THE EFFECT OF SYNTHETIC FLUX ON THE QUALITY
OF LARGE CENTRIFUGAL CASTINGS

A. I. Shevchenko, V. A. Efimov,
V. A. Chichaev, G. S. Akubov,
E. V. Gerlivanov, and M. M. Komarov

Large centrifugal castings are commonly used in the manufacture of wide-width paper machinery for
making suction shaft sleeves. The quality of the large cylindrical blank made by centrifugal casting is de-
termined by the specific features of metal solidification in molds under the action of alternating force fields.
The solidification of large cylindrical blanks and pipes is characterized by a relatively large free surface
of metal in contact with air. Cooling of the external surface and ends of the casting occurs through the
mold walls. The inner surface of the casting is cooled due to the heat lost by radiation from the mold ends
as well as by convection of the air circulating within the mold cavity.

Cooling of the casting from the side of the external surface ensures solidification in the appropriate
direction and this often helps in obtaining castings free of defects. Convection occurs in the interior layers
of the liquid metal due to bilateral cooling. This helps in creating favorable conditions for directional
crystallization because the cooler metal being heavier, concentrates at the peripheral layers of the cast-
ings.

However, when casting thick-walled blanks even at high mold rotation speeds, this sequence of cry-
stallization is usually disrupted. A hard skin is formed on the inner surface of the casting and a secondary
crystallization front is set up. As a result, the nonmetallic inclusions which are precipitated during metal
solidification are unable to float to the free surface of the casting and are retained at a depth of up to one-
third the casting thickness from the direction of the inner surface. In order to remove the defective layer
it is necessary to increase the machining allowance on the internal surface to 25-30 mm for a casting thick-
ness of 100 mm.

Besides this, when casting large blanks with alloys which are easily oxidized, e.g., aluminium bronze,
there is also secondary oxidation of the alloy. The oxide films which are formed contaminate the casting
over the entire section. Lamination occurs at the places where oxide films are present and this leads to
complete rejection of costly blanks.

Increased contamination of metal with nonmetallic in-
cclusions and undesirable impurities facilitates formation of
longitudinal and transverse cracks as well as micro-cracks
at the grain boundaries. In fact, crack formation is an ex-
tremely common defect in large centrifugally cast stainless
steel blanks. The above shortcomings considerably reduce
the technical and economical effectiveness of centrifugal cast-
ning for making large pipes and cylindrical blanks.

The Institute for special problems in the Academy of
Sciences, Ukrainian SSR and the Izhtyazhbummash plant
have together designed and introduced a completely new
technology of centrifugal casting under liquid synthetic flux.
This new technology is intended to improve the microstruc-
ture and macrostructure of large steel and bronze castings,

Fig. 1. The fracture (a) and micro-
structure (b) of BrAZhNMts 9-4-4-1
bronze blanks made by centrifugal
casting under liquid synthetic flux.
TABLE 1

<table>
<thead>
<tr>
<th>Type of specimen</th>
<th>Yield strength $\sigma_Y$, kgf/mm²</th>
<th>Ultimate tensile strength $\sigma_T$, kgf/mm²</th>
<th>Relative elongation, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tangential</td>
<td>23.5</td>
<td>57.5</td>
<td>27.0</td>
</tr>
<tr>
<td></td>
<td>25.5</td>
<td>58.5</td>
<td>28.0</td>
</tr>
<tr>
<td>Radial</td>
<td>25.6</td>
<td>58.5</td>
<td>25.5</td>
</tr>
<tr>
<td></td>
<td>26.5</td>
<td>62.5</td>
<td>32.0</td>
</tr>
</tbody>
</table>

TABLE 2

<table>
<thead>
<tr>
<th>Layer No.</th>
<th>Chemical composition of metal, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cu</td>
</tr>
<tr>
<td>1</td>
<td>82.53</td>
</tr>
<tr>
<td>2</td>
<td>82.76</td>
</tr>
<tr>
<td>3</td>
<td>83.05</td>
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<tr>
<td>4</td>
<td>83.41</td>
</tr>
<tr>
<td>5</td>
<td>83.80</td>
</tr>
</tbody>
</table>

Note: The layers have been numbered starting from the external surface of the casting towards the internal surface. The distance between each layer was 8 mm and the casting thickness was 40 mm.

to reduce machining allowance, and to reduce rejections on account of crack formation.

The liquid synthetic flux consisting of fusible or exothermic flux-forming mixtures is added to the stream of liquid metal poured into the mold. The flux refines the metal and prevents secondary oxidation during entry into the mold and solidification of the casting. It also prevents loss of heat from the free surface of the casting and facilitates directional crystallization.

For example, when casting large aluminium bronze blanks the oxide films $\gamma-Al_2O_3$ which are formed in the metal enter into active chemical reaction with the CaF₂ contained in the liquid flux according to the equation

$$3\text{CaF}_2 + \gamma-Al_2O_3 = 3\text{CaO} + 2\text{AlF}_3.$$ 

The reaction is accompanied by considerable heat generation and formation of gases. Therefore, intensive mixing of the entire volume of metal occurs when refining aluminum bronze with fluxes containing CaF₂. This facilitates effective removal of nonmetallic inclusions and gases.

When refining steel in the centrifugal machine mold with fluxes based on fluorspar there is a further reaction

$$2\text{CaF}_2 + SiO_2 = 2\text{CaO} + SiF_4.$$ 

The CaO formed during these reactions interacts with sulfur compounds, i.e., desulfurizes the metal. These reactions effectively refine the metal by removing the main nonmetallic inclusions: aluminates, silicates, and sulphides.

During the casting process the liquid flux which is 2.5-3 times lighter than the metal is forced to the free surface under the action of centrifugal forces. This eliminates secondary oxidation of the metal in the mold. While the casting solidifies the liquid flux prevents heat loss from the free surface, facilitates directional crystallization of metal, and consequently, helps in more complete removal of nonmetallic inclusions, undesirable impurities, and gases.

The quality of experimental blanks made from BrAZhNMts 9-4-4-1 bronze by the centrifugal casting process according to the new technology was studied using ring-type specimens cut from the end faces of the castings.

The mechanical properties of the experimental castings were determined using tangential and radial (short) specimens. The results of mechanical tests (see Table 1) show that the mechanical properties of tangential and radial specimens are practically identical.

Tests showed that the mechanical properties of the experimental castings were higher than those specified in the standards for cast cylindrical blanks made of aluminum bronze.

Metal from each layer along the casting thickness was analyzed chemically to determine whether there was segregation of the various elements included in the bronze composition. The results of chemical analysis are shown in Table 2. It can be seen that the chemical composition of the metal across the casting cross-section is comparatively uniform.

Metallographic investigations of the fracture, macrostructure, and microstructure of metal from the experimental castings were conducted to establish the nature of crystallization, to locate casting defects, and to determine the phase composition of the metal along the casting cross-section.