A preliminary note on the thermal degradation of greensand

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Synopsis

The thermal breakdown of a foundry greensand has been measured using thermogravimetry. Four distinct regions of weight loss have been identified; moisture loss, the loss of volatiles from a natural coal dust in a coal dust substitute, the loss of synthetic organics from the substitute and the loss of chemisorbed water from the clay in the greensand. Phenolic urethane core sand has shown a distinctive pattern of weight loss not seen in the other constituents. It is thought that this may lead to a method for measuring the amount of core sand in greensands.

Background

Greensand moulding remains the most common method of making iron castings and the thermal breakdown of greensand plays a vital role in the production of quality castings. When greensand is heated by molten metal the various constituents must produce the gases within the mould cavity which are necessary to ensure that the castings have a good surface finish, and that they are free from oxidation and metal penetration. It is also widely believed that the absorption of gases arising from the breakdown of greensand, by the metal, may promote the formation of defects such as pinholes and fissures.

The major constituents of greensand which produce gases are moisture and organic additives such as coal dust or coal dust substitutes. Organic residues from core materials will also produce gaseous compounds on heating.

The purpose of the preliminary work described in this note was to establish the thermal breakdown pattern of greensand using thermogravimetry (TG). It is the first step towards understanding more clearly the role of the various constituents and their breakdown products in the casting process and towards deriving a quantitative method for measuring the amount of core residue materials in greensand. The work forms part of the BCIRA research programme on mould-metal reactions. It should be noted that the results have been obtained for one particular greensand with a limited number of samples. The technique is however expected to give useful results with other greensands.

Thermogravimetry (TG) is a technique in which the weight of a sample can be measured continuously during accurately controlled heating, isothermal or cooling cycles. This enables the amount of material lost through combustion and vaporisation (including drying), and the temperature at which these processes occur to be measured. The temperature range available is 20°C to 1550°C with simultaneous thermal analysis (STA) equipment at BCIRA. Measurements can be carried out in various atmospheres: oxidizing, reducing or inert. Thus, more detailed and precise measurements of weight changes similar to loss-on-ignition, volatile matter and moisture content, which are widely used in foundries, may be made.

Method

Samples of a greensand obtained from a production foundry and its individual constituents (coal dust substitute and clay) were analyzed using TG. Samples of coal dust and a phenolic urethane coresand were also analyzed for comparison. The samples (approximately 1g) were heated from 20°C to 1000°C in a nitrogen atmosphere at 20°C per minute. Weight loss (TG) curves were obtained over the temperature range and were differentiated to produce dTG curves which showed the rate of weight loss at any particular temperature.

Results and discussion

Figure 1 shows the TG and dTG (rate of weight loss) curves for the foundry greensand. The TG curve can be divided into two general regions of weight loss. The first occurs at about 100°C and represents the loss of moisture. The second region of weight loss, 400°C to 900°C, represents three weight loss processes. These are seen more clearly in the dTG curve as three troughs (450°C, 650°C and 780°C). The bottom of each trough represents the temperature at which maximum rate of weight loss occurs.

Figure 2 shows the TG and dTG curves for a sample of the coal dust substitute used in the greensand. This is a material which consists of natural coal dust and other organic additives. The dTG curve shows two troughs, that is, two

Fig. 1 TG and dTG curves for a foundry greensand
weight losses. The first represents the loss of moisture (approx. 50°C) and the second, at about 650°C is thought to be due to the loss of the organic additives in the substitute. It can also be seen (Figure 2) that there is a small shoulder at about 450°C. All three weight changes coincide with troughs in the dTG curves for the greensand sample (Figure 1), indicating that the troughs in the greensand trace at 450°C and 650°C can be identified as weight losses from the coal dust substitute.

Figure 3 shows the dTG curve for a natural coal dust. This trace again shows two weight loss troughs. The first represents the loss of moisture from the sample, approximately 50°C, while the second, which occurs at about 480°C, represents the loss of volatile organics from the coal dust. This trough agrees well with the shoulder at about 450°C observed in the dTG for the coal dust substitute (Figure 2).

A comparison of Figures 2 and 3 highlights the differences between the breakdown characteristics of the coal dust substitute and a natural coal dust. It is fair to assume that the rate of weight loss gives a good indication of the rate of gas evolution. The temperature of evolution determines at least in part how the gases produced from the heated sand will interact with the cooling (solidifying) metal. A further important parameter to be considered in future work is the chemical composition of the gases evolved.

Figure 4 shows the TG and dTG traces from a sample of the clay used in the greensand. There are again two weight loss stages. As in the above samples there was a loss of moisture at 100°C, which in this case represents the loss of the physi-sorbed water or water of crystallization of the clay. The other weight loss is the loss of the chemi-sorbed water of the clay at 720°C. This trough can be seen to coincide reasonably closely with the third trough in the greensand dTG trace (Figure 1).

Phenolic urethane core sand has been shown to lose weight continuously between 200°C and 900°C with a distinctive double trough in the dTG curve between 200°C and 350°C. These troughs were not apparent in the curves for the greensand or its constituents. This suggests that measurement of the weight loss in the temperature range 200 - 350°C, or an analysis and measurement of the volume of gases evolved, could provide the basis for a quantitative method of measuring the amount of phenolic urethane core sand in a system greensand. This idea could perhaps then be extended to other core sands. The immediate need is to determine whether a meaningful calibration can be made and this aspect is being investigated further within the collaborative programme of work.

All of the above results are summarized in Table 1 for easy comparison.

It has been shown previously that thermal analysis can be coupled with mass spectrometry (MS) to provide a chemical analysis of the gases produced during the thermal breakdown of moulding materials. It is hoped that by using TG-
MS it may be possible not only to identify the gaseous compounds produced but to measure the amount of the source materials of the gases, that is to measure the amount of coal dust, coal dust substitutes and any core sand in the greensand.

**Practical implications**

1. Thermogravimetry provides a useful means of obtaining a detailed analysis of the thermal breakdown of greensand. The major constituents can be identified from dTG curves.
2. Thermogravimetry can be used to distinguish between coaldust substitutes and natural coaldust.
3. The weight loss from phenolic urethane core sand is distinctive and could provide the basis of a quantitative method for determining the amount of this type of core residue in a greensand.
4. It is envisaged that the use of TG-MS may enable minor organic compounds present in greensand, such as core binders, to be identified and quantified.

**Reference**