DECREASE OF RESIDUAL INTERNAL STRESSES
IN METAL MACHINE PARTS
BY VIBRATION-HEAT TREATMENT

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In precision instruments, the size of cast iron parts is stabilized by treating the parts by strong impact and by vibration at frequencies of several tens of Hz. The decrease of the stresses resulting from this treatment is related to the singularities of the microstructure and the properties of cast iron (low yield strength of the base metal and local plastic deformation at the places of stress concentration at graphite inclusions).

The vibration treatment at room temperature of cast samples (so-called settling grids) of steel or aluminum alloys under conditions close to those used for cast iron [1] (frequency of 50 Hz, amplitude of 1.5 mm, duration 4 h) showed a decrease of stresses. We may assume that the effectiveness of the vibration treatment would increase if it were combined with heating, since the relaxation processes are accelerated at high temperatures.

To study the vibration-heat treatment* we constructed an apparatus (Fig. 1) consisting of a vibrator 1 on which is a support 2, a cover of the heating furnace which is lowered 3, a fan 4, and welded frame 5.

The furnace in the working position is placed on the lined table attached to the frame.

The gap between the support for the machine part and the table prevents the transfer of the vibrations to the furnace. Heating of the table is prevented by thermal insulation (or cooling with water) in the column of the support 2. The source of vibrations was the ST-300 mechanical vibrator with a frequency of 80-300 Hz (lower range of sound).

We tested cast samples in the form of ordinary settling grids [2] attached to the support with two plates. The materials and the conditions of preliminary heat treatment of samples were as follows:

<table>
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<tr>
<th>Material</th>
<th>Preliminary heat treatment</th>
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<tbody>
<tr>
<td>35L steel</td>
<td>Quenched from 860°C in water, tempered at 550°C for 1 h.</td>
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<tr>
<td>AL9 steel</td>
<td>Quenched from 535°C in water, aged 3 h at 160°C.</td>
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<tr>
<td>AL2 steel</td>
<td>Heated 2 h at 535°C, cooled in water.*</td>
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</table>

*This treatment was selected to increase the internal stresses, since the un-strengthened Al2 steel has a low internal stress after annealing.

The vibration treatment of the strengthened alloys was carried out at the tempering temperature (aging) after quenching: the Al2 alloy was heated to the standard annealing temperature (260°C). The treatment was continued for 1.5 h.†

The effectiveness of the vibration-heat treatment was measured by the magnitude of the residual stresses remaining in the sample after stabilization as compared to the stresses remaining after heating without vibration. The magnitude of internal stresses was calculated by the deformation of the sample after careful cutting of the middle stem [2]. To ensure high precision of the measurements, the samples were hand finished with a special device (to obtain the necessary frequency and ensure that the surfaces investigated were parallel). We introduced corrections for the change in temperature in the building, etc. The error in measurements did not exceed 1 micron on the vertical optimeter.


†During the vibration-heat treatment, the vibrator was turned on after the upper part of the support with the sample was heated to the desired temperature.

The decrease of internal stresses at 550°C in samples of 35L steel depends to a great extent on the frequency (Fig. 2a). When the amplitude of elastic oscillations is 0.2 mm and the frequency is 80 Hz, the residual stresses are 26.2% lower than after similar heating without vibration; at the frequency of 150 Hz the residual stresses are 3.6 times lower and at the frequency of 250 Hz they are 4.1 times lower than without vibration.

The residual internal stresses in AL2 samples after vibration-heating treatment at 260°C with an amplitude of 0.2 mm and a frequency of 80 Hz are 18.9% lower than after heating without vibration (Fig. 2b). After treatment with the frequency of 150 Hz, they are 2.1 times lower; at a frequency of 150 Hz they are 3.3 times lower.

The internal stresses in the AL9 alloy (Fig. 3) do not change as compared to those after heating when treated at 160°C at an amplitude of 0.2 mm and a frequency of 80 Hz. When the frequency is 150 Hz, the internal stresses decrease by 23.3% as compared to those resulting from heating alone and at the frequency of vibration of 250 Hz the internal stresses decrease 1.8 times as compared to those resulting from heating alone. The difference in the effectiveness of vibrations in the AL2 and AL9 alloys can be explained by the lower treatment temperature in the second case.

The effectiveness of the vibration-heating treatment increases with increasing amplitude of elastic oscillations. For samples of the AL9 alloy at a frequency of 80 Hz and an amplitude of 0.8 mm the stresses after treatment decrease by 24.2%, while when the amplitude is 1.5 mm they decrease by a factor of 2.25. However, the increase in the frequency of vibrations has a relatively stronger effect than the increase in the amplitude of oscillations. Figure 3 shows that the increase in the amplitude of oscillations by a factor of 4 is approximately equivalent to doubling the frequency in this case; the increase in the amplitude by a factor of 7 is equivalent to tripling the frequency.

We also investigated the influence of impact stress at high temperature on samples of the AL9 alloy. To create impact strength, we left 2-3 mm gaps between the plate and the sample. During the operation of the vibrator, the samples were hitting the table, the lower support, and the upper plates at random.

Multiple impact is more effective than vibration-heating treatment with definite vibration parameters. When the frequency of the vibration was 150 Hz and the amplitude 0.2 mm, the magnitude of residual stresses turned out

**Fig. 1.** Diagram of the apparatus for stabilizing vibration-heat treatment.

**Fig. 2.** Effectiveness of the vibration-heat treatment of materials as a function of the frequency of oscillations: a) 35L steel; b) AL2 steel.