Essential Readings in Light Metals: Cast Shop for Aluminum Production.
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INFLUENCE OF HOMOGENIZING ON THE PROPERTIES OF CAST ALUMINIUM PRODUCTS

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1. Introduction

Annealing treatments are of the same importance in aluminium processing as casting, extruding or rolling. Numerous properties are influenced and optimized by annealing processes. The first annealing treatment given to aluminium, is the so-called "homogenizing" in most cases. It must be made quite clear from the beginning that the designation "homogenizing" is not absolutely correct, since in many cases not the homogeneous, but the heterogeneous structure obtained by annealing with segregations has the better properties. For the sake of simplicity, however, the term "homogenizing" will be maintained. Furthermore, in the modern way of looking at things, no longer annealing to a predetermined temperature level is to be assessed on its own but the full annealing cycle consisting of heating - annealing - cooling and reheating to the temperature by hot forming of the primary metal. That this is necessary has been proved in recent examinations of the influence of small additions of manganese in AlMgSi alloys on the heat formability (1).

2. Possibilities for Describing the Homogenized Condition

A description of the quality of homogenizing by means of measurable and comparable criteria is of particular importance. Detailed studies in this direction have unfortunately shown that it is not possible to describe the homogenized condition clearly and adequately with a sole characteristic figure and/or sample. About a dozen possibilities were tested, of which the following have proved useful:

a) assessment of microscopic section in a range of up to a 500 fold enlargement. In this way conclusions can be drawn about the kind and size of intermetallic phases and about their distribution. In Fig. 1 the influence of manganese additions in AA 6063 is shown on the heterogeneous distribution (1).

b) electron microscopic examinations for example indicate the arising of sub-microscopic segregations or nucleus formation procedures (see Fig. 2 with very fine needle-shaped Mg_2Si segregations) (1).

Neither the light microscopic nor the electron microscopic structural assessment let direct conclusions be drawn as to the formability, since the segregation pattern, the secondary segregations during reheating and for example influences of the cell structure cannot be recorded.

c) microprobe analyses give a picture of the element distribution and the equalizing effect of a homogenization annealing as shown in Fig. 3 for extrusion billets in alloy AA 6063. Very good indications as to the quality of the homogenizing treatment are obtained from such concentration sections, but such analyses are not suitable as a routine method for assessing the billet production of a casthouse over a longer period of time.

d) measurements of the electrical conductivity are easily carried out in operation. Rough indications can also be obtained as to the characterization of the cooling intensity. However, this method is also not suitable as a testing method for routine checks in operation since only one step in the annealing cycle is recorded. Furthermore, mostly the permissible analysis fluctuations of an alloy type mean a more marked change in the electrical conductivity (1) than is influenced by the different cooling rate (Fig. 4).

e) homogeneity/heterogeneity depending on the cooling rate from homogenizing temperature, different quantities of Mg and Si remain in solid solution in the AlMgSi alloys from virtually 100 % dissolved up to 100 % heterogeneous segregated as Mg_2Si. This condition can be characterized by simply measuring the Brinell hardness. The "degree of homogeneity" can be determined as follows:

$$HO = \frac{HB_x - HB_{20}}{HB_w - HB_{20}} \cdot 100 \ [\%]$$

HO = homogeneity in %
HB_x = Brinell hardness (5/125) after a random cooling from full annealing temperature and age hardening (48h/20°C and 7h/175°C).
HB_w = Brinell hardness after water quenching and age hardening
HB_{20} = Brinell hardness after cooling with τ= 20h and age hardening (48h/20°C and 7h/175°C).

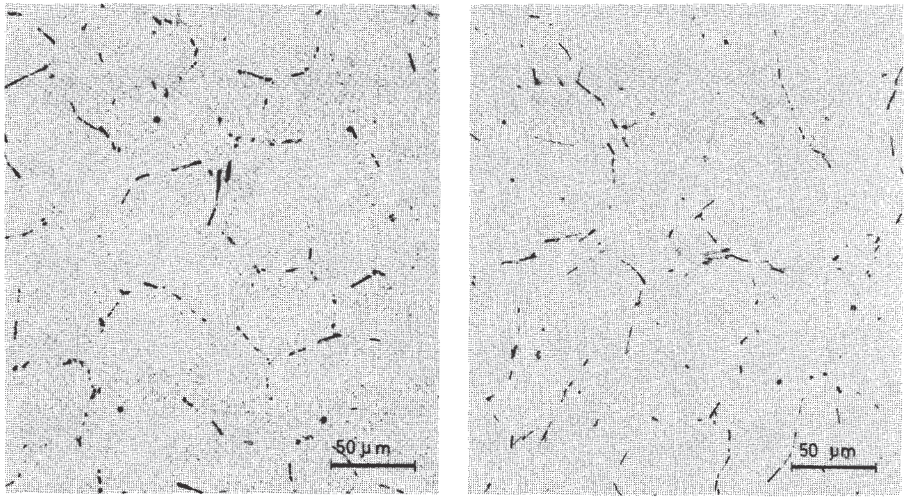


Fig. 1 Influence of small additions of manganese on the structure of AA 6063 billets after homogenizing at 580 °C/for 3 hours/water quenching
on the left : with~0.1 % Mn
on the right: < 0.01 % Mn

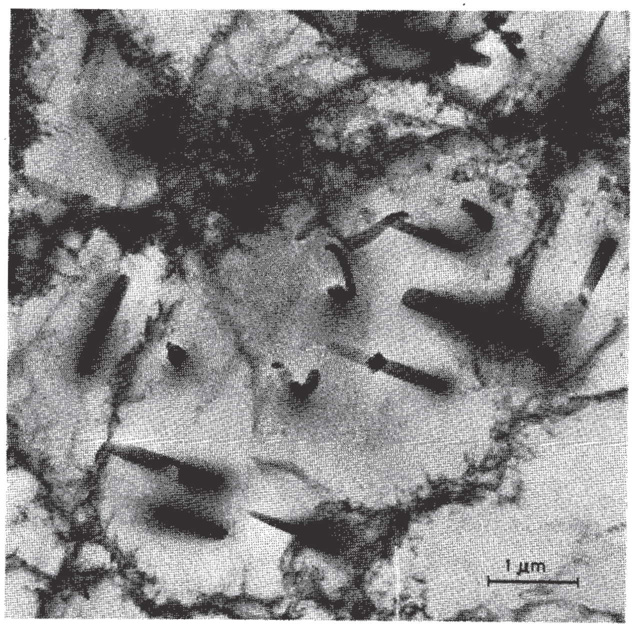


Fig. 2 Nucleus formation of Mg_2Si needles in AA 6063 with small manganese addition with forced cooling after homogenizing (electron microscopic photo).

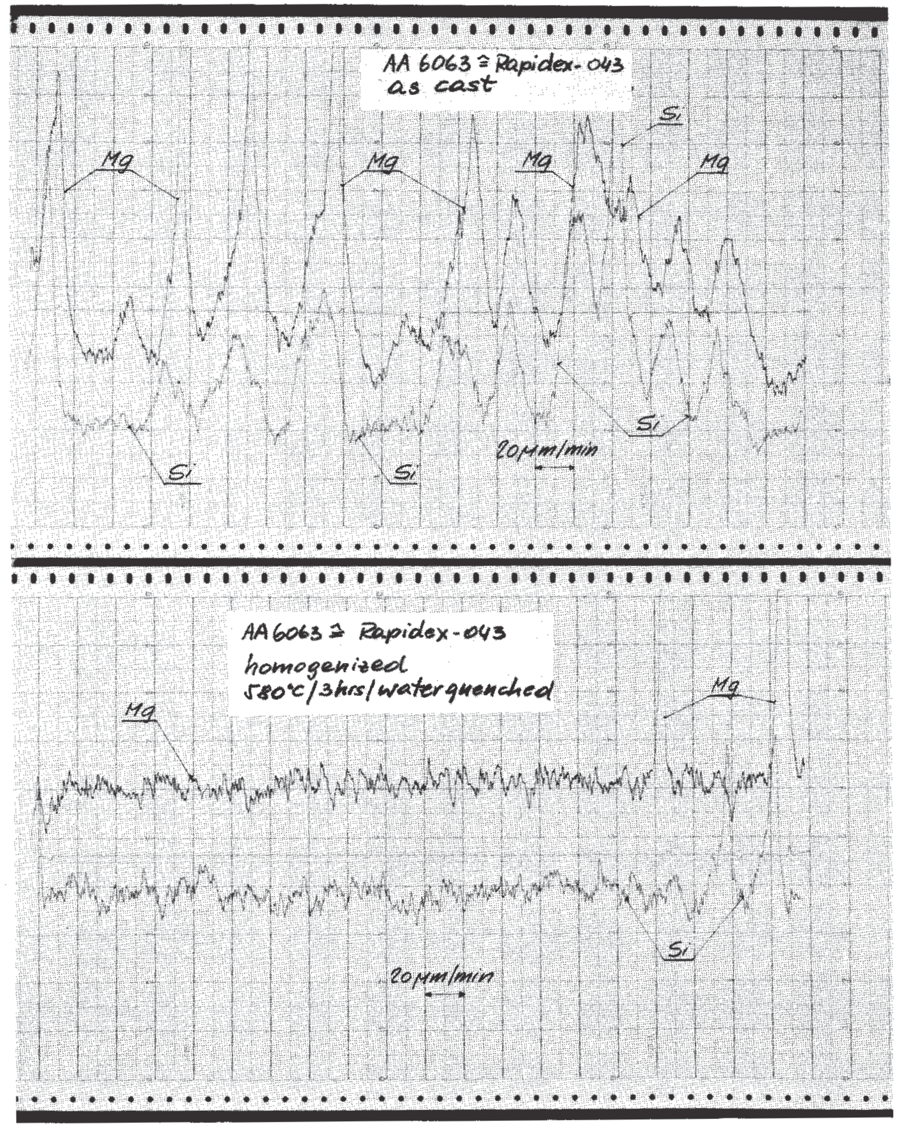


Fig. 3 Concentration profiles for Mg and Si, determined by microprobe on samples of AA 6063 in cast condition (top) and after homogenizing (bottom).

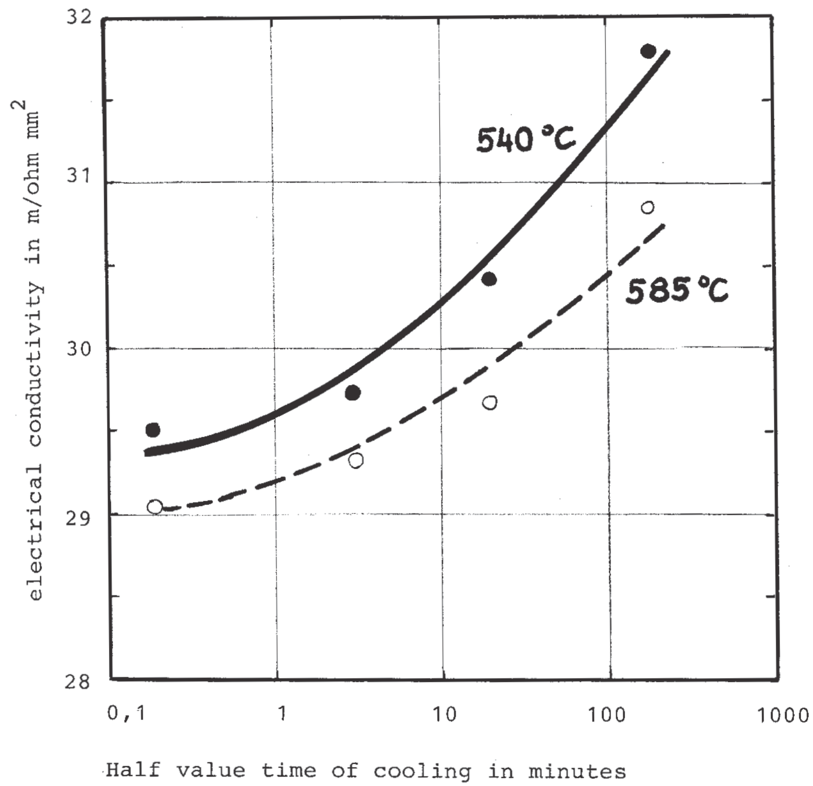


Fig. 4 Change in the electrical conductivity of AlMgSi 0.5 extrusion billets in dependence on the homogenizing temperature and on the rate (half value time) of cooling of annealing temperature

The "degree of heterogeneity" is accordingly

HE = 100 - HO (%)

These characteristic figures make it possible above all to assess the current production as regards consistency of quality but only as regards the evenness of the co ling of the billets.

Each of the five criteria introduced here can describe a partial aspect of homogenizing. Practical experience shows, however, that only the combined application of these tests, partially with the help of guide photo homogenized condition.

3. Examples of Pratical Effects of Different Homogenizing Treatment

In the following, three examples are introduced, which represent a large number of pertinent examinations. In each case different measures have been taken to solve the problems in question.

3.1 Influence of Homogenizing on the Extrusion Properties of AlMgSi 0.5 Billets

Due to the considerable progress in the construction of dies for extruding, in many extrusion plants more and more, the tendency of an alloy to edge cracks is the factor with the most effect on profitability. This tendency to edge cracks is a result of the rise in temperature during the forming procedure in the extrusion tool and depends on the yield stress of the alloy. By reducing the content of the alloy elements Mg and Si, the yield stress can be kept lower (3) but because of the necessary strength level of the sections and also for operational reasons such as for example limited intermediate storage times between extruding and age hardening, further limits are set (4). The yield stress is, however, also dependent on the cooling speed after annealing or on the content of dissolved Mg and Si in the structure. According to R. Akeret (5), the following differences are ascertained between water quenching and slow cooling in the furnace in the case of quenching. AlMgSi 0.5 billets (example for 0.53 % Si, 0.50 % Mg and 0.22 % Fe for a deformation speed of 0.66 s^{-1}:

	Yield Stress	
Forming Temp.	HO*) = 95%	HO = 5%
350 °C	76 N/mm^2	40 N/mm^2
400 °C	52 N/mm^2	32 N/mm^2
450 °C	38 N/mm^2	27 N/mm^2
500 °C	27 N/mm^2	24 N/mm^2
550 °C	22 N/mm^2	22 N/mm^2

*) HO according to definition in chapter 2, paragraph e).

In Fig. 5 the result of a test series with AlMgSi 0.5 billets with different HO degrees is shown. The sections were extruded so quickly in each case that just no edge defects occurred. The positive effect of the low yield stress in 65 and 45 % homogeneity is clear and results in a significantly higher productivity of the extrusion press.

It is mentioned furthermore that changes in the homogenizing temperatures and the duration of homogenizing in the problem described here is not a solution or a noticeable improvement.

3.2 Optimation of the Structure of AlCu Alloy Billets for Large Forgings

Homogeneization treatment has an even great significance in the case of copper containing alloys than in the AlMgSi system, since the intermetallic phases in the cast condition are very difficult to dissolve and the micro segregations arising in the area of the grain boundaries are still considerably more marked. It was ascertained for example that the concentration balance in the α-phase in the case of an Al-alloy with 4,5 % Cu only takes place completed after 24 hours of annealing at 520 °C (6). Also the influences of the cell size, the structural formation and above all of other alloying elements are known in AlCu alloys. Lymber et al (7) describe an influence of the homogeneization treatment on the tendency to form coarse grains in heat shaping of AlCuSiMn alloys and Fuchs and Roosz (8) theoretical formula for calculating the dissolution kinetics of copper-containing intermetallic phases.

In practical operation, however, it has been found again and again that it is necessary to adapt the heat treatment to the specific forming requirements of complicated large forgings. In the example described here a large wheel wrench of almost 1000 mm diameter had to be forged from only 290 mm thick blanks of alloy AA 2014 for forging-specific reasons, which in the case of such large spreading means a very high tensile strength and risk of cracks on the circumference of the forging. While in the case of only homogenizing (e.g. Fig. 6a: 480 °C/7 hours + 495 °C/10 hours/air cooling) the grain boundaries still show segregations that led to cracks, an annealing treatment with a prolonged homogeneization (480 °C/3 hours + 500 °C/30 hours) with subsequent heterogeneization at 350 °C for 6 hours (Fig. 6b) resulted in a perfectly forgeable metal. In a similar manner the influence of the heat treatment was proved in laboratory tests with hot punch tensile tests samples. In particular the reduction of area of such samples reacts to different thermal preliminary treatments.

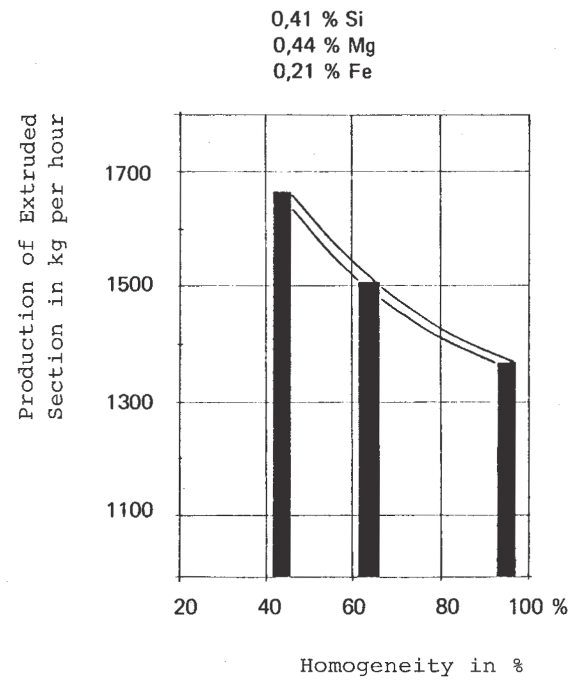
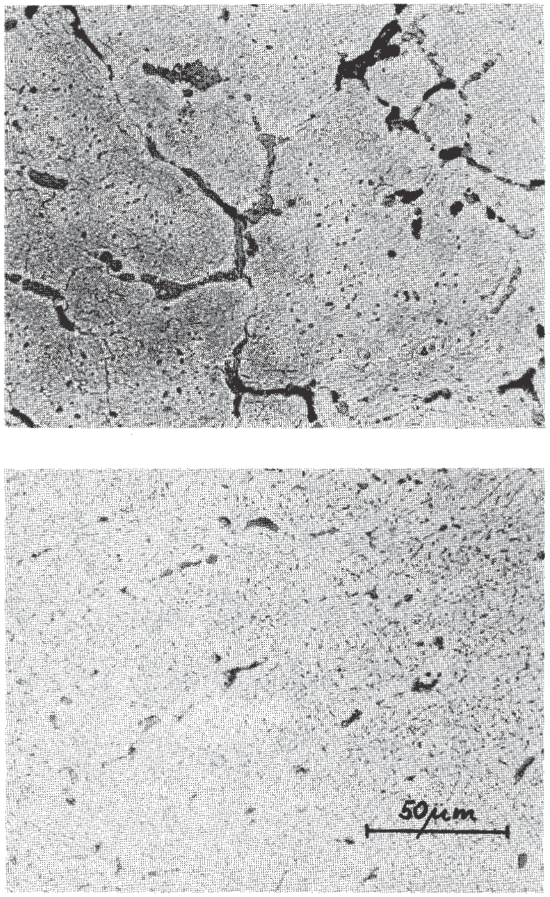


Fig. 5 Dependence of the productivity of an extrusion press on the structural condition of AlMgSi 0.5 billets (criterion of speed limit is the formation of edge cracks)



a)

b)

Fig. 6 Structure of AlCuMgSi billets according to different homogenizing

a) 480 °C/7 hours + 495 °C/10 hours/air cooling

b) 480 °C/3 hours + 500 °C/30 hours + 350 °C/6 hours/air cooling

3.3 Thin-walled Tubes made from AlMn Alloys for Automobile Radiators

The problem that was to be solved was that thin-walled, indirectly extruded tubes can to be brought to a narrowly tolerated strength level in soft annealing. The decline in strength in the temperature range of 300 °C had to take place not steeply but as flatly as possible over a wider temperature range. The question had to be answered whether, by varying the annealing treatment and with that the structural condition, this can be made possible.

First of all casting charges are divided and half of the billets subjected to a different heat treatment, in order to exclude an influence of the chemical composition. The figures 7a and b show, for the material AA 3103, the two extreme structural conditions

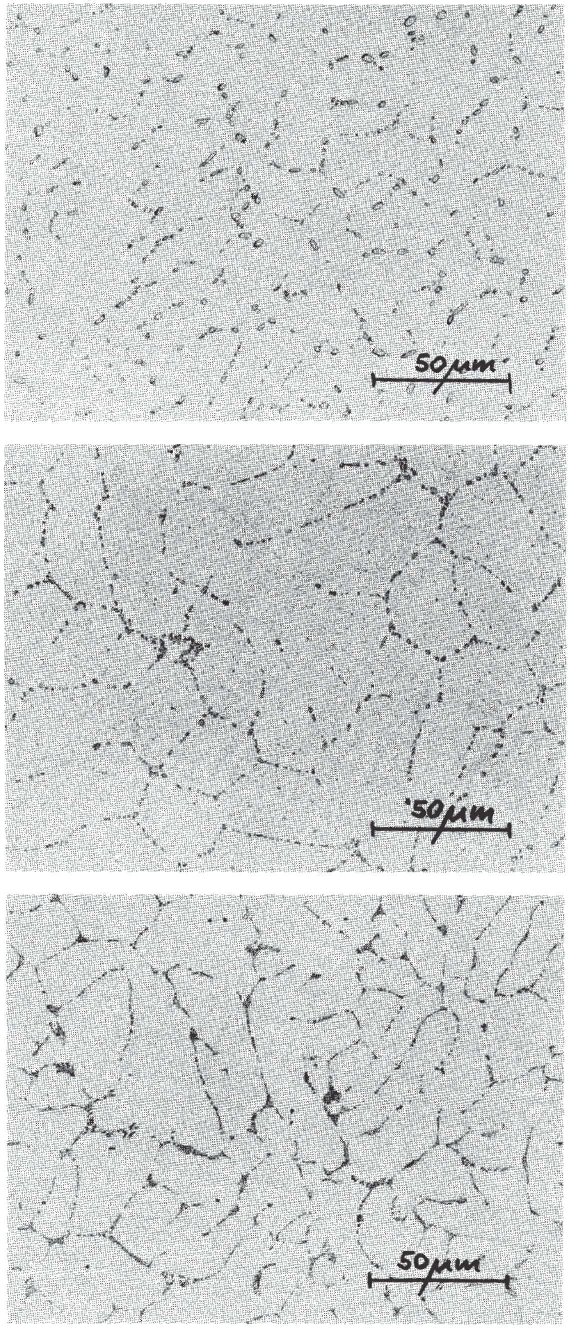
- homogeneous structure after annealing at 630 °C/12 hours/water quenching
- heterogeneous structure after annealing at 580 °C/7 hours + slow cooling to 490 °C/6 hours + slow cooling to room temperature.

In Fig. 7c for example the structure is shown in cast condition.

In spite of the different structural formation, practically no differences can be ascertained in the destrengthening behaviour of 1 mm thick tubes (Fig. 8). A solution of the problem is not offered by this different kind of homogenizing but the use of a different alloy.

4. Résumé

It can be maintained that the heat treatment of primary aluminium of different types of alloy is the essential factor that determines the suitability for a perfect, further heat shaping by extrusion, forging or rolling. To date, no simple method has been found to describe the homogenized condition comprehensively. However there are ways of testing in the plants in order to observe the consistency of the homogenizing treatment over longer production periods. Based on three examples from practice, it is shown in what way optimized homogenizing treatments have an effect on increasing profitability and avoiding waste.



630 °C/12 hours/
water

580 °C/7 hours +
490 °C/5 hours +
slow cooling
to room temperature

cast condition

Fig. 7 Influence of different annealing treatment on the structure of billets in alloy AA 3103

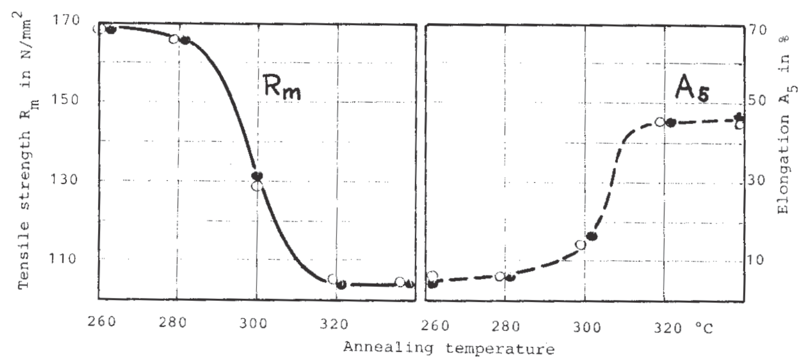


Fig. 8 Change of tensile strength R_m and elongation A_5 by 3 hours soft annealing at different temperatures (alloy AA 3103)

homogeneous structure ...... ○
heterogeneous structure .... ●

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Recommended Reading

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