Coaldust replacement as a greensand additive


Introduction
Coaldust is used extensively as an additive to clay bonded moulding sands to improve the surface finish of iron castings. The amounts of coaldust used for this purpose vary from 2% for small thin sectional castings up to 10% for large heavy sectional castings.

The casting surface defect which results from using insufficient amounts of coaldust is known as “burn on”. When this occurs a tenaceous bond exists between the metallic casting surfaces and the moulding sand. This adhering sand is difficult to remove, and close examination shows that liquid metal has penetrated the adjacent sand layer producing a rough unacceptable surface finish.

It is generally believed that at metal pouring temperatures, there is a reaction between iron oxide on the liquid metal surface and silica of the moulding sand, producing fusible iron silicates of the general form;

\[
\begin{align*}
\text{SiO}_2 + \text{FeO} &= \text{FeSiO}_3 \\
\text{SiO}_2 + 2\text{FeO} &= 2\text{Fe}_2\text{O}_3\cdot\text{SiO}_2
\end{align*}
\]

There has been a considerable amount of research to explain the mode of action of coaldust in preventing burn on. However, the general lack of agreement was responsible for the emergence of three theories. The gas cushion theory suggests that gas evolved from coaldust during the pouring process, produces a gas cushion between the mould walls and the molten iron, thus preventing their interaction.

The reducing atmosphere theory assumes that a reducing atmosphere is produced in the mould, thus inhibiting the oxidation of iron to iron oxide.

The lustrous carbon theory suggests that during the pouring of molten iron a layer of lustrous carbon is deposited from the heavy hydrocarbons of the coaldust, thus preventing the wetting of silica sand by molten metal and, therefore, inhibiting iron silicate reactions.

In the early 1960s, due to both technical and environmental reasons, the foundry industry felt the need for coaldust replacement. However, with three apparently diverging theories, the industry was not in a very strong technical situation to develop suitable substitute materials. The mid-1960s saw publications by many investigators which showed that metallostatic pressure was always sufficient to prevent the formation of a gas layer in a normally permeable mould, furthermore mould atmosphere was never completely oxidizing nor reducing. The conclusion was reached that the amount of lustrous carbon produced was the critical factor. Bindernagel developed a rapid and simple method for determining the ability of carbonaceous materials to produce lustrous carbon. This prompted many foundry supply companies and a few oil companies to develop coaldust replacement products, these being of three types, liquid products, solid products, and carbonaceous material/clay blends. Current trade literature relating to these products claims dust freedom, bentonite economy, smell and smoke free, lower sand mix moisture levels, and smaller additions.

However, it has been found from practical experience that there is less dust, but at the same time more smoke and fume. Smaller carbonaceous addition levels may be made, but there is no overall bentonite economy.

Surface finish effects
Many investigations have shown that the amount of lustrous carbon produced is the critical factor when putting the three coaldust theories in perspective. The test devised by Bindernagel is most effective in determining the lustrous carbon producing ability of a carbonaceous material.

Test method
The apparatus is made of quartz glass and consists of a cylindrical tube with a mating crucible at one end and a small gas escape hole at the other. The tube is loosely packed with quartz glass wool to simulate moulding sand. Both tube and crucible are weighed, and the crucible charged with a test specimen. The tube is then heated in a muffle furnace to 950°C, drawn to the mouth of the furnace and mated with the charge crucible. The whole unit then being replaced in the furnace for two minutes. During this time the carbonaceous specimen gasifies to deposit a layer of lustrous carbon on the quartz glass wool. By simply reweighing the tube, the lustrous carbon deposit can be found from

\[
\% \text{L.C.} = \frac{\text{change in tube weight}}{\text{original specimen weight}} \times 100
\]

Typical test results for some carbonaceous products are shown in Table I.

Casting trials
When casting trials were carried out to find the correct
Coal dust replacement as a greensand additive

amount of coal dust to produce a smooth, clean, casting surface finish, (using a wedge shaped casting to indicate the effects of varying section thickness), 5% coal dust sand mix addition level was found to give the optimum surface finish. When considering the lustrous carbon producing ability of moulding sand as a whole, to obtain a smooth casting surface finish, the moulding sand would require a 5% addition of a coal dust which produced 7% of its own weight of lustrous carbon (Table I), giving such a greensand mix a lustrous carbon index of $7 \times 5 = 35$. It is, therefore, possible to divide this required index of 35 by the lustrous carbon producing ability of a particular additive in order to determine the necessary addition level to achieve casting smoothness. These addition levels are also shown in Table I.

![Lustrous carbon test apparatus](image)

**Fig. 1 Bindernagel's test apparatus**

<table>
<thead>
<tr>
<th>Material</th>
<th>% Lustrous carbon</th>
<th>Required addition level (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal dust A</td>
<td>7.00</td>
<td>5.00</td>
</tr>
<tr>
<td>Coal dust B</td>
<td>6.15</td>
<td>5.70</td>
</tr>
<tr>
<td>Liquid prod C</td>
<td>47.00</td>
<td>0.75</td>
</tr>
<tr>
<td>Liquid prod D</td>
<td>41.60</td>
<td>0.85</td>
</tr>
<tr>
<td>Liquid prod E</td>
<td>46.00</td>
<td>0.75</td>
</tr>
<tr>
<td>Blend prod F</td>
<td>6.40</td>
<td>5.50</td>
</tr>
<tr>
<td>Solid prod G</td>
<td>54.00</td>
<td>0.65</td>
</tr>
</tbody>
</table>

**Table I**

![Graph: Bonding strength of heated materials](image)

**Fig. 3 Bonding strength of heated materials**

![Graph: Relationship between bonding strength and sand mix composition](image)

**Fig. 2 Relationship between bonding strength and sand mix composition**

Effects on bonding properties

There seems to be a lack of technical information dealing with the effects of carbonaceous sand additives on bonding clays. Some foundry supply companies promote trade literature illustrating the effects of coal dust replacement products on bonding clay under room temperature testing conditions. However, such

![Graph: Clay degradation as a function of temperature](image)

**Fig. 4 Clay degradation as a function of temperature**
information can be somewhat misleading as it is based upon the effects of adding various amounts of these products to a standard greensand mix under room temperature testing conditions, i.e., no information is offered of what the effects would be under metal pouring conditions. This type of graphical relationship is shown schematically in Fig. 2.

However, if both coaldust and coaldust replacement materials are compared for their effects upon sand bonding properties under conditions of thermal cycling, then they show a completely different trend of results. These results (shown in Fig. 3) are of course more relevant than those of figure two as they do actually simulate metal casting conditions.

If the relationship in Fig. 3 is further explored by simply heating samples of bonding clay and coaldust or bonding clay and replacement material the clay activities in relation to temperature are as shown in Fig. 4.

Microscopy
Fig. 5 illustrates a greensand, containing replacement product C and having been heated up to 500°C for one hour.

Conclusions
1. The lustrous carbon producing potential of a sand mix is the most important factor when considering casting surface finish.

2. Coaldust is a poor lustrous carbon producer, and due to their superior lustrous carbon production, some replacement products may be added to greensands at much lower levels than coaldust for the same surface finish effects.

3. Generally all-carbonaceous sand additives have a damaging effect upon bonding properties when subject to casting temperatures. Some replacement products are worse than coaldust in this respect.

4. Coaldust replacement products do produce less dust at the sand milling stage, but generally more smoke and fume at the casting knock out stage.

5. Microscopy illustrates the "balling up" of inactive clay on the sand grain surfaces, as a consequence of thermal treatment and the presence of a coaldust replacement product.

6. In respect of casting surface finish, the general sand mix volatile test should be supplemented by the lustrous carbon test, in order to distinguish between useful lustrous carbon forming volatiles and general foundry atmosphere pollution.

References
5. General trade literature.
Fig. 5 The sand-clay bond as affected by temperature