

Applied temperature analysis for designing technology of composite materials: parameter determination of aluminium alloys rolling

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Abstract. The solution of the problems for designing new materials by methods of applied temperature analysis of ATA provides the conversion of experimental data to a digitized form. Their application in the development of mass compositions of a new series of products with an aluminosilicate matrix, dispersion-hardened composites and conglomerates, in all cases it turned out to be useful and effective, the optimization of composition and structure was greatly simplified. In the presented work, ATA is used to determine the parameters of rolling sheet blanks of layered composites to a thickness providing the necessary strength of work in the composition. The correspondence to the principle of periodicity of temperature analysis - $T^m A$ of the number of passes of rolling the alloy of the {Al – Mg – Li} system, changes in sheet thickness, strain resistance and microhardness is established. A linear correlation of the parameters of the deformation process with a decrease in elasticity due to local contact integration of volume particles characteristic of Li compounds with respect to temperature is noted. Structural transformations by $T^m A$ microhardness are precisely limited by stationary temperatures of 171°C and 514°C mesh isothermal discrete scanning IDS. The obtained $T^m A$ diagrams were used to determine the parameters of the technology for overcoming the known limit of plastic deformation. It is experimentally proved that the optimum deformation range belongs to this temperature range by characteristic bends of the lines in the microhardness-temperature diagram at various penetration rates and hardening times.

1. Introduction

The designs previously intended only for aircraft began to be applied more widely in the construction. A series of new light products for various purposes is born, without which it is difficult to imagine the implementation of original architectural forms of large-scale creative projects. Appropriate methods for their preparation and processing are developed in teams in all regions of Russia. A number of key factors for the creation of materials are indicated, their convergence to two primary theories, the beginnings of which originated in the field of building materials science, is noted. The theory of artificial building conglomerates ISK by I. A. Rybiev, theory and technology of composites, the founder of the school of biotechnology, by V. I. Solomatov.

Design schemes have been developed linking databases of various industries, specific solutions and new research and analysis methods including tool support. This allows accelerating and predicting the formation of material structures in products of various types of filling the volume of the structure.



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Applied temperature analysis, ATA, also applies to them. It is also declared in the construction industry of materials science. In combination with thermal analysis, it is used as an additional for the intervalization of smooth thermographs [1]. When designing, it is used to determine the intervals for optimizing the technological parameters of the production of composites and conglomerates.

Laminated products are made from standard sheets, however, for composites; a wider range of thicknesses and sizes is usually required. Their preparation is associated with the study of the influence of deformation processing on the structure and properties of alloys, taking into account heat treatment, and assessment of the effect of textures of internal surfaces on the operation of the entire structure. The use of ATA as a guide at all stages, when designing technology parameters, obtaining, processing, operating various materials in compositions, seems useful since its principles are universal and consistent with the thermodynamics of nonequilibrium processes in a solid.

The process of plastic deformation during cold rolling of sheet samples of aluminium-lithium alloy is investigated by decomposition into separate passages in accordance with the response effects that are caused by these passages. A characteristic feature of such rolling is the use of a very similar connection of the efforts along the passes from the rolled sample thickness, taking into account the complex composition and structure of the alloy [2, 3].

It is recognized that at high speeds of cold rolling of the sample, the resulting heat release in local zones due to deformation heating can cause their melting and destruction. Relatively low rolling speeds are important for passing relaxation processes per pass and increasing the ductility of the metal for the next rolling pass [4]. Nevertheless, in this way, it is also not possible to pass beyond the strain limit barrier.

The intensification of the evolution of the dislocation structure, leads to the increase in the resistance to deformation and heating of the material. Therefore, during intense deformation, small strain rates are usually used. The effect of high speeds was not investigated in combination with the IDS of the sample before cold rolling. Such thermal activation of the material provides an increase in temperature in the zones of localization of plastic shear. With large shifts, this increase can very quickly reach hundreds of degrees, which is quite enough for the rearrangement of atoms of the grain boundary structure, especially in pure metals, characterized by high mobility of dislocations.

For a total improvement of the internal boundaries, general heating of the sample to the return temperature is required, and for the formation of high-angle boundaries, a significant influx of lattice dislocations to the cell boundaries is also required. In addition to the size factor, two more factors act: the state of grain boundaries and critical temperatures [5, 6]. The established viscosity values near the amorphization point of the crystalline state in the zones of plastic shear localization do not exclude the effect of superplasticity due to a change in the mechanism of the deformation process [7, 8]. Then it became possible to solve the problem of rolling Al – Li alloy having dispersion intermetallic hardening, preventing plastic deformation to the required thickness [9, 10].

The aim of this work is to study the cold rolling of alloy samples of the {Al – Mg – Li} system by matching the data of the degree of compression during cold rolling with the principle of periodicity of temperature analysis.

2. Materials and methods

In the {Al – Mg – Li} system, the Academician I.N. Friedlander and VIAM researchers found the concentration region of alloys, which included alloy 1420, with a significant effect of dispersion intermetallic hardening after artificial aging. It is possible to prevent such a sharp hardening during cold rolling by regulating the volume fraction of precipitated dispersed particles of excess equilibrium phases and the uniformity of their distribution in a matrix with a preferred particle size of the order of 0.5-0.8 microns. Alloy 1420 is highly alloyed (Al = 5.4 %, Mg = 2.14 %, Li), its crystallization is well studied. The interest in such compounds is also related to the fact that lithium and magnesium occupy an initial position in the periodic system of D.I. Mendeleev's elements, i.e. all studies of such systems are representative as the source for the inclusion of subsequent elements.

The synthetic effect of plastic deformation is accompanied by heat and temperature changes at the contacts of various structural fragments. Its growth has the nature of a spontaneous desire for stationarity over temperature ranges as a thermodynamic limit, expressed in the *intervalization* of the process of structural transformations and the periodicity of the dynamics of changes in properties. According to the principle of periodicity of temperature analysis, structural transformations are expected in the vicinity of temperatures that are multiples of 343°C, small displacements are possible and are associated with the specifics of the operation of the devices. Two discrete series of temperature analysis were used - thermal $T\pi$ (1) and elastic displacements $L\sigma$ (2) [11]. The thermal series (1) reflects the process of energy absorption by the masses of grains of the sample material, structural transformations are consistent according to series [3].

$$T\pi = 171.5-514.5-857.5-1200.5-1543.5-1886.5^{\circ}\text{C} \quad (1)$$

$$L\sigma = 343 - 686 - 1029 - 1372 - 1715 - 2058^{\circ}\text{C} \quad (2)$$

The standards of structural transformation criteria were taken for temperatures less than 171.5°C, as incoming, and more than 514.5°C, as leaving. Both series were combined to more accurately identify the parameters of cold rolling to transformations in the material by the response lines [12]. After IDS a sample of initial thickness 1.8 mm., each pass was cold and before rolling at the laboratory rolling mill KVARTO K220-75 / 300, the thickness at was calculated taking into account the values of series (3) [3].

$$\Delta_i = 0,618; 0,465; 0,380; 0,324; 0,285; 0,255; 0,232; 0,213 \quad (3)$$

The order parameter Δ_i is linearly related to the critical values of stability loss and system symmetry, a change in the sample thickness, and the degree of compression at each pass.

3. Research results

All presented diagrams depict cross-sections of sample deformation lines for each of the indicated temperatures of the sample heating IDS. The sweep property of the temperature analysis means that the values on the left are past, and the value on the right is the future of the state, and not so much because it was done during the experiment, on the contrary, this is not required for temperature analysis; the discrete result is determined by its temperature and the time of preliminary heating of the sample. Each subsequent value is related to the previous inclusive, i.e. contains the past or consists of it.

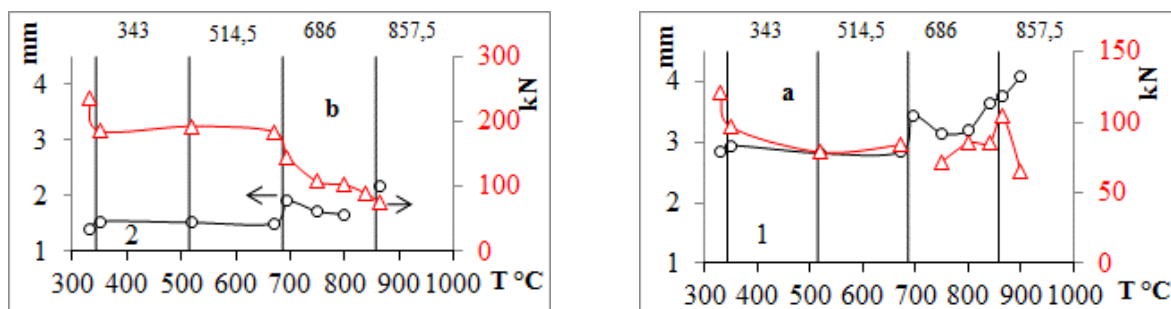


Figure 1. Thickness of the samples and the rolling force after IDS. The initial thickness of the sample is 4.8 mm, the exposure time of the preliminary IDS of heating is **3 min**, a - the rolling speed is 0.1 m/min, b - is the second pass of cold rolling.

Commentary on figure 1. Significant effects on $T^m A$ in these diagrams are: 1) anomalies in the vicinity of temperatures 343 and 686, 514.5 and 857.5°C, 2) increments in these neighborhoods have different signs for sheet thickness and actual forces; 3) with respect to the discrete axis, with a general increase

in temperatures, a smaller force corresponds to a larger sheet thickness; the anomalies correlate with the thermal series (1) and exactly correspond to 514.5°C; it is accepted as the reference one. At section 343-686 of the power series (2), the observed stabilization of the state transition is the result of the possible completed phase transformations.

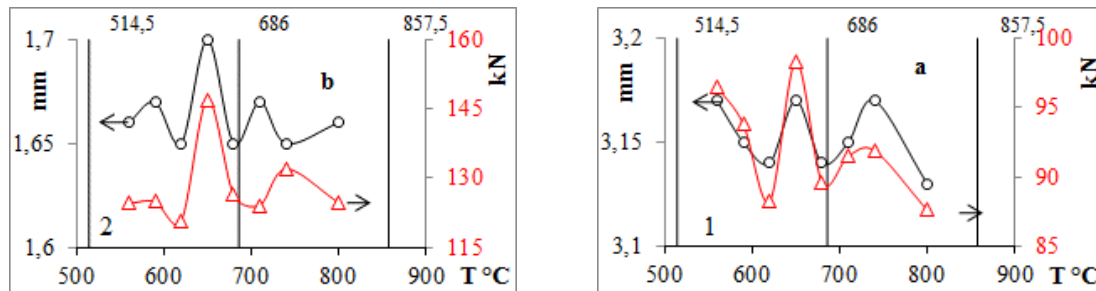


Figure 2. Thickness of the samples and the rolling force. The initial thickness is 4.8 mm, the exposure time IDS is 2 min, the rolling speed is 0.1 m/min, a - the first pass, b - the second pass.

Commentary on figure 2. The states preceding in time are shown, i.e. if the exposure time of the IDS heating of the sample was 2 minutes, the shifts began earlier, a relaxation shift is observed and in the series (2) the resistance is maximum. A typical jump in the phase transition of 660°C of aluminium is observed in response to a thermal pulse. The increase in rolling speed and scanning of the neighborhood $\Delta 343^\circ$ for (2) are required.

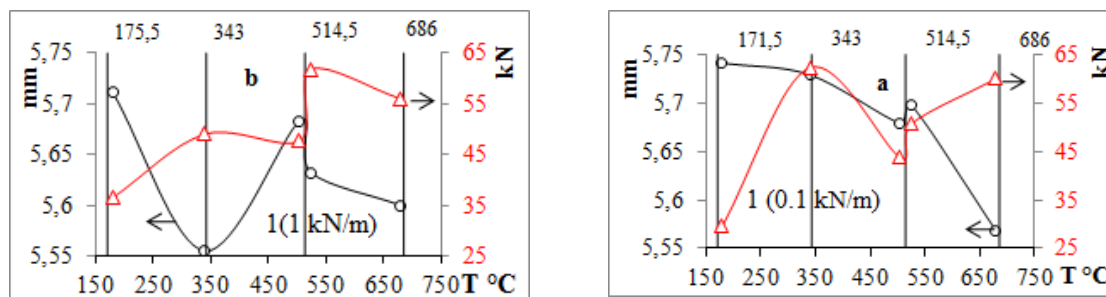


Figure 3. Thickness of the samples and the rolling force. The initial thickness is 7.2 mm, the exposure time of the preliminary heating IDS is 2 min, the first pass speed, m/min: a - 0.1; b - 1.0.

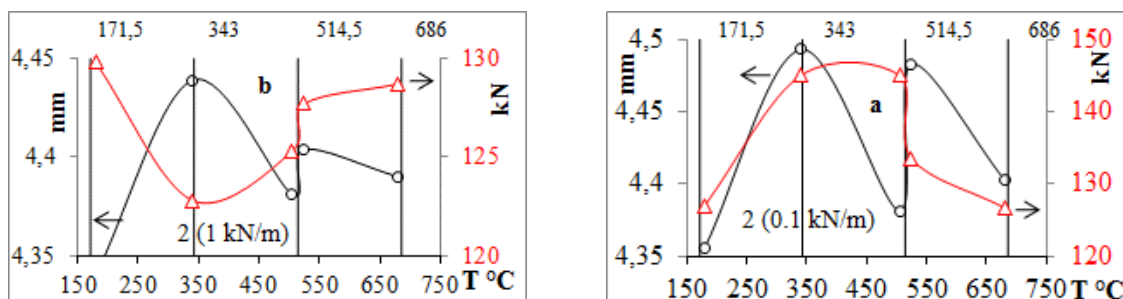


Figure 4. Thickness of the samples and the rolling force, the initial thickness of the workpiece is 7.2 mm, the exposure time of the preliminary heating IDS is 2 minutes, the second pass: a - rolling speed of 0.1 m/min; b - rolling speed 1.0 m/min.

Commentary on figure 3. The increase in rolling speed is effective in the range of 171.5-514.5°C power series (2). The boundaries of the interval of thermal effects are precisely expressed - 514.5°C. With the increase in the rolling speed by ten times for the time pre-IDS-heating with a time delay of 2 minutes, a shift of the sweep to the temperature range region (2) is observed, which is not shown in figure 2, and already shows not a shift, but a break in the sweep at 514.5°C.

Commentary on figure 4. In the range of 171.5-514.5°C in the second pass, the increase in speed is not justified, the speed factor is significant, the force decreases sharply as it relates to atomic states of lithium, but its content in the alloy would have little effect on the change in thickness. However, it should be noted that the workpiece is one and a half times thicker and the fact that in the necks pass the rolling speed should be increased. Features of behaviour at 171.5°C are associated with lithium; its melting point is 180°C.

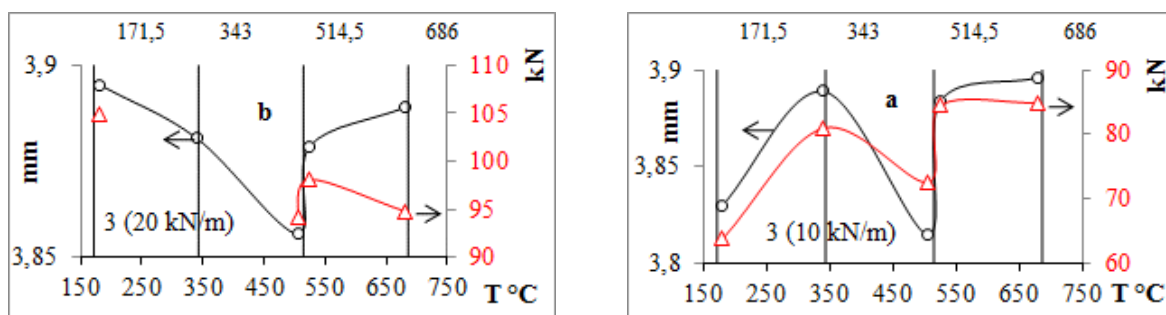


Figure 5. Thickness of the samples and the force of resistance to alloy deformation. The initial thickness of the workpiece is 7.2 mm, the exposure time of the preliminary heating IDS is 2 minutes, the third pass the rolling speed: a - 10 m/min, b - 20 m/min.

Commentary on figure. 5. Such high speeds are not used for cold rolling. an increase in the rolling speed to 10 m / min and then to 20 m/min in the third pass justifies the need for preliminary heating, but only in the fourth pass can the temperature be increased. This was taken for further research, the preheating temperature was 525°C, the exposure time was reduced 3 → 1 min.

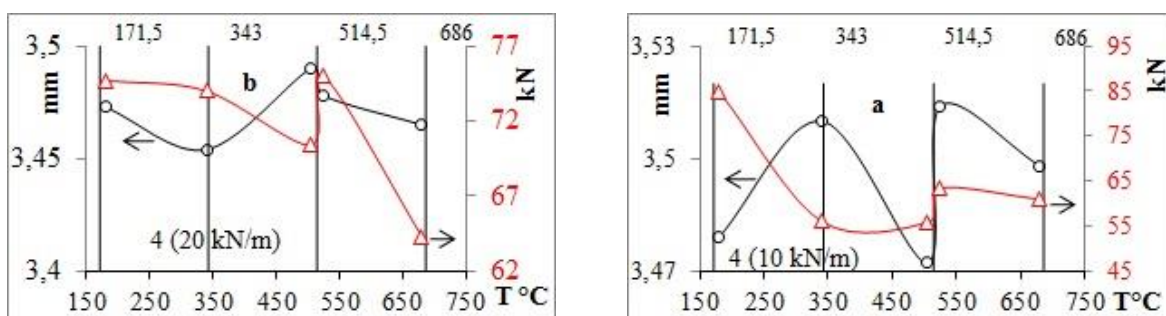


Figure 6. Thickness of the samples and the force of resistance to alloy deformation. The initial thickness of the workpiece is 7.2 mm, the exposure time of the preliminary heating IDS is 2 minutes, the fourth pass the rolling speed: a - 10 m/min, b - 20 m/min.

Commentary on figure 6. The state boundary is also precisely marked - 514.5°C. Outside, a decrease in alloy resistance is significant, but does not affect the change in thickness. In order to determine this effect, a microhardness scan was performed.

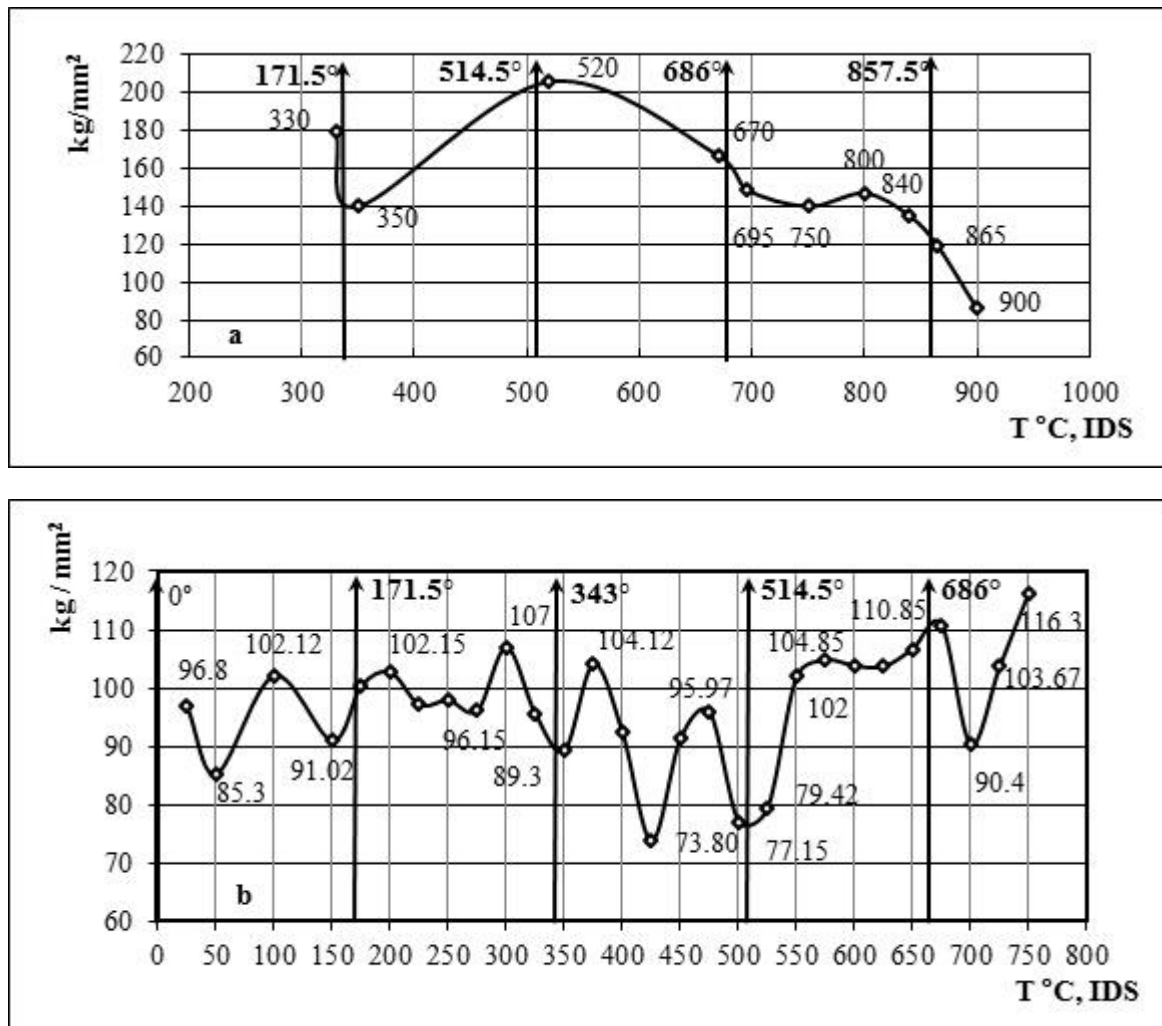


Figure 7. Micro hardness values of samples, a - after the second pass of cold rolling, b - after the fourth pass of cold rolling.

Commentary on figure 7. The temperature grid (1) and (2) plotted on the pressure resistance data diagram breaks them into intervals relative to temperature. The hardness minima in each interval form the overall optimal rolling regime. The maximum permissible temperature is 520°C.

4. Discussion

Performing discrete analysis currently still requires special training. The technique of performing temperature analysis is special because of its discreteness. A lot of intermediate and auxiliary graphic forms of images are used. The presented detailed analysis of the temperature analysis is given for the first time and, as can be seen, can serve to optimize the correction of the rolling force.

The specifics of processing the research results is not a linear function in the classical sense, since this is a typical discrete analysis and the fact that the points are connected by lines is made here only to show the connections when considered, but in no way causation on the sequence of temperatures of the preliminary IDS of heating the sample. If there are no other points between the points, an additional scan is required to find out what is between them. The presence of a point in one diagram means that it also exists in other diagrams, discreteness of parameters allows it being inserted at the place of definition.

As it is noted earlier, structural transformations with radical effects are expected in the vicinity of the internal temperature of 343°C thermal row (2). This temperature is a characteristic of structural

changes, spontaneous desire for temperature stationary at intervals and the formation of the expected geometric center and the beginning of transformations in each interval. This serves as a reference point for choosing the appropriate temperatures for preliminary heat activation of processing samples of the alloy of the {Al – Mg – Li} system before cold rolling.

5. Conclusion

The above fragment of the temperature analysis can be expanded. However, it already leads to the conclusion that there is a large (interval step of the order of 343°C) linearity in temperature in addition to the linearity of the change in the thickness of the sample.

Using the principle of periodicity of temperature analysis makes the decomposition into separate passages of cold rolling experimentally objective. On a piecewise linear scan of the data, the rolling force and microhardness of the samples allows making timely adjustments to the setting of the pressing mechanisms of the stands of the laboratory rolling mill.

It is recommended that the number of passes should be controlled by the example of cold rolling of samples of the {Al – Mg – Li} system alloy according to the data on the correspondence of thickness changes to the rolling force and microhardness values of the samples, to the principle of periodicity of temperature analysis, thus ensuring the thickness of the sheet filler specified by the composite design.

The action of high rolling speeds in accordance with preliminary IDS heating is expressed as the inclusion of steps in the optimal rolling mode by changing the required number of passes.

The obtained data also serves to solve the inverse problem - the selection of the preliminary thermal activation mode. The relaxation phenomenon is visualized as part of the overall process, in the diagram it looks like jumps in the rolling force values, with the exact value of the corresponding transition temperature.

6. Acknowledgments

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