ULTRASONIC TREATMENT

USE OF ULTRASONICS IN METAL SCIENCE
AND HEAT TREATMENT OF METALS

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Ultrasonics has begun to be used in the heat treatment of metals only comparatively recently. Work in this area can be divided into two basic types: Intensification of heat treatment processes and study of the singularities of the influence of ultrasonic vibrations on the structure and properties of metals and alloys.

The use of ultrasonic vibrations in heat treating metals and alloys is based on the transmission of elastic vibrations to the parts either through the surrounding medium (water, oil, emulsion, molten metal or salt) or by firm contact with the wave guide. It is also possible to subject parts to ultrasonic vibrations without direct contact by placing them in a variable electromagnetic field. However, this method has been explored very little.

The intensification of heat treatment with ultrasonic vibrations is explained by the influence of ultrasonic vibrations on the processes occurring on the surfaces of the parts in contact with the surrounding medium and within the parts.

Under the influence of ultrasonic vibrations the kinetics of the formation of the solid solution must change, and perhaps even the position of the solubility curve in alloys. It was found in [1], for instance, that the residual austenite in KhVG steel is highly stable when the samples are subjected to ultrasonic vibrations of sufficient intensity during heating to the quenching temperature. These results are an indirect indication of a higher degree of alloying of the solid solution. It is true that it could prove to be the result not only of acceleration of diffusion of the excess phase in the austenite as the result of the influence of elastic vibrations but also a certain increase in the temperature of the samples as the result of the absorption of part of the energy of elastic vibrations. As was shown in [2], samples may heat up greatly under the influence of ultrasonic vibrations.

A considerable amount of work has been done on the accelerating influence of ultrasonic vibrations on the decomposition of solid solutions. In [3] the effect of ultrasonic vibrations on natural and artificial aging of aluminum alloys D1, D16, AL4, and V95 was investigated. In the Duralumin alloys D1 and D16 aging proceeds 20–25 times faster than in Silumin AL4 at room temperature. Natural and artificial aging of the V95 alloy was also considerably accelerated.

The acceleration of the aging of Duralumin D16 by 40 times at room temperature and 1.6 times at 50°C was also noted in [4, 5]. The acceleration of aging of the KhN77TYuR alloy at 700 and 750°C was noted in [5], the effect increasing with the amplitude of alternating stress.

However, the effect of initial heating of the samples in the process of exposure to ultrasonic waves and the influence of this heating on aging was not investigated in [1–5]. Thus, the thermal effect of ultrasonic vibrations was not separated from the effect of the alternating elastic stress, which is of great importance in studies of the mechanism of the effect of ultrasonic vibrations on the processes of diffusion and dispersive hardening.

The use of ultrasonic vibrations in tempering and aging of quenched steels leads to acceleration of the precipitation of carbon from martensite, promoting stabilization of the dimensions of the parts. Replacing high-temperature stabilizing tempering with tempering and ultrasonic vibration shortens the time, reduces the treatment temperature, and allows the parts to retain their high hardness. The acceleration of the relaxation of residual stresses makes it possible to attain a high degree of stabilization of the dimensions of the parts, which is very important in manufacturing machine tools, instruments, and other machines.

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Intensive ultrasonic vibration in some cases considerably accelerates the isothermal decomposition of austenite and in other cases slows it down.

Complete transformation of residual austenite was found [6] in the process of hardening U8, U10, U12, 7Kh, 7Kh3, 9KhS, and ShKh15 steels in the field of a hydraulic hammer with a frequency of adequate magnitude. If after hardening in a medium without exposure to ultrasonic vibrations the steels retained as much as 25% residual austenite, then complete decomposition of the austenite could be attained by increasing the electrical discharge voltage in the quenching liquid to 60-70 kV.

In [7] it was found that vibrations with amplitudes of 10 and 18μ increase the stability of austenite in samples of KhVG steel at 450°C and accelerate its decomposition at 250°C, while vibrations with an amplitude of 3μ have the opposite effect.

In a series of investigations it was established that ultrasonic vibrations have an accelerating effect on processes of chemicothermal treatment. Some results of investigations in this area are given in [3]. One of the authors found acceleration (approximately double) in the process of case hardening in a solid carburizer under the influence of ultrasonic vibrations. A similar effect was found in the case of a liquid case hardening bath. There have been many studies of the effect of ultrasonic vibrations on nitriding of various steels in gaseous vibrations leads to an acceleration of the process, an increase in the depth of the nitried layer, and an increase in the amount of nitrogen in the layer.

At the same time, in studies of gas case hardening and nitriding of steels [11] and the diffusion of copper in gold and hydrogen in commercial iron it was found that elastic vibrations had no effect on these processes. In [2] the possibility of any influence of elastic ultrasonic vibrations on diffusion, ionic mobility, viscosity, or thermal diffusion was denied.

The contradictory data require further investigations in this area, particularly studies of the effect of ultrasonic vibrations on the activation and cleaning of the surfaces of parts, on the acceleration of the dissociation of reagents, and what happens on the surface.

The accelerating influence of ultrasonic vibrations on the recrystallization of alloys is well known. The effect of ultrasonic vibrations from a hydraulic generator on the D1 and AL8 alloys was investigated in [8]. It was found that plastic deformation decreased by 1-42% and that the temperature of the beginning of recrystallization of these alloys in the field of a hydraulic generator dropped by 270-370°C.

In a series of investigations it was shown that ultrasonic vibrations have a marked effect on the increase of the grain size of steels during recrystallization.

In [3] it was established that samples of 12KhN3A steel exposed to ultrasonic waves reached the temperature of the oil bath 1.5 times faster (in 6 min instead of 9) than samples not exposed to ultrasonic waves. The samples were exposed to ultrasonic waves from a quartz crystal oscillator with a frequency of 1000 kHz and an intensity of 1.7 W/cm². This confirms the effect of ultrasonic vibrations on the heat transmission coefficient.

There are many data in the literature concerning the great increase in the cooling capacity of different quenching media when ultrasonic vibrations are used. The mechanism of the action of ultrasonic vibrations probably consists of changes in the conditions of evaporation on the surfaces of the parts being treated. The use of ultrasonic vibrations is especially effective for parts made of steels with low hardenability. The application of ultrasonic vibrations during quenching permits the use of less highly alloyed steels in place of more highly alloyed steels.

Furthermore, the use of ultrasonic vibrations during quenching makes it possible to use various fine quenching emulsions of the water-oil type with different rates of cooling. However, in spite of the considerable amount of work done on methods of using ultrasonic vibrations in the heat treatment of metals and alloys, which has now been in progress for more than 30 years, there is still no precise explanation of the effects. The use of ultrasonic vibrations in the heat treatment of metals and alloys is being held back for this reason.

The passage of ultrasonic vibrations through a solid body is accompanied by a series of effects such as intense heating of the samples to the melting temperature, the appearance of traces of residual deformation, and accumulations of structural fatigue and even fatigue destruction [10]. It should be noted that for the heat treatment of metals and alloys one usually uses ultrasonic vibrations producing deforma-