Int. J. Chem. Sci.: 13(1), 2015, 541-550
ISSN 0972-768X
www.sadgurupublications.com

EFFECT OF CHEMICAL COMPOSITION OF AD31 ALUMINUM ALLOY ON ITS PHYSICAL AND MECHANICAL PROPERTIES

A. B. TELESHEVA*, A. T. TURDALYEV, YE. V. CHUMAKOV and A. B. ALYMBETOV

Institute of Industrial Engineering, Kazakh National Technical University Named After K. I. Satpayev, ALMATY, REPUBLIC OF KAZAKHSTAN

ABSTRACT

This paper presents the results of an experimental study of the effect of differences in the chemical composition of AD31 aluminum alloy within the limits specified by standards and small deviations of separate elements from it. The need for such research is due to the fact that there is sufficient evidence stating that insignificant changes in one of the parameters leads to significant changes in the other.

Key words: Aluminum alloy, Chemical composition, Mechanical properties.

INTRODUCTION

At the present time, substantial progress is observed in the field of development and creation of new structural materials due to successful research processes of structural changes and ways to influence their purposeful course and behavior. Microstructure depends on the state of the physical and mechanical properties of materials. In the modern machine engineering, the deformable aluminum alloys of D, AD and AB grade are increasingly used. As for the use, they take the second place after metals and iron-based alloys. This is due to the fact that the aluminum alloys have a number of advantages over the iron-based alloys. First of all, it should be noted that aluminum alloys have significantly low specific density and strength and plastic properties compared to steel and alloys. Furthermore, they have good heat and electrical conductivity, reflectivity, and are sensitive to mechanical, thermal, and thermomechanical treatment.

---

*Author for correspondence; E-mail: assel_telesheva@mail.ru

The main characteristic of the alloy is its chemical composition. For example, the introduction of hundredths of a percent of rare earth elements as alloying addition significantly change its strength, plastic properties, as well as chemical and corrosion resistance.

An important integral part of the structure of AD31 aluminum alloy is a ternary phase of aluminum-iron-silicon, which falls along the grain boundaries and leads to the material strengthening. Therefore, GOST specifies a limit on the total content of iron and silicon for this alloy grade, which shall not exceed 1%. It should also be noted that the dimensions of these phases, their number and distribution depends on the temperature and force conditions.

EXPERIMENTAL

The studies were conducted on samples of aluminum alloy AD31 produced at the plant Alprof Almaty. To obtain more reliable data, chemical composition analysis was carried out by two methods: the method of spectral analysis on plant equipment Alprof and X-ray fluorescence method.

RESULTS AND DISCUSSION

The percentage of alloying elements in AD31 aluminum alloy is small, but there are cases where even very small changes in the chemical composition of the material led to considerable effects. Below are given the results of study of the effect of iron and silicon content in AD31 aluminum alloy on its mechanical properties such as yield point stress, yield strength and ductility margin. Regarding yield point, it should be noted that it is an integral structural-sensitive parameter. Any changes in the structure are reflected in its numerical value[1].

Table 1 Shows the data on content of these elements in the samples studied.

Table 1: Chemical composition of samples studied

S. No.	Si (%)	Mg (%)	Fe (%)	Si + Fe (%)
1	0.675	0.550	0.421	1.096
2	0.542	0.500	0.346	0.888

Cont…

S. No.	Si (%)	Mg (%)	Fe (%)	Si + Fe (%)
3	0.633	0.512	0.367	1.000
4	0.473	0.442	0.292	0.765
5	0.600	0.533	0.383	0.983
6	0.475	0.442	0.310	0.785
7	0.481	0.418	0.410	0.891
8	0.375	0.325	0.327	0.702
9	0.705	0.517	0.630	1.335
10	0.553	0.450	0.540	1.093
GOST	0.3-0.7	0.4-0.9	0.3-0.5	

Note: The content of iron and silicon in the amount shall not exceed 1%.

Separate column in the table gives the total content of silicon and iron. It can be seen that in some cases (numbers 1, 9 and 10) the total content of these elements exceeds the permissible content.

Short-term mechanical properties were determined based on tensile stress-strain diagrams, which were obtained using universal experimental plant under uniaxial tension[2]. One of them is shown in Fig. 1.

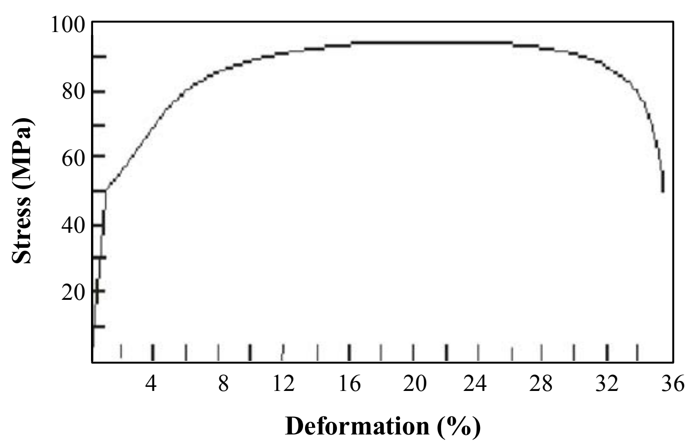

Fig. 1: Aluminum sample tensile stress-strain diagram after annealing

For the samples studied, the tensile stress-strain diagrams had a qualitatively similar form, and for this reason they are not given here. Analysis and processing of tensile stress-strain diagrams of AD31 aluminum alloy samples was carried out according to the traditional methods. The results of experimental plots processing are shown in Table 2.

Table 2: The dependence of short-term mechanical properties of deformable AD31 aluminum alloy on the content of silicon

S. No.	Si (%)	σ_{02} (MPa)	$\sigma_{в}$ (MPa)	E (%)
1	0.675	110.1	149.7	20.0
2	0.542	94.0	117.3	29.7
3	0.633	98.5	131.7	22.0
4	0.473	77.7	106.2	29.2
5	0.600	99.0	135.7	22.5
6	0.475	81.6	102.0	30.7
7	0.481	89.1	122.3	26.1
8	0.375	77.3	96.3	34.3
9	0.705	132.6	159.2	11.5
10	0.553	110.0	147.3	21.3
GOST	0.3-0.7			

Here σ_{02} – is a yield point strength, $\sigma_{в}$ – is a tensile strength, and ε – is a ductility margin

As expected, the values of yield point stress, tensile strength and ductility margin for samples with various silicon content are different. For example, the yield point stress σ_{02} is changing in the investigated range from 77.3 MPa to 132 MPa. The data in Table 2 were used to construct a plot shown in Fig. 2. The plot is constructed in simple Cartesian (orthogonal) coordinates and has a form of straight line. But at the same time, sufficiently large scattering of experimental points should be noted.

Therefore, the plot in the form of straight line should be considered as conventional. It can be definitely and only stated that with the increase of silicon content, the yield point strength increases. A similar pattern is observed also in the behavior of tensile strength depending on silicon content.

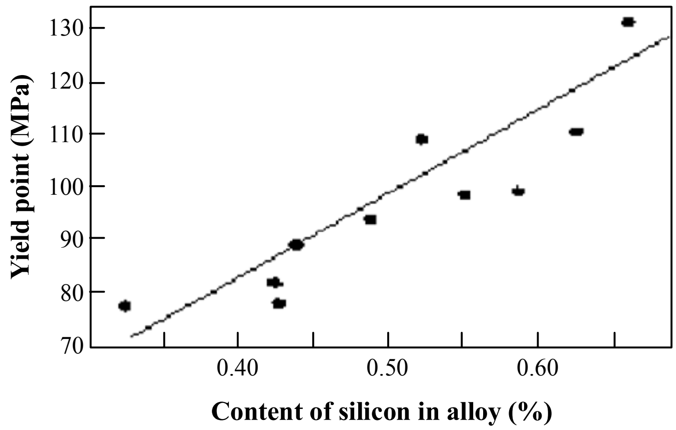

Fig. 2: Dependence of the yield point strength of AD31 aluminum alloy on silicon content

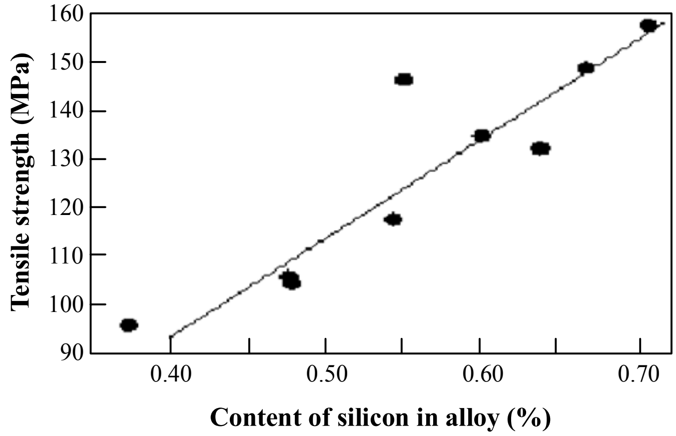

Fig. 3: Dependence of tensile strength of AD31 aluminum alloy on silicon content

The plot is constructed in simple Cartesian coordinates and there is the same noticeable scattering of points as for the dependence of yield point strength. With confidence we can only speak about the general tendency towards the growth in the numerical value σ_B with the increase in silicon content. In the literature there is a lot of evidence that with the increase of the strength characteristics, which refers to the yield point strength and tensile strength, the ductility margin of structural materials is reduced. Exceptions are the materials with nanostructures. Plot shown in Fig. 4 reflects the nature of ductility margin change with the growth in silicon content. Similar to the above cases, the plot is constructed in simple Cartesian coordinates.

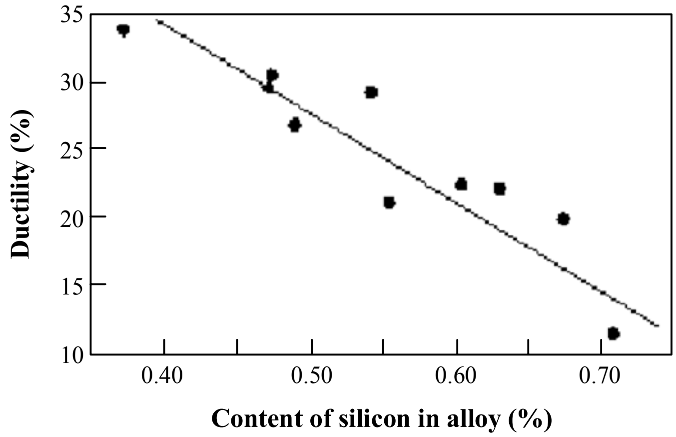

Fig. 4: Dependence of ductility margin of AD31 aluminum alloy on silicon content

For dependence shown in Fig. 4, the picture is not much different from the previous two. Also, we can only talk about the tendency towards a steady reduction in the ductility margin with the increase in silicon concentration.

The results of tensile stress-strain diagrams processing considering the iron content are given in Table 3.

Table 3: Dependence of the short-term mechanical properties of AD31 aluminum alloy on iron

S. No.	Fe (%)	σ_{02} (MPa)	σ_B (MPa)	E (%)
1	0.421	110.1	149.7	20.0
2	0.346	94.0	117.3	29.7
3	0.367	98.5	131.7	22.0
4	0.292	77.7	106.2	29.2
5	0.383	99.0	135.7	22.5
6	0.310	81.6	102.0	30.7
7	0.410	89.1	122.3	26.1
8	0.327	77.3	96.3	34.3
9	0.630	132.6	159.2	11.5
10	0.540	110.0	147.3	21.3
GOST	0.3-0.5			

In this case it is also observed the growth in the strength characteristics and decrease in ductility with the increase in iron concentrations in the alloy.

Plotting the dependence of yield point strength, tensile strength and ductility margin on iron content in the deformable AD31 aluminum alloy has demonstrated a considerable scatter of the experimental points from the straight or any other plots. For this reason, the presentation of experimental results has been limited by Table 3.

The above analysis indicated that the strength characteristics are directly dependent on the iron and silicon content in the alloy. But for ductility margin, the dependence is the inverse. Such behavior is consistent with the known views on the deformation behavior of structural materials.

It has been suggested that short-term mechanical properties of AD31 aluminum alloy depend on quantitative content of ternary phase of aluminum-iron-silicon. For this reason, it was necessary to consider their dependence on the total content of iron and silicon. The results are given in Table 4.

Table 4: Dependence of the short-term mechanical properties of AD31 aluminum alloy on the total content of iron and silicon

S. No.	Si + Fe (%)	σ_{02} (MPa)	$\sigma_{в}$ (MPa)	E (%)
1	1.096	110.1	149.7	20.0
2	0.888	94.0	117.3	29.7
3	1.000	98.5	131.7	22.0
4	0.765	77.7	106.2	29.2
5	0.983	99.0	135.7	22.5
6	0.785	81.6	102.0	30.7
7	0.891	89.1	122.3	26.1
8	0.702	77.3	96.3	34.3
9	1.335	132.6	159.2	11.5
10	1.093	110.0	147.3	21.3

Similar to previous cases, we see that with the growth in the total content of iron and silicon, there is increase in the strength characteristics and decrease in the ductility.

Dependence in the graphical form is shown in Fig. 5.

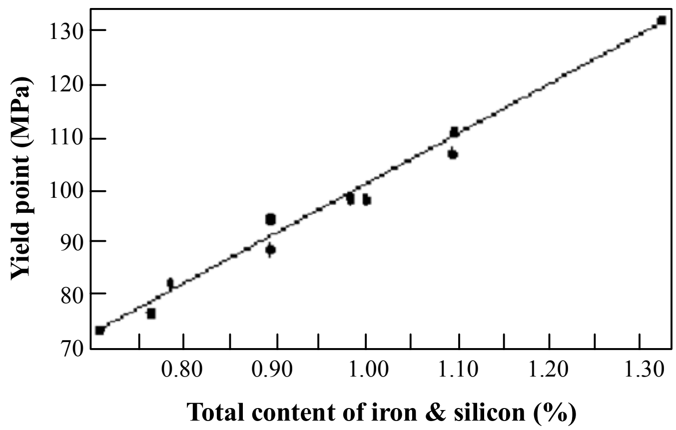

Fig. 5: Dependence of the yield point on the total content of iron and silicon in AD31 aluminum alloy

It shows the dependence of the yield point of the total content of iron and silicon AD31 in aluminum alloy. The plot is constructed in simple Cartesian coordinates. Qualitatively, this plot repeats the plot shown in Fig. 2. It also has a form of straight line, but in this case, the experimental points fall strictly on a straight line. The observed scatter of points, obviously, is associated with a different content of magnesium and experimental errors in measurement. Linear dependence allows applying the following equation:

$$\sigma_{02} = \alpha + kC \qquad \ldots(1)$$

where α and k – are coefficients.

Dependences of tensile strength and ductility on the total content of iron and silicon in AD31 aluminum alloy are shown in the following Figs. 6 and 7.

For the dependence of tensile strength on the total content of iron and silicon in AD31 aluminum alloy (Fig. 6), the picture is qualitatively the same as in the previous Fig. 5. The points fall strictly on a straight line. Consequently, we can write the equation.

$$\sigma_{в} = \beta + nC \qquad \ldots(2)$$

where β and n – are coefficients.

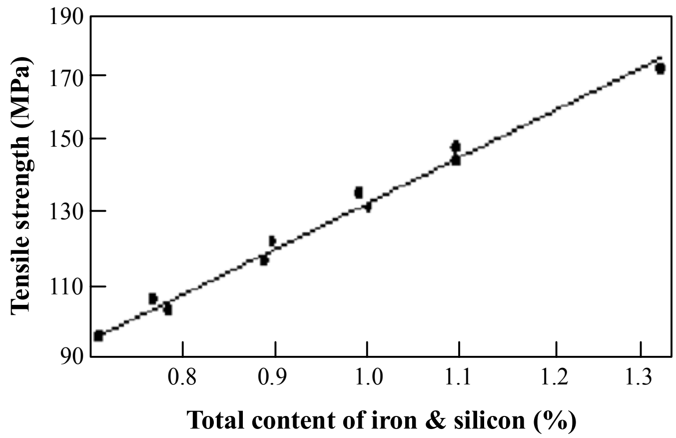

Fig. 6: Dependence of tensile strength on the total content of iron and silicon in AD31 aluminum alloy

As can be seen from Fig. 7, the dependence of ductility on the total content of iron and silicon in AD31 aluminum alloy is also of linear character and obeys the equation

$$\varepsilon = \gamma + mC \quad \ldots(3)$$

where γ and m - are coefficients.

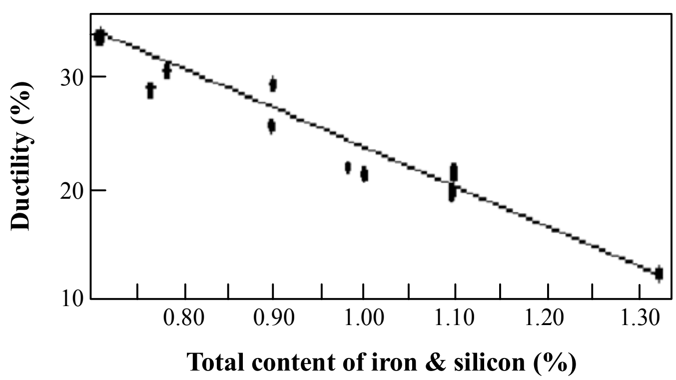

Fig. 7: Dependence of ductility on the total content of iron and silicon in AD31 aluminum alloy

Thus, the analysis of experimental results allowed writing three equations, which explicitly show the relationship of yield point strength, tensile strength and ductility margin and their dependence on the content of such phase forming elements as iron and silicon in AD31 aluminum alloy. However, it should be noted that the range of concentrations studied is small and is practically limited by the frames of allowable GOST. For a much larger range, such dependence may not be executed.

CONCLUSION

The research carried out may lead to the following conclusions:

(i). Cast sections of samples of deformable AD31 aluminum alloy differ in chemical composition and volume and for different lots;

(ii). During the analysis of effect of such chemical elements as iron and silicon on short-term mechanical properties of AD31 alloy, it is necessary to take into account their total content, and not each individually;

(iii). It is found that with the growth in the total content in the iron and silicon alloy, the yield point and tensile strength increases and ductility decreases;

(iv). It is shown that dependences of short-term mechanical properties on the total content of silicon and iron in the range studied are adhered to the linear equations of the first degree.

REFERENCES

1. E. V. Chumakov, D. N. Choi and Z. A. Zhanserkeeva, Yield Point as Structurally Sensitive Element-Proceedings of the International Scientific and Practical Conference, Science and Innovation in Railway Transport, Almaty, KazATC, **8**, 129-132 (2007).

2. E. V. Chumakov and Z. A. Zhanserkeeva, Experimental Installations for the Study of the Yield Point and Creep Rate at Non-steady Stage-Almaty, Bulletin of KazNTU Named After K. Satpayev, **4**, 123 (2008).

Accepted : 17.02.2015