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REPORT

6MPM63 Thermal Conductivity of Mould Materials

T1/M01 Review current sand casting practices and requirements for thermal conductivity and thermal diffusivity data of moulded foundry sands in the Sand Casting Industry.

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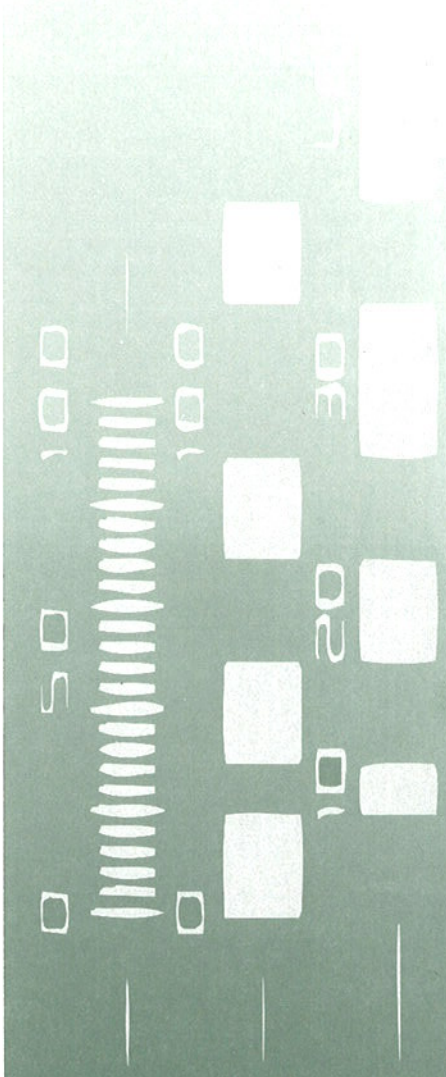

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6MPM6.3 Thermal Conductivity of Mould Materials

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ABSTRACT:

The data requirements for sand moulds and current practices used in the Sand Casting Industry have been reviewed as part of the DTI project 6MPM6.3 The Thermal Conductivity of Moulded Foundry Sands. The principal findings are listed below.

- Sand casting practice and in particular the mould construction vary amongst foundries. The moulded foundry sands used may have different compositions, particle sizes, binder concentrations and packing densities. This limits the transferability of mould patterns between foundries.
- All foundries contacted stated they could make use of better thermal conductivity and heat absorbing property data of mould materials.
- Measurement of the thermal conductivity and heat absorbing properties are difficult because of the complex nature of the heat flow through sand mould materials and the variable nature of mould materials.
- The use of a pulse transient hot wire technique is most suitable method for the measurement of the thermal properties of moulded foundry sands.

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T1/M01 Review current sand casting practices and requirements for thermal conductivity and thermal diffusivity data of moulded foundry sands in the Sand Casting Industry.

The data requirements for sand moulds and current practices used in the Sand Casting Industry have been reviewed as part of the 6MPM6.3 Thermal Conductivity of Moulded Foundry Sands Project. The cooling rate of a casting is critical in determining the mechanical properties of a casting. To predict and control the cooling rate of a casting, knowledge of the thermal properties and the factors that affect the thermal properties of the mould material are required. This review is being carried out in order to understand the current thermal property requirements of the Sand Casting Industry with respect to mould materials. It is based on the following:

1. The National Physical Laboratory (NPL) report CMMT(A)110[1]. This is a general review of the British Casting Industry carried out by NPL with support from the Casting Development Centre (CDC). The report was in four sections.
   - An industrial survey. 250 companies in the British Casting Industry (Sand, Investment, Gravity Die) were polled by CDC to assess their data requirements and casting process set up.
   - A review of requirements for thermophysical properties of mould materials by NPL
   - A review of thermal property data for sand and investment moulds by NPL
   - A review of methods for the measurement of sand, investment and die mould materials.

If required a copy of report CMMT(A)110[1] is available from NPL on request.

2. Works visits to sand casters.
3. Discussions with foundry engineers.
4. Published literature since the completion of the original NPL review[2-12].

The principal findings of the previous review and this review are summarised below. Information gained from the works visits reiterated these findings. Little new or relevant data were obtained from the literature search of work since the 1998 review.

Sand Casting Process

In general, to make a sand casting, several sand mould segments are made and assembled to produce the final casting. Wood or metal patterns of the mould half are fabricated, placed in a box and packed using a sand treated with a binder. Often a face-coat is applied to the metal mould side to improve the casting surface finish. Cores, usually made from resin-bonded sand, are used to define the internal geometry of the casting. The top segment of the mould is then aligned with the bottom segment and the metal is then poured. This process can be utilised in short runs or batches, as used in a jobbing foundry, or highly automated and high volume as used in a repetition foundry.

Mould Materials

The principal sand materials used in the sand casting industry are silica, chromite, zircon and to a lesser degree silicon carbide. Binder systems are too numerous to list but most are covered by the following categories: alkaline phenolic, furane, phenolic urethane, resin shell, silicate and green (water). Also the amount of recycled sand used in a sand mix, and how the sand is recycled, are issues with respect to the thermal properties of the sand. Therefore, both can be considered as thermal property variables. There are some recent articles in the literature addressing issues of sand reclamation and use[3,4,8].

Although based on the same material, usually silica, most sand compositions used in the casting industry are unique to the caster. Also the sands used by different Casters are likely to have different particle sizes and be packed to different densities. These "different" sands will have different thermal properties. **This limits the transferability of pattern equipment from one foundry to another.**

Heat Transfer in Sand Moulds

The heat transfer through a sand mould is extremely complex[1,11]. It may contain contributions from the thermal conductivities and radiative properties of the constituent mould materials as well as diffusion and mass transport of the mobile or less stable materials in the mould. The relative size of these contributions will be very dependent on nature of the sand (composition, packing density etc.) and the temperature of the material being cast. In addition, the heat transfer is further complicated by the enthalpic release or adsorption of energy as binders (chemical or water) burn off. There are no models available that are able to take account of all such variables. **The solidification models currently available are able to account for some of the complex behaviour of the heat transfer properties of mould materials by utilising effective thermal conductivities and heat capacities of the mould materials[12].**

Although not highlighted in the CMMT(A)110[1] report, it is worth noting that the majority of work appearing in the literature pertinent to the Sand Casting Industry is focused on the modelling of heat transfer boundary conditions at the metal mould interface. Most of this work is being carried out by Pehlke's[13] group at the University of Michigan in the USA and Rappaz's[14] group in Lausanne in Switzerland. In the long term this information will improve the predictions of solidification modelling by improving the understanding of heat flow in a casting. At present it does little to help a caster to engineer his heat extraction requirements as thermal property data of the mould materials as a function of temperature, binder and porosity, are key[11].

Property Measurement Methods

In report CMMT(A)110[1] Mills was of the opinion that a hot wire or line source method was most suited to measuring the thermal conductivity of sand mould materials. The robustness of the technique and its high temperature capability were the principal reasons for this judgement. In principle, the author agrees with this assessment although it is difficult to envisage any currently available techniques[15] that could be used in real sand systems and on plant. **It is envisaged that a method based on the hot wire developed specifically for mould materials is required if significant improvements in the data are to be obtained[17].**

Thermal Property Data

It was clear from the returns to the CDC questionnaire [1], the Mills data review[1] and the feedback from the works visits, that **thermal property data are required for mould materials.**

In the CMMT(A)110 report[1] Mills reviewed and presented thermal conductivity and heat capacity data available for sand mould materials as a function of temperature, density, porosity, expansion, binder and grain size. Issues such as the effect of radiation on the mould heat transfer where discussed. The data presented had a high uncertainty associated with them and may be best considered as semi-quantitative values.

The CDC questionnaire (confirmed by works visits) demonstrated that should better thermal property data be available, Casters would make more use of them. Property data would be useful for selecting specific mould systems to engineer heat extraction or enabling better prediction of times for casting "knockout" or in improving solidification modelling

predictions. Also, as pointed out in the works visits, better **thermal property data may be critical in achieving any success in the drive to make thinner walled castings in the Aerospace Industry.**

For thermal property data to be used by the Casting Industry it would need to be in a "suitable" form. Requested suitable forms were:

- data sheets with recommended or evaluated data for the mould materials.
- data files in a format that is compatible with the solidification software currently in use.

The current sources of thermal data used for mould materials are from journals, text books, in-house measurements (rare) or databases supplied with the solidification packages. **It was interesting to note that some Casters viewed the population of databases for the solidification software as not their problem but that of the software suppliers. This contrasts with some software producers, where data provision is the customers responsibility.**

Due to the limited experience of handling the current solidification modelling packages the author cannot give a clear view of the capability of the current solidification models to incorporate thermal property data. Information obtained from the plant visits and other sources imply that data may be incorporated as effective thermal properties, as outlined in heat transfer in sand moulds[12,16].

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