**Determination of processing conditions of 1420 alloy of Al-Mg-Li system by applied temperature analysis**

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**Abstract.** The design of airplanes and spacecraft of the new era requires the creation of materials that will be distinguished by lightness, increased strength and load capacity. When determining the processing parameters, the method of applied temperature analysis turned out to be useful and effective, the optimization of the composition and structure was greatly simplified, as well as the very transformation of the obtained experimental data into a ready-made digital form. Thanks to the method of applied temperature analysis, by linking to the periodicity of discrete states, the accuracy of determining the processing conditions of alloy 1420 of the Al-Mg-Li system is increased. The number of rolling passes can be reduced if, in addition to the data of forces, rolling speed, changes in sheet thickness, control of the dynamics of cracking is included. To perform the decomposition of the continuous deformation process of the blanks by scanning through the crack formation elements relative to the temperature axis in agreement with the determination of the sample size change data.

**1. Introduction**

The main purpose of this study was to determine the processing conditions for alloy 1420 of the Al-Mg-Li system by the method of applied temperature analysis. It is impossible not to note the relevance of this topic, since the 1420 alloy is highly promising. It is used for the manufacture of transport engineering, in aircraft structures (welded sealed compartments, window frames, cockpit components), hulls of missile systems, as well as for ground transport (stamped wheels).

Researches by Evgeny Nikolaevich Kablov (Academician of the Russian Academy of Sciences, General Director of FSUE "VIAM") showed that alloy 1420 has unique characteristics and marked the scale of prospects for the use of this aluminum-lithium alloy [1], especially for rocket and space technology. The big advantage of the 1420 alloy over other aluminum alloys is its low density, which is less than 2.5 g / cm³ [2]. This alloy has a high general corrosion resistance (after hardening in air), welded by all types of welding [3]. The combination of high strength with low density inherent in alloy 1420 determines the great interest in it for aircraft designers. The use of alloy 1420 in structures instead of alloy D16 makes it possible to reduce of the product weight by 10–15% [4].
However, this alloy also has disadvantages [5], including the complexity of determining the rolling modes, the elimination of which is one of the tasks of this direction of research at the Department of OMD (metal pressure processing-?) of Samara University.

The use of the method of applied temperature analysis as a guideline at all stages in the design of technological parameters, obtaining, processing, using various materials in composites is unique, since its principles are universal and consistent with the thermodynamics of nonequilibrium processes [6] in a solid [7, 8]. To determine the conditions for the application of an innovative approach to the selected alloy, based on the application of the theory of temperature analysis to the deformation processes of light alloys, made it possible to achieve the necessary plasticity of alloy 1420 with an allowable degree during repeated cold rolling by selecting the temperature and holding time by the method of isothermal discrete scanning (IDS). The study of the process of plastic deformation of cold rolling of sheet samples of alloy 1420 was carried out by decomposing it into separate passes in accordance with the response effects that they cause. An important feature of this rolling was the connection of the forces along the passes from the thickness of the rolled sample taking into account the development of cracks.

2. Experimental part
As described above, the material for the study was alloy 1420 of the Al-Mg-Li system [9]. For the experimental part, samples of 30x50 mm in size, of different thicknesses: 1.8 mm, 4.8 mm and 7.2 mm were previously prepared. Cold rolling was carried out on a K220-75 rolling mill. Lots of samples were prepared for each of the three thicknesses. The thermal regime of the IDS was selected individually, according to the power series of stationary temperatures (1):

$$L = 343-686-1029-1372-1715-2058 \text{ S.}$$

(1)

Knowing the property of the density sweep over temperature, it is already possible to assume the periodicity not only for the density and distribution of microvolumes in the sample, but also the forces of cold rolling of the samples and the resulting cracks. Before cold rolling, each sample was heated to a certain temperature and kept in an oven for 1,3,5,7,10,12 or 15 minutes. All processing is given in the work earlier. In this part, we made a sample for the interval 500-600°C, which includes the optimal processing temperature, the results are shown in table 1.

Table 1. Results of sampling the results of cold rolling of samples in the temperature interval of 500-600°C.

| Sample No., original thickness IDS temperature [°C] | Pass | Thickness, [mm] | Effort, [kN] | Sample No., IDS temperature | Pass | Thickness, [mm] | Effort, [kN] |
|-------------------------------------------------|------|----------------|-------------|-----------------------------|------|----------------|-------------|
| Sample 18, 1.85mm, 500°C, 1.0 min               | 1    | 1.58           | 15.2        | Sample 19, 1.84mm, 525°C, 1.0 min | 1    | 1.57           | 15.2        |
|                                                 | 2    | 1.26           | 29.8        |                             | 2    | 1.26           | 27.3        |
|                                                 | 3    | 0.9            | 54.6        |                             | 3    | 0.9            | 56.6        |
|                                                 | 4    | 0.56           | 91.5        |                             | 4    | 0.57           | 93          |
| Sample 20, 1.84mm, 550°C, 1.0 min               | 1    | 1.58           | 11.5        | Sample 21, 1.84mm, 575°C, 1.0 min | 1    | 1.58           | 6.3         |
|                                                 | 2    | 1.25           | 25.2        |                             | 2    | 1.25           | 21.1        |
|                                                 | 3    | 0.89           | 49.4        |                             | 3    | 0.9            | 55          |
|                                                 | 4    | 0.55           | 87.2        |                             | 4    | 0.57           | 85.6        |
| Sample 22, 1.84mm, 600°C, 1.0 min               | 1    | 1.57           | 10.8        |                             | 1    | 1.57           | 10.8        |
|                                                 | 2    | 1.25           | 20.7        |                             | 2    | 1.25           | 20.7        |
|                                                 | 3    | 0.9            | 58          |                             | 3    | 0.9            | 58          |
|                                                 | 4    | 0.57           | 93.3        |                             | 4    | 0.57           | 93.3        |

Samples 1.8 mm. thick
Samples 4.8 mm. thick

| Sample 3, 4.85 mm, 520 °C, 3.0 min | Pass | Thickness, mm | Effort, kH | Sample 8, 4.85 mm, 560 °C, 2.0 min | Pass | Thickness, mm | Effort, kH |
|-----------------------------------|------|---------------|------------|-----------------------------------|------|---------------|------------|
| 1                                 | 2.82 | 78.7          |            | 1                                 | 3.17 |               | 96.5       |
| 2                                 | 1.52 | 193           |            | 2                                 | 1.66 |               | 124.5      |

Sample 6, 4.84 mm, 590 °C, 2.0 min

| Passage | Thickness, mm | Effort, kH |
|---------|---------------|------------|
| 1       | 3.15          | 93.8       |
| 2       | 1.67          | 124.9      |

Samples 7.2 mm. thick

| Passage | Thickness, mm | Effort, kH |
|---------|---------------|------------|
| 1       | 3.815         | 72.6       |
| 2       | 3.472         | 55.8       |
| 3       | 3.143         | 52.4       |
| 4       | 2.751         | 44.7       |
| 5       | 2.428         | 38.8       |
| 6       | 2.105         | 28.8       |
| 7       | 1.903         | 17.4       |
| 8       | 1.769         | 15.4       |

Sample 3, 7.27 mm, 505 °C 2.0 min

| Number of passes | Right side | Left side | Right side | Left side | Right | Left |
|------------------|------------|-----------|------------|-----------|-------|------|
| 1                | 2          | 15        | 4.329      | 7.25      | 1.46  | 3    |
| 2                | 4          | 16        | 4.476      | 6.5       | 0.1   | -0.7 |
| 4                | 4          | 17        | 4.452      | 6.75      | -0.024| 0.25 |
| 4                | 4          | 18        | 4.460      | 6.9       | 0.008 | 0.15 |

The data obtained for the efforts and changes in thickness are consistent with the period (1) relative to the boundary temperature of 514.5°C. After reaching the maximum effort, there is a steady decrease. Referring to the dynamics of fracture formation, it is also worth drawing a parallel with the optimum temperature of 520. The integrity of the sample at a given temperature remains unchanged, the continuity of the sample is not violated.

The application of IDS shows real responses during rolling if the temperature is known, and in order to isolate the actual reactivity with decreasing sheet thickness, a technique for determining the correspondence of forces as the cracks develop is required. The dynamics of cracking at a temperature of 525 °C is shown in table 2.

A batch with a thickness of 7.2 mm was heated to a uniform temperature of 525 for 5 samples. A selection from the table is given from sample 4, which was rolled to the required thickness of 0.5 mm.

**Table 2.** Results of cold rolling for 32 passes of sample 4, thickness 7.2 mm, holding time 15 minutes at IDS temperature 525 °C.

| Right side | Left side | Number of passes | Number of cracks at the edges of the rolling direction | Average elongation of cracks at the edges of the rolling direction | Actual increment, mm | Right | Left |
|------------|-----------|------------------|------------------------------------------------------|---------------------------------------------------------------|----------------------|-------|------|
| 1          | 2         | 15               | 4.329                                                | 7.25                                                           | 1.46                 | 3     |
| 2          | 4         | 16               | 4.476                                                | 6.5                                                             | 0.1                  | -0.7  |
| 4          | 4         | 17               | 4.452                                                | 6.75                                                            | -0.024               | 0.25  |
| 4          | 4         | 18               | 4.460                                                | 6.9                                                             | 0.008                | 0.15  |
The number of rolling passes does not correspond to IDS TmA, it is integral; each subsequent deformation is superimposed on the previous one. A part of the data is lost while working at the same temperature on different samples, but with different thicknesses.

The influence of the number of passes in the interval of 500-600 °C until the moment when the force begins to increase to 580-600 °C is tracked by the change in the length of the cracks and their number. The temperatures that correspond to them are distributed over the sections and correlate with the thickness. And by how the average elongation of cracks can be negative in terms of the ratio of increments on the branches of distributions - the next and the previous, left and right, one can determine the degree of influence of the applied force.

3. Conclusion

Thus, it can be concluded that due to the method of applied temperature analysis, the principle of periodicity, the conditions for processing alloy 1420 were experimentally recorded: changes in the sheet thickness, deformation resistance.

The use of the principle of periodicity of temperature analysis makes the decomposition into separate sections of cold rolling experimentally objective. Thanks to the data obtained for the rolling force and cracking, it is possible to make adjustments to the tuning of the rolling mill operation.

It is recommended to control the number of passes using the example of cold rolling of alloy samples of the Al - Mg - Li system according to the data on the correspondence of thicknesses, changes in the rolling force and values of the increment of the crack length. Minimum cracking starts at 520 and increases to 525 also promote rolling, and the number of passes can be reduced.

As a result, when rolling samples with a thickness of 7.3 mm, rolled samples with a thickness of 0.5 mm were obtained with preliminary heating of 525 IDS and a time holding of 15 minutes, the temperature of this particular range turned out to be ideal. The influence of thermal effects during rolling of samples is associated with a change in thickness; this makes it possible to determine those modes of passes during rolling that were previously unavailable and had limitations at the limit of structure fragmentation.

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