Expansion and Deformation Characteristics of Synthetic Molding Sands at Elevated Temperatures

S. V. Sambasivam, Research Scholar
H. Md. Roshan, Assistant Professor
Department of Metallurgy
Indian Institute of Technology
Madras, India

Abstract

The details of an experimental technique in which an inductive displacement transducer is attached to a high-temperature testing apparatus to determine the linear thermal expansion and hot deformation of synthetic molding sands at elevated temperatures are presented in this paper. The influence of variables such as clay content, moisture content, size of sand, coal dust, silica flour and wood flour on linear thermal expansion and hot deformation has been determined and presented here.

Introduction

Expansion defects such as sears, buckles and rat tails in castings are caused by undesirable expansion and deformation characteristics of molding sands at elevated temperatures. To minimize such defects, sand must be selected and processed so as to obtain the lowest expansion possible. The sand should also have a hot deformation greater than the expansion at all temperatures through which the sand must pass when it is in contact with the molten metal. A systematic investigation of the expansion and deformation characteristics of various sand systems with possible combination of different ingredients normally found in practice enables the formulation of sand systems which are least prone to expansion defects.

Experimental Details

The following sand systems are studied:

1) silica sand M (avg grain size: 0.192 mm) + 6% bentonite B
2) silica sand M + 4% bentonite B
3) silica sand M + 8% bentonite B
4) silica sand M + 10% bentonite B
5) silica sand M + 6% bentonite B (25% compactability)
6) silica sand M + 6% bentonite B (55% compactability)
7) silica sand M + 6% bentonite B + 5% silica flour
8) silica sand M + 6% bentonite B + 10% silica flour
9) silica sand M + 6% bentonite B + 3% coal dust
10) silica sand M + 6% bentonite B + 6% coal dust
11) silica sand M + 6% bentonite B + 9% coal dust
12) silica sand M2 (avg grain size: 0.282) + 6% bentonite B
13) silica sand M3 (avg grain size: 0.215) + 6% bentonite B
14) silica sand M + 6% bentonite B + 1% dextrin
15) silica sand M + 6% bentonite B + 1.5% dextrin
16) silica sand M + 6% bentonite B + 2% dextrin
17) silica sand M + 6% bentonite B + 0.5% wood flour
18) silica sand M + 6% bentonite B + 2% wood flour

The sands are mixed in a laboratory sand muller with a batch capacity of 3 kg. Sand and bond additions are dry milled for 1 min before adding water and are then milled for 10 min. In all experiments with the above sand systems (except 5 and 6), the moisture content is so adjusted that the sand has a compactability value of 50%. The mixed sand is sieved through 3-mm openings and then held in air-tight plastic bags for at least 1 hr before testing for properties.

Details of the experimental setup to measure linear thermal expansion and hot deformation of synthetic molding sands are shown in Fig. 1. Here an inductive displacement transducer is attached to the moving compression post of the high-temperature sand testing apparatus. The output of the transducer is fed into an electronic strip chart recorder through an amplifier, to continuously measure either expansion or deformation.

Test Specimen

A sand specimen 11 mm in diameter and 20 mm in height is prepared in a hand press by compacting to a density of a standard AFS specimen with 3 rams. The size of the specimen permits rapid penetration of heat by radiation that actually occurs in practice. The diameter of the specimen corresponds to approximately double the thickness of the sand shell formed in the mold when it is subjected to radiation heat from molten metal. The properties of this layer are of considerable significance in the formation of expansion defects.

Measurement of Linear Thermal Expansion

The test specimen on a cylindrical silica disc is placed on the movable bottom compression post and raised until the convex silica cover disc placed on the top of the sand specimen just touches the top fixed compression post in the apparatus. This
position is set as zero reading on the strip chart recorder. The furnace set for a temperature of 1000°C (1832°F) is lowered onto the specimen and switched on. As the furnace temperature rises, the specimen gets heated up and the resulting expansion is continuously recorded on the strip chart recorder.

Measurement of Hot Deformation

The test specimen is placed between the compression posts of the apparatus. The furnace preheated to the desired temperature is lowered onto the specimen. The soaking time before the specimen is loaded in compression depends on the temperature at which the test is carried out and is determined from Fig. 2. This ensures that the specimen attains the desired furnace temperature before the test is carried out. As the specimen is loaded in compression, the deformation is continuously recorded. Maximum deformation before the specimen fails is determined at different temperatures.

Test Results and Discussion

Some casting defects are caused by failure of surface layers in the mold as a result of heat from the molten metal. The most important casting defects in this group are rat-tails, buckles and scabs. These are called expansion defects, as they are caused by the expansion characteristics of the mold material.

Sand grains expand under the influence of heat. This is especially more pronounced in the case of silica sand grains which undergo transformation in structure with accompanying increase in volume around 573°C (1064°F). Expansion characteristics of synthetic molding sands of various compositions should be determined to permit formulation of sand systems least prone to expansion defects. Further, continuous determination of linear thermal expansion can be used as a simple method of controlling the quality of system sands in foundries.

A molding sand compact undergoes a certain amount of deformation under compressive load before it fails. The extent to which the sand deforms is a function of its composition and the temperature. The ability of sand to deform and permit the rearrangement of sand grains without fracture plays an important role in the control of expansion defects. When a cope surface of the mold is exposed to the radiation heat from the molten metal in the drag mold, the surface layers initially expand. Maximum expansion occurs around 400-600°C (752-1112°F), during initial stages of pouring. Thus the deformation at 400-600°C (752-1112°F) is significant during initial stages when the expanding layer is near the surface. However with the increase in time, the expanding layer moves below the surface while there will not be further expansion in the surface layers although the temperature is more than 600°C (1112°F). The forces due to the expansion of internal layers exert a force on the surface layers. Here the deformation characteristics of sand beyond 600°C (1112°F) are of significant value. Thus the data for hot deformation of synthetic molding sands at various temperatures is important in the production of defect-free quality castings.

Influence of Bentonite

The influence of bentonite on the linear thermal expansion of sand systems at various temperatures is shown in Fig. 3. The amount of bentonite is varied from 4-10%. A study of this figure shows that the expansion increases gradually with the increase in temperature, reaches a maximum around 600°C (1112°F) and remains fairly constant with further increase in temperature. The expansion that accompanies α-β transformation is not sharp but it is only gradual. Increasing the amount of bentonite causes reduction in the linear thermal expansion. Expansion decreases by about 0.10% when the bentonite content is varied from 4-10%.

The influence of bentonite on the hot deformation of sand systems at various temperatures is shown in Fig. 4. This figure shows that the hot deformation does not vary appreciably up to 600°C (1112°F), beyond which there is a steep rise in the deformation up to 1000°C (1832°F). The quantity of bentonite does not have an appreciable effect on the deformation up to a temperature of 600°C (1112°F). At higher temperatures, hot deformation increases with increase in the amount of bentonite in the sand mixture.

Influence of Moisture

Figure 5 illustrates the influence of moisture expressed in terms of compactability on the linear thermal expansion of sand systems at various temperatures. This figure shows that the expansion increases with increase in moisture content. Expansion increases by 0.20% when compactability is varied from 25-55%.

The influence of moisture on the hot deformation of sand systems at various temperatures is shown in Fig. 6. This figure
Fig. 4. Influence of bentonite on hot deformation.

shows that the hot deformation of wet sands is higher than that of dry sands at all temperatures. The hot deformation value of sand is about 0.60% and does not vary appreciably up to 700°C (1292°F). Beyond a temperature of 700°C (1292°F), hot deformation of sands increases rapidly. Hot deformation at 1000°C (1832°F) increases by about 2.25% from the lowest moisture to the highest used in the present investigation.

**Influence of Silica Flour**

The influence of silica flour on the linear thermal expansion of sand systems bonded with 6% bentonite is shown in Fig. 7. This figure shows that the expansion increases with increasing amounts of silica flour addition to the sand system. The expansion increases by 0.07% for a silica flour addition of 10% to the bentonite bonded sand system.

Figure 8 illustrates the influence of silica flour on the hot deformation of sand systems at various temperatures. A study of this figure shows that the presence of silica flour in the sand systems does not alter the deformation behavior of bentonite bonded sand systems. In fact there is a slight decrease in the amount of deformation at 1000°C (1832°F).

Fig. 5. Influence of moisture on linear thermal expansion.

Fig. 6. Influence of moisture on hot deformation.

Fig. 7. Influence of silica flour on linear thermal expansion.

Fig. 8. Influence of silica flour on hot deformation.

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Influence of Coal Dust

Figure 9 shows the influence of coal dust on the expansion of 6% bentonite bonded sand systems. The amount of coal dust is varied from 0-6%. Figure 9 shows that the expansion decreases with the presence of coal dust in the sand system. The expansion decreases by 0.1% when coal dust is increased in the sand system from 0-6%.

The influence of coal dust on hot deformation of sand systems at various temperatures is shown in Fig. 10. This figure shows that the presence of coal dust does not affect the deformation-temperature characteristic up to 600°C (1112°F). Beyond 600°C (1112°F), hot deformation is higher for sand systems containing coal dust.

Influence of Grain Size

Figure 11 shows the influence of grain size on the expansion of 6% bentonite bonded sand systems at various temperatures. The grain size is varied from 0.192-0.282 mm. Figure 11 illustrates that the expansion is not influenced appreciably with variation in grain size within the range of 0.192-0.282 mm.

Figure 12 shows the influence of grain size on hot deformation of sand systems at various temperatures. This figure illustrates that sand compacts with coarser grains are capable of undergoing higher deformation at 1000°C (1832°F). Deformation values up to 700°C (1292°F) are independent of grain size.

Influence of Dextrin

The influence of dextrin on the linear thermal expansion of 6% bentonite bonded sand systems at various temperatures is shown in Fig. 13. The amount of dextrin is varied from 0-2%. Figure 13 shows that the expansion decreases with increase in dextrin addition. The expansion decreases by 0.15% when the dextrin content is increased from 0-2% in the sand system.

Figure 14 illustrates the influence of temperature on hot deformation of sand systems with and without dextrin. This figure shows that the presence of dextrin in the sand system increases hot deformation beyond 700°C (1292°F). However, it does not have an appreciable effect up to a temperature of 700°C (1292°F). Figure 14 further indicates that increasing amounts of dextrin cause a reduction in the hot deformation at 1000°C (1832°F) at the time of failure of the specimen. It is observed during the recorded progress of the experiment that the sands containing higher amounts of dextrin have a higher rate of deformation but their hot compression strength is very low. The low strength of sand causes the failure of sand specimen at lower deformation values. In fact the deformation at failure of sand specimen containing 2% dextrin at 1000°C (1832°F) is lower than a system free from dextrin.

Influence of Wood Flour

The influence of wood flour on the expansion at various temperatures of 6% bentonite bonded sands is shown in Fig. 15. The amount of wood flour is varied from 0-2%. Figure 15 shows that the expansion decreases with increasing additions of wood flour. The expansion decreases to an extent of 0.25% when the wood flour is varied from 0-2%.

Figure 16 illustrates the influence of temperature on hot deformation of sand systems with and without wood flour. This figure shows that the presence of wood flour in the sand system increases hot deformation beyond 700°C (1292°F) and exerts no influence up to a temperature of 700°C (1292°F).

A study of the above observations indicates that all the sand systems have a similar expansion-temperature characteristic curve independent of their composition. The linear thermal
Fig. 12. Influence of grain size on hot deformation.

Fig. 13. Influence of dextrin on linear thermal expansion.

Fig. 14. Influence of dextrin on hot deformation.

Fig. 15. Influence of wood flour on linear thermal expansion.

Fig. 16. Influence of wood flour on hot deformation.
expansion gradually increases with increase in temperature, reaches a maximum around 600°C (1112°F) and remains constant with further increase in temperature. The maximum expansion attained depends on the composition of the sand mixture. Wood flour, dextrin and coal dust are in the decreasing order of their ability to reduce expansion in the range of additions investigated.

A study of the above observations further indicates that all the sand systems investigated show similar deformation-temperature characteristic curves, independent of their composition. The hot deformation is not altered appreciably up to a temperature of about 700°C (1292°F), beyond which there is a steep rise in hot deformation of sand systems. Hot deformation of sand systems is independent of their composition up to a temperature of 700°C (1292°F). Beyond 700°C (1292°F) hot deformation invariably increases with the presence of additives, the actual value depending on the type and amount of additive used.

Conclusions

1) Synthetic molding sands, independent of their composition exhibit a characteristic expansion-temperature curve. Linear thermal expansion gradually increases with increase in temperature, reaches a maximum around 600°C (1112°F) and remains fairly constant with further increase in temperature.

2) Increasing the amount of bentonite causes a reduction in linear thermal expansion of molding sand systems.

3) Increasing amounts of coal dust, dextrin and wood flour to bentonite bonded sands reduce their linear thermal expansion.

4) Wood flour, dextrin and coal dust are in the decreasing order of their ability to reduce linear thermal expansion, in the ranges of additions investigated.

5) Increasing moisture content and increasing additions of silica flour to bentonite bonded sand cause a reduction in their linear thermal expansion. Expansion is not influenced appreciably with variation in grain size.

6) Synthetic molding sands exhibit a typical hot deformation-temperature characteristic independent of composition. Hot deformation does not vary appreciably up to a temperature of 600°C (1112°F), beyond which there is a steep rise in deformation up to 1000°C (1832°F). Composition of sand does not affect hot deformation values up to 600°C (1112°F). The variation of hot deformation beyond 600°C (1112°F) depends on composition.

7) Increasing the amount of bentonite increases the hot deformation of synthetic molding sands.

8) The presence of coal dust, dextrin and wood flour in bentonite bonded sand systems increases their hot deformation.

9) Decreasing the moisture content and decreasing the grain size decrease the hot deformation of bentonite bonded sands. Additions of silica flour do not influence their hot deformation.

References