ISOTHERMAL HARDENING OF MAGNETS IN A FLUIDIZED BED


UDC 66.096.5:669.018.58

For producing the maximum magnetic properties in Ticonal alloys having high cobalt and titanium contents (YuNDK35T5), it is necessary to carry out the isothermal thermomagnetic treatment (ITMT) with rapid cooling of the magnet to the isothermal holding point and with simultaneous application of a strong magnetic field.

The production of uniform magnetic fields of high strength and large volumes is difficult. This limits the dimensions of the hardening baths, and therefore the ITMT of the magnets is conducted individually in baths whose volume does not greatly exceed the volume of the treated articles. A high cooling rate is ensured by the application of media having high thermal conductivity (molten salts, tin or lead). Treatment in such media, however, does not always ensure the production of the requisite properties. This is due to the difficulties in maintaining the temperature conditions in the isothermal bath, in particular due to the introduction of the hot magnet.

The application of high-temperature liquid media increases the difficulties in measuring and controlling the bath temperature. Standard industrial thermocouples, encased in a metal screen, and used for temperature measurement, have a high intrinsic time lag and do not accurately record the disturbance introduced into the system. It should be noted that all the media enumerated are quite corrosive at 800°C. In addition, the liquid melts erode the lining of the bath and in the course of a short time cause its complete breakdown. Molten salts and metals adhere to the surface of the magnets and necessitate cleaning of the latter after ITMT. Molten lead gives off toxic vapors; during the cleaning of the surface of the magnet, even more harmful lead dust is formed. In addition, the scarcity and high cost of lead and tin result in the need for their replacement by cheaper technological materials.

It has been proposed [1] to use a fluidized bed of finely granular heat-resistant material for the hardening and ITMT of magnets. Figure 1 shows a diagram of the laboratory apparatus.

![Diagram of experimental apparatus](image)

The bath with the fluidized bed 1 is located between the poles of an electromagnet. The fluidized bed (quartz sand with grains 200 μ in size) 250 mm deep is formed in a bath 150×170 mm by blowing air through.

The fluidized bed is heated by Silit heating elements 4, situated in tubes 25×2 mm in diameter made of steel Kh18N10T. This construction

![Graph](image)

Fig. 2. Coercive force versus temperature of quenching medium.


© 1972 Consultants Bureau, a division of Plenum Publishing Corporation, 227 West 17th Street, New York, N. Y. 10011. All rights reserved. This article cannot be reproduced for any purpose whatsoever without permission of the publisher. A copy of this article is available from the publisher for $15.00.
of the apparatus ensures heating of the fluidized bed to 850°C. The bath is heated for 1 h. The fluidized bed is a liquid-like mass having the same temperature throughout the entire volume of the bath (in the working zone between the poles of the electromagnet the variation in temperature was 5°C). Even this deviation would not have been noticed if the construction eliminated the comparatively cold ends, located in the fluidized bed. It is known [2] that the intensity of heat exchange in a fluidized bed is approximately the same as that in molten metals and salts. By means of the quantity of air supplied to the bath 1, it is possible to regulate the rate of cooling of the specimen 2.

For accurate temperature regulation of the fluidized bed, a device [3] has been developed for the supply of cold water directly into the bed from a tank 8.

Location of the (unscreened) Chromel-Alumel thermocouples 0.5 mm in diameter in the working zone of the fluidized bed and their connection respectively to an indicating instrument 5 and a regulating device 6 through a portioned supply unit 7 enabled the temperature in the central zone of the treated specimen to be maintained with an accuracy of up to ±3°C. The excess amount of heat introduced by the magnet and heating elements 4 (which were not switched off during the working process), was instantly removed by the evaporating water. An exhaust fan was mounted in the upper part of the apparatus above the bath; the result of this was that no dust or sand found its way into the room. The walls of the apparatus made of Kh18N10T steel suffered no changes after one year’s operation.

The investigation was carried out on specimens of 20 × 25 × 30 mm of the alloy YuNDK35T5. Before hardening, the specimens were held for 30 min (including the heating-up time) at 1260°C, whereupon they were placed in the bath with the fluidized bed, heated to a predetermined temperature. The specimens remained in the bed for 11 min with simultaneous application of a magnetic field of 2000 Oe. The fluidized bed conditions were so selected as to ensure maximum cooling capacity of the medium [2].

After the ITMT, the specimens were demagnetized and air cooled. The surface of the specimens after passing through the fluidized bed was clean, and did not require any additional treatment before grinding.

The optimum temperature conditions of the fluidized bed were determined on specimens of an equiaxial alloy having the composition: 35% Co; 14.5% Ni; 7.5% Al; 3.5% Cu; 4.5% Ti; 1% Nb; 0.1% S; 0.1% Ce; remainder Fe. The conditions were selected according to a coercive force Hc, since this is the most structurally sensitive characteristic [4]. The results obtained are presented in Fig. 2, showing that the curve of the variation of coercive force has a steep maximum. The temperature of the hardening medium must therefore be maintained with a high degree of accuracy. In our experiments and in [5] the optimum temperature was 790°C. Treatment in the fluidized bed results in the production of magnets having stable properties. To study the stability of the properties, five alloys (40 specimens) of a composition close to that mentioned but with directed crystallization were melted. The compositions of all the alloys were within the permitted limits indicated in [6] for the production of the necessary properties.

For comparison, specimens were treated in molten lead. The results of the investigation are shown in Table 1. The mean values of the coercive force agree and are 1480 Oe independently of the medium in which the magnets were treated. However, the stability of the properties of magnets which have undergone treatment in the different media is different. According to the data of the table, the root mean square deviation for magnets treated in the fluidized bed is 25.4 Oe, and for magnets treated in lead it is 42.1 Oe.

### CONCLUSIONS

1. The fluidized bed may replace molten metals and salts used for hardening in the isothermal thermomagnetic treatment of magnets of the type of YuNDK35T5.

2. The fluidized bed is technologically a better medium for the isothermal thermomagnetic treatment of magnets compared with liquid media.