SINTERED SOFT MAGNETIC Fe-Al, Fe-Si, AND Fe-Si-Al Alloys

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Sintered soft magnetic materials are at present chiefly used in dc devices. For this purpose, sintered magnetic cores compacted in one piece from iron or iron-silicon alloys are commonly employed. For ac equipment, such magnetic cores are less suitable, because their specific losses are high compared with those of laminated magnetic cores from electrical steel.

However, since the manufacturing technology of sintered one-piece magnetic cores is relatively simple, it would be tempting to produce such parts whose characteristics in ac system would not differ greatly from those of laminated components.

The properties of sintered soft magnetic materials produced in one piece and rolled were described in [1-3]. The possibility of using sintered alloys for the magnetic cores of various ac systems was discussed in [4, 5]. So far, however, their properties, particularly their magnetic loss value (P_{1/50} = 40 W/kg), have not been outstanding.

### TABLE 1

Specific losses of sintered Fe-Al with 12% Al, measured by different methods at different induction values (Frequency 50 cps)

<table>
<thead>
<tr>
<th>Induction B_{max}, T</th>
<th>Specific losses P, W/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ferro-meter</td>
</tr>
<tr>
<td>0.7</td>
<td>4.7</td>
</tr>
<tr>
<td>0.8</td>
<td>6.3</td>
</tr>
<tr>
<td>0.9</td>
<td>8.4</td>
</tr>
<tr>
<td>1.0</td>
<td>11.2</td>
</tr>
</tbody>
</table>

Fig. 1. Effect of sintering temperature on physical properties on sintered Fe-Al (12% Al) alloy:
1) magnetic induction (B_{max}) in field H_{max} = 16 A/cm (f = 50 cps); 2) electrical resistivity; 3) density.

Sintered one-piece magnetic cores for ac system can be improved in two ways: 1) Their magnetic characteristics can be raised (by using Permalloy type materials). 2) their electrical resistivity can be increased. The results are presented here of an investigation into the properties of sintered Fe-Al, Fe-Si, and Fe-Si-Al base alloys (as materials for the magnetic cores of ac systems) differing from one another in either magnetic properties or electrical resistivity.

The starting materials for the preparation of specimens comprised an iron powder obtained by eddy mill grinding and Fe-Al and Fe-Si master alloy powders of various compositions, produced by ball mill grinding. Powder mixtures were compacted in the form of toroids (diam 35 x 25 x 6 mm) and rectangular blocks (5 x 5 x 50 mm). The resultant compacts were sintered in a hydrogen atmosphere, after which they were cooled at a rate of about 35 deg C per minute. The toroids were used for studying magnetic characteristics and specific losses, and the blocks for determining electrical resistivity and density.

Magnetic characteristics and specific losses were measured in a U-542 apparatus at a 50 cps alternating current:
- a) by means of a ferrometer (by measuring the loss angle cos φ); b) in a direct manner, from the hysteresis loop (on the oscillograph). In addition, the specific losses of some specimens were compared with results obtained by means of a wattmeter apparatus. The data obtained were found to show satisfactory agreement (Table 1).

Electrical resistivity was measured with a Thomson-Wheatstone bridge and density by the hydrostatic method. In
An iron-aluminum alloy with 88% Fe and 12% Al was selected for the investigation. This alloy has high electrical resistivity, which is practically unaffected by cooling conditions after sintering—an important feature for sintered soft magnetic materials. A study was made of the effect of temperature and holding time during sintering on the magnetic properties, specific losses, electrical resistivity and density of the alloy. It will be seen from Fig. 1 that, when sintering temperature is raised to 1575 K, the magnetic induction and density of specimens increase. At the same time, their electrical resistivity decreases.

Analysis of the curves shows that sintering is essentially completed at 1575 K, when the physical properties of the