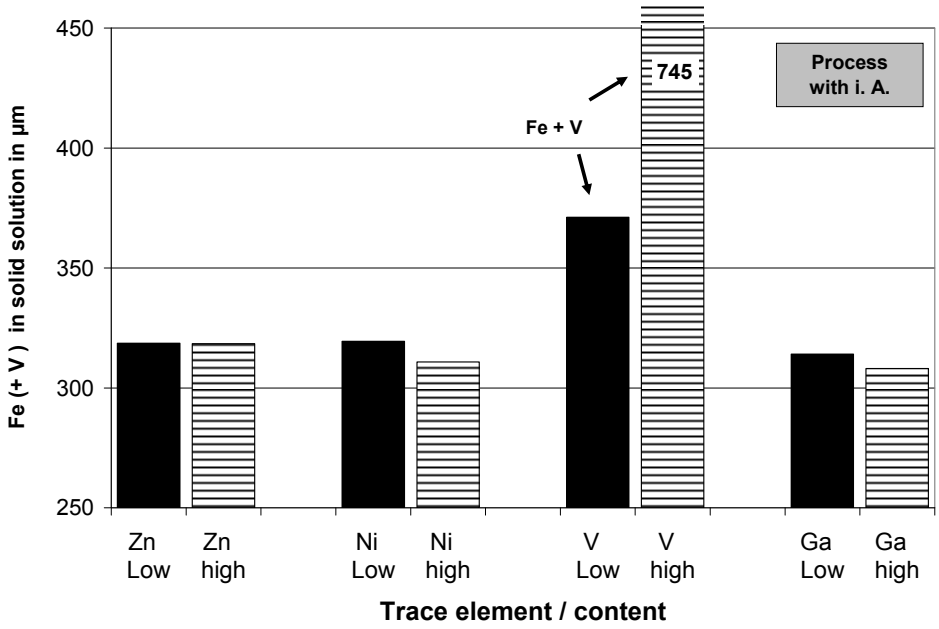


Fig.4: Influence of trace elements on solute level Fe (V)

It is known that the element vanadium has a large influence on the electrical resistivity [6]. The calculated values of Fe in solid solution therefore were strong affected by vanadium additions.

The solute level of Fe (+ V) is largely increased by higher amounts of vanadium.
The other trace elements show no significant deviations of the solute level of iron.
The influence of the trace elements on the recrystallisation behaviour and the resulting grain structure was checked by grain size measurements (figure 5) after an O-temper annealing (350°C). Surface sections of final thickness were prepared and analysed by image analysis of light microscopy.

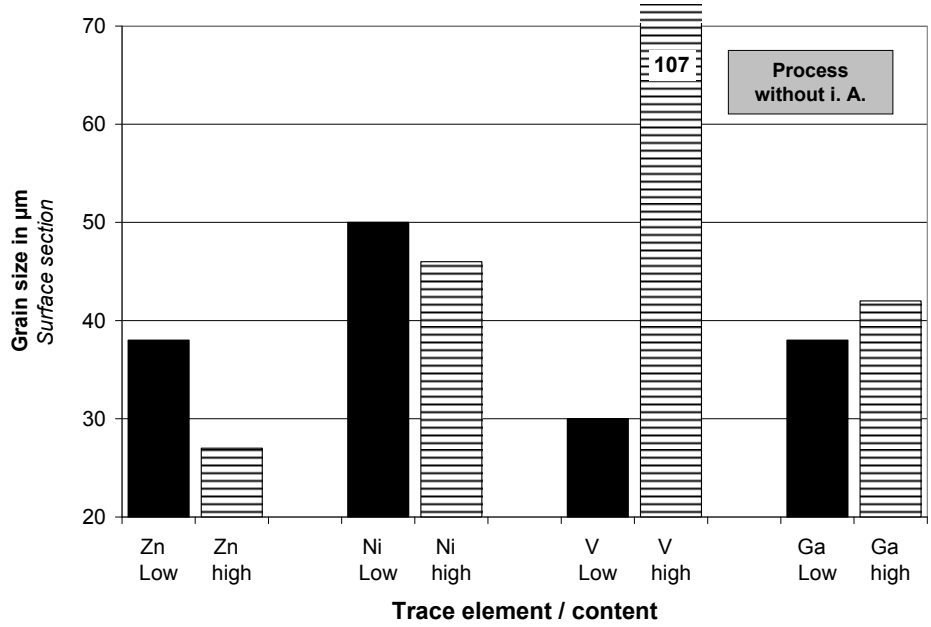


Fig.5: Influence of trace elements on grain size (process without I.A.)

The addition of higher contents of Zn or Ni is helpful in minimizing the grain size. A higher level of gallium promotes a slight increase of the grain structure. The addition of a higher vanadium content results in a very coarse grain.

Strength and thermal stability

At final thickness the strength was determined in the as-rolled condition and after annealing 280°C/ 10 min. by tensile tests.
The strength behaviour (Rp) in the as-rolled condition is illustrated in figure 6. The findings show that the strength is only slightly affected by additions of trace elements. A somewhat larger contribution reveals the vanadium addition and the strength value increased by a higher V-content.

The thermal stability of the test material is checked after annealing for 280°C/ 10 min. The figure 7 shows the results for the process without and with intermediate annealing.

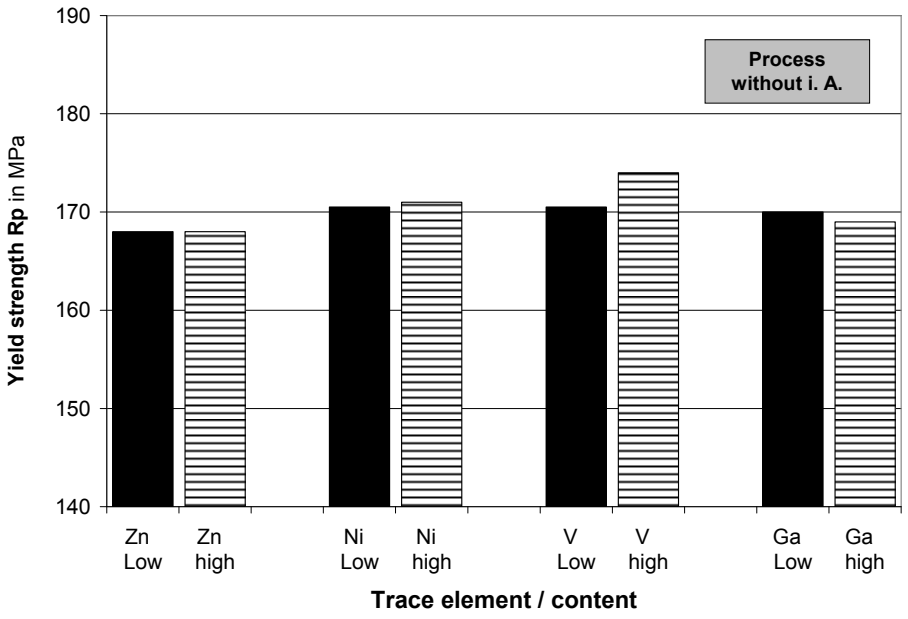
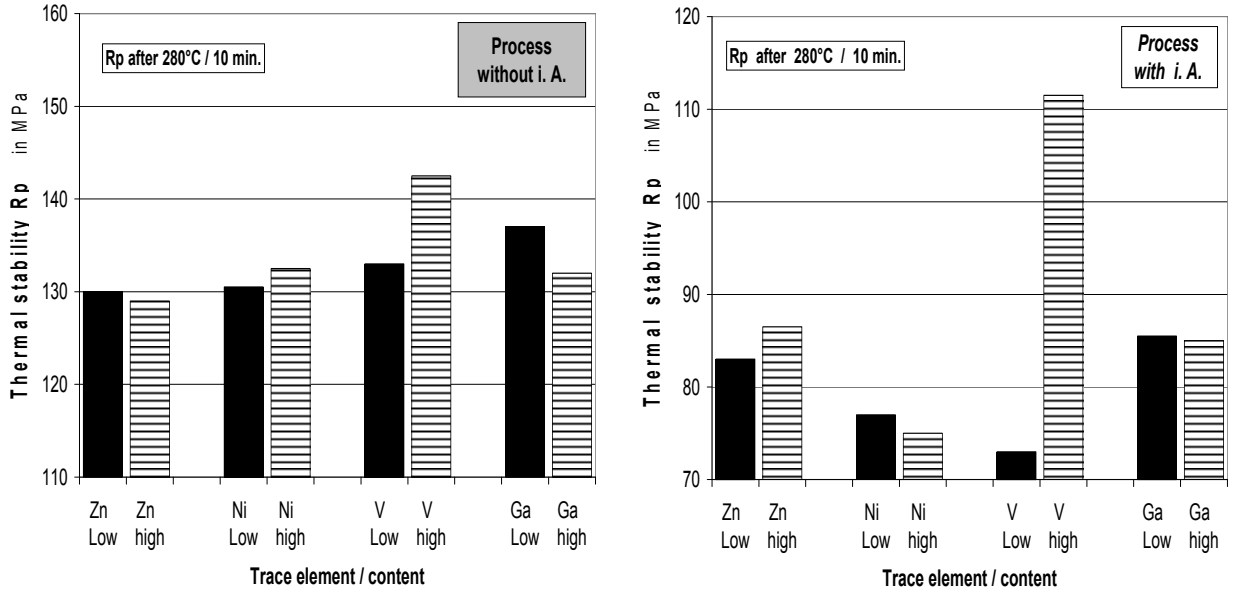


Fig.6: Influence of trace elements on the strength Rp (process without I.A.)



a) Process without I.A. b) Process with I.A.

Fig.7: Influence of trace elements on the thermal stability Rp

The process step intermediate annealing has a large influence on the strength level. The strength values after processing without intermediate annealing are clearly higher than in the case of

processing with intermediate annealing. In the series without I.A. the variations due to trace elements is less pronounced than in the series with I.A. In both process routes the most prominent effect is found for the trace element vanadium. A higher content of V results in higher values for the thermal stability.

4. Discussion and conclusions

The addition of trace elements to a basis Al-Fe 0.35% -alloy reveals only slight effects on the cast microstructure. The particle size, an important factor for foil rolling, is unchanged.
The recovery and recrystallisation behaviour is clearly more influenced by trace elements. Especially noteworthy in this regard is the element vanadium, which is in solid solution in the as-rolled material. During thermal treatment, the vanadium can start to dissolve out of the solid state and the precipitates leads to optimum dislocation pinning and results in a high thermal stability [5]. On the other hand, if the precipitation of vanadium interacts with the occurrence of recrystallisation [7], the resulting grain structure shows coarse grain.
An important process step is the intermediate annealing treatment. The solute level is affected by the process routing without / with intermediate annealing and therefore the thermal stability show a large influence by the process step intermediate annealing.
The investigation demonstrates the importance of looking at trace elements in the process chain. The effects depend on processing and quality requirement for the rolled product.

References:

[1] J.F. Grandfield, J.A. Taylor : Light Metals 2009, TMS (2009) p. 1007
[2] Ch. J. Simensen : International Seminar on Refining and Alloying, Aug.1985 (1985) p. 165
[3] A.H. Maitland, D. Rodriguez : 8. Int. Leichtmetalltagung Leoben (1987) , p. 423
[4] H. Kimura, O. Nakano : Journal of Japan Institute of Light Metals 20 (1970) p. 481
[5] B. Grzemba, J. Hasenclever, G. Scharf : Aluminium 65 (1989) p. 175
[6] W. Hufnagel, al. : Aluminium-Taschenbuch 14 (1983) p. 104
[7] E. Hornbogen : Zeitschrift Metall 27 (1973) p. 780