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QUALITY CONTROL OF SECTIONS IN THE PROCESS OF THEIR EXTRUSION

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ABSTRACT

Aluminum alloys can compete with conventional aluminum casting alloys, as well as with other materials, for cost-critical applications. Aluminum alloys, based on the Al–Mg–Si (6XXX) system, are being used in widespread applications such as automotive, marine, and aerospace industries due to their low density and appropriate mechanical properties. Al6063 is a high performance aluminum alloy with relatively desirable mechanical strength. These outstanding attributes can increase the motivation to replace ferrous metals with light weight aluminum alloys. Despite their low weight, they have inadequate strength hand hardness for this great purpose[1].

Key words: Aluminum alloy, Quality control, Chemical composition, Sections, Mechanical properties.

INTRODUCTION

All aluminium alloys can be extruded. However, while large quantities of pure aluminium are extruded for production of electrical conductors, strong alloys in the 2000, 7000 and 8000 series used for spars and stringers in airframe construction and large sections in the 5000 series employed in marine structures, the biggest share of the extrusion market is taken by the 6000, Al-Mg-Si series. These groups of alloys have an attractive combination of properties, relevant to both use and production and they have been subject to a great deal of R & D in many countries, mainly UK, USA, Germany, France, Switzerland and Japan. The result is a set of materials ranging in strength from 150 MPa to 350 MPa, all with good toughness and formability. They can be extruded with ease and their overall "extrudability" is good but those containing the lower limits of magnesium and silicon e.g. 6060 and 6063 extrude at very high speeds - up to 100 m/min with good surface finish, anodising capability and maximum complexity of section shape combined with minimum section thickness.

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Their strengths are at the bottom end of the range, and they find wide use in architectural applications where shape and finish are more important than strength. Also, the elastic modulus of all the 6000 series is the same, as is their fatigue strength when welded and these two facts coupled with the other attractive features of the 6063/6005A type make them of increasing value in transport applications. Here stiffness and fatigue often override strength as a requirement, and the complexity of thin sections possible with the lower strength versions means that maximum advantage can be taken of the reduction in welding costs made possible by their use.[2]

Extrusions are particularly important in this regard, owing to the ease with which aluminium alloys, particularly the Al–Mg–Si series, can be extruded to form complex profiles.

In general, stiffer and lighter designs can be achieved with aluminium alloys than is feasible with steels.

EXPERIMENTAL

Studies conducted by the authors of this research paper[3] have shown that in many cases as a result of discontinuity of structure of the alloy by volume of cast section, its properties have notable differences. For example, differences in chemical composition are observed for various melts. It follows from the data in Table 1.

Table 1: The content of chemical elements in different melts of aluminum alloy 6063

Melt number/ Chemical element	Melt 1, surface layers	Melt 2, surface layers	Melt 3, surface layers	Reference data
Fe	0.39/0.31	0.38/0.32	-	0.5
Si	0.60/0.48	0.48/0.39	-	0.3-0.7
Mg	0.56/0.44	0.44/0.30	-	0.4-0.9
Melt number/ Chemical element	**Melt 1, center layers**	**Melt 2, center layers**	**Melt 3, center layers**	
Fe	0.38/0.30	-	0.63/0.53	-\\-
Si	0.64/0.48	-	0.71/0.56	-\\-
Mg	0.53/0.45	-	0.52/0.45	-\\-

Cont…

Melt number/ Chemical element	Melt 1, lower layers	Melt 2, lower layers	Melt 3, lower layers	
Fe	0.42/0.34	0.43/0.33	-	-\\-
Si	0.67/0.54	0.48/0.37	-	-\\-
Mg	0.54/0.50	0.44/0.32	-	-\\-

In Table 1, the first numeric characters indicate the content of chemical elements in the surface layers of the cast rod and the second at its center. The iron content in three different melts ranges from 0.38% to 0.63%, silicon from 0.48% to 0.71%, and magnesium from 0.44% to 0.56%. Differences in chemical composition by volume of the rods are due to distinctive features of crystallization, and primarily due to the cooling rate and conditions. Furthermore, it was found out that the physico-mechanical properties are affected by such factors as aging time, modes of homogenizing, preliminary sludge in receiver, extrusion speed, modes of cooling of finished products, and modes of artificial aging. In addition to these, there is always a probability of influence of unaccounted factors.

RESULTS AND DISCUSSION

Differences in the structure and physico-mechanical properties must necessarily affect the modes of pressing and production quality. Control over the quality of produced Ø120 mm cast rods and Ø190 mm cast sections led to the formulation of the problem to find a possibility of such control in the process of sections manufacturing. Analysis of equipment and their instrumentation resulted in speculation that such control can be carried out based on the load curves on the unit press-stem for the production of extruded sections. A series of such curves is shown in Fig. 1.

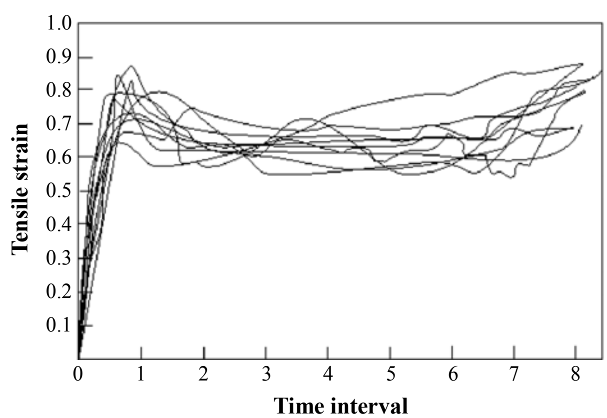

Fig. 1: Loads change curves on press-stem during the extrusion of section of the same type

The curves are plotted in relative coordinates. This is provided for ease of curves comparison, which were obtained during the extrusion of sections different by purpose and complexity. That determined the selection of cast sections, whose length is within the limits of 340-920 mm at Ø190 mm. In view of this and the above-mentioned differences in the mechanical properties, it was expected that there will be differences in the size of load on the press-stem. This phenomenon has been observed in practice. Furthermore, the rate of extrusion of different sections was also different. It was maintained at a constant level during pressing of section of the same type. Therefore, the absolute values of loads and rates of pressing did not give the information required for analysis. Moreover, in practice, the control over the process time, and not control over the extrusion rate was carried out.

Therefore, the relative load was laid along the ordinate axis. This was provided as follows. The maximum permissible load on the press-stem was taken as a unit, and the real operating load was rated onto it. Just note that this gives an opportunity to talk about the equipment loading, and the use of its capacity. Time was also divided into intervals. Estimated time of extrusion, which was determined based on the capabilities of the equipment use by 100% (at the ordinate axis, it is a unit), and, consequently, the maximum pressing speed was divided into 10 equal intervals.

Referring back to Fig. 1, where each line represents the change in the load on the press-stem during the extrusion of section of the same name, there are 10 such lines in the figure. The first thing that attracts attention is the non-linearity of curves, each of which has its own characteristics. But there are also common patterns that should be considered in details. For this, let's consider individual curves in Fig. 1, and analyze their behavior. Such curves are shown in Fig. 2-4.

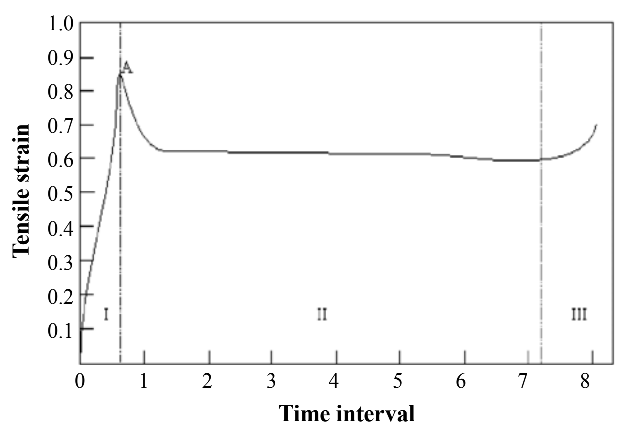

Fig. 2: Curve of the load change on press-stem during the extrusion of section of the same type. Detail No. 1

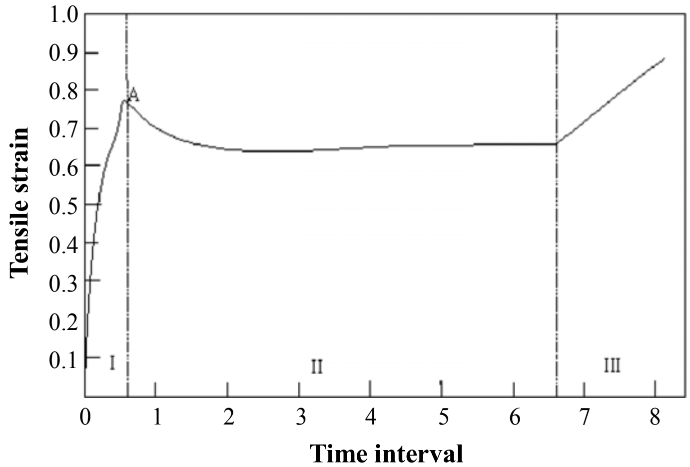

Fig. 3: Curve of the load change on press-stem during the extrusion of section of the same type. Detail No. 2

On the curves, it is possible to single out three conditional stages. The increase in load at Stage I should be attributed to the common patterns. The load on press-stem is increasing up to the point of start of the section pressing, indicated as point A.

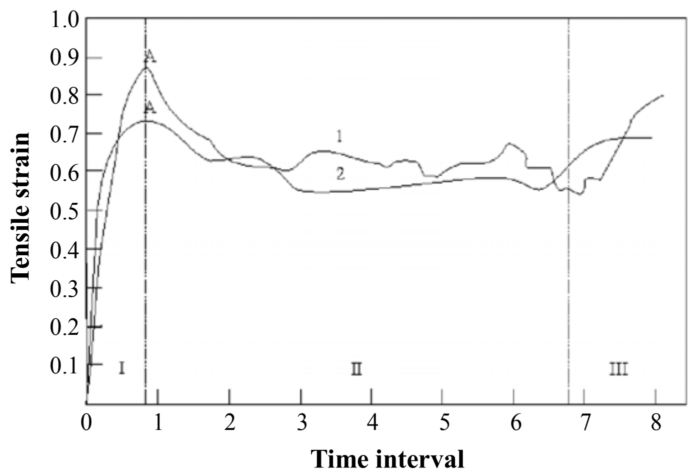

Fig. 4: Curve of the load change on press-stem during the extrusion of section of the same type. Detail No.3 and No. 4

At the beginning of pressing, the load on the press-stem falls to a certain value and then behaves ambiguously: slightly changes (Fig. 2), does not change at all (Fig. 3), changes are significant (Fig. 4). At Stage III, there is the increase in the load. Note that the load at points A is different. Because the plastic deformation is possible provided that the value of effective stresses is $\sigma_e > \sigma_{02}$, then such a behavior is most likely due to differences in yield points of cast sections for pressing. This is consistent with the results of experimental research published in[1]. There, based on an example of one of the most successful melts, is shown that the yield stress value is different. In addition, a significant impact on its value may have the presence of slag inclusions, similar to those shown in Fig. 5.

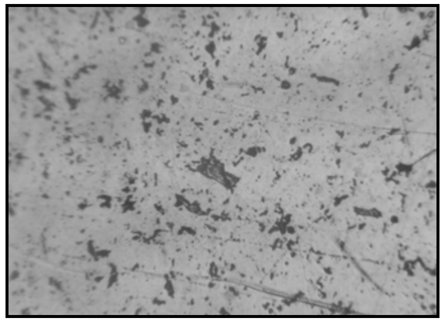

Fig. 5: Surface of sample with small slag inclusions. Increase by x 100

Decline in the relative load on press-stem at the beginning of Stage II can be explained by temperature effect. Cast section before pressing is heated up to a temperature of 450-490°C. In the process of section extrusion, there is an additional self-heating of the alloy due to the accumulated energy of plastic deformation up to 520-560°C. From the literature data, it is known that as the temperature increases, the strength characteristics goes down, and the plasticity of metals and alloys is increasing. In the literature[3-4], the presence of the maximum values of the yield strength in certain temperature ranges as also noted. As can be seen from the Fig. 6, for aluminum and aluminum alloys, such a maximum is in the range of 100-140°C (273-413 K).

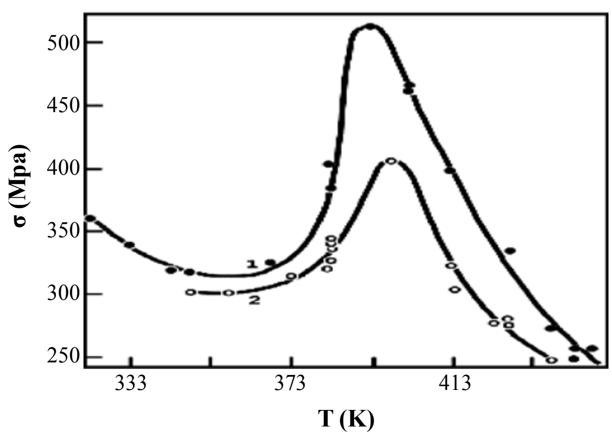

Fig. 6: Temperature dependence of the yield strength of aluminum alloy D16

In this case, the working temperatures range is far from the peak. On curves 1, 2 in Fig. 4, the interval II is characterized by irregularly distributed load, which is also explained by irregularity of structure even in terms of cast section volume. In-depth analysis of production of sections has also revealed that although the rate of extrusion of sections of the same name remains constant within the one melt, it is different for different melts. This is evidence of differences in the structure of aluminum alloy of different melts.

Increase in load on the press-stem in the area III is probably due to the strain hardening. From the point of view of arrangement of a system of indirect control over the quality of output product, as the beginning of Stage III, it should be considered the command to stop pressing and sending the press residues (remainders of billet) for recycling. For a set of statistical data, the analysis of diagrams of dependence of specific load on press-stem on section pressing time has been carried out using the section batch of other configuration. The results are shown below.

Curves of Fig. 7-9 demonstrate the situation in the production of section of other name. Fig. 9 is generalized. In these curves, there is no defined maximum of loads as it was in the previous case. The probable reason for such a behavior can be weakly pronounced temperature effect. But then, the work spent on pressing should be quite insignificant and small; and it is small, when the deformation amount is small. In fact, a comparison of sections No. 1 and No. 2 has shown that the second section has a level of maximum strains by 2.3 times less. For the full assessment of work in both cases, it was necessary to calculate the overall deformation for both sections. It was impracticable in this paper.

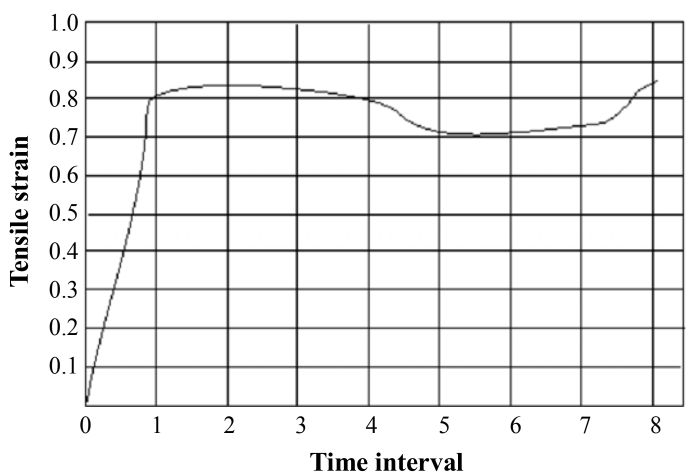

Fig. 7: Curve of the load change on press-stem during the extrusion of section of the same type. Detail No. 1. Section No. 2

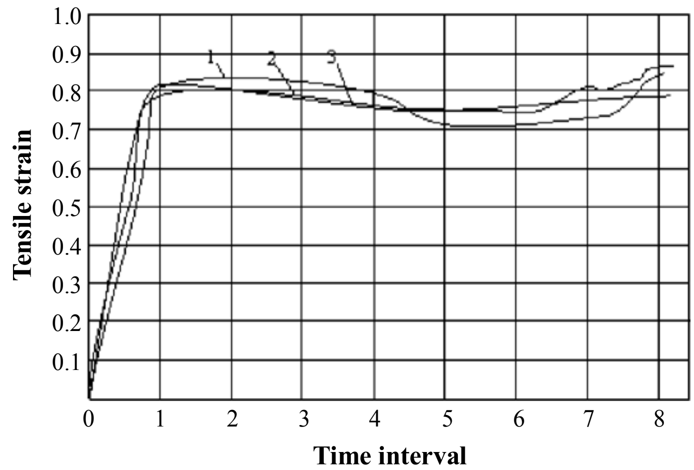

Fig. 8: Curve of the load change on press-stem during the extrusion of section of the same type. Detail No. 1, 2, 3. Section No. 2

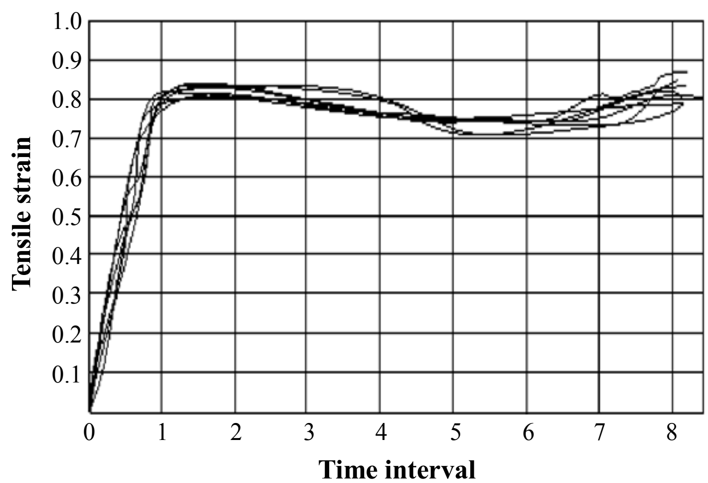

Fig. 9: Curve of the load change on press-stem during the extrusion of the section No. 2

CONCLUSION

Comparison of loads using the press-stem in the production of sections of two types, demonstrates that their numerical values are very close. But with equality of loads, the rates of pressing were different. It should be noted that the maintenance of the load in the range of 0.75-0.85 of the maximum permitted - is the process requirement. Unfortunately, for each certain section, it was not possible to determine the extrusion rate due to technical reasons. It remains a matter of individual studies. However, it was possible to determine the ranges of rates. For particularly complex sections with increased strength, the extrusion rate was set at a level of 5 m/min, while for the most simple - the maximum rate reached 42 m/min. But once again, it should be noted that during the production of section of the same type, the rates of pressing were often different for different cast sections of the same melting and in particular for cast sections of different melts. The reasons for this behavior have been analyzed.

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