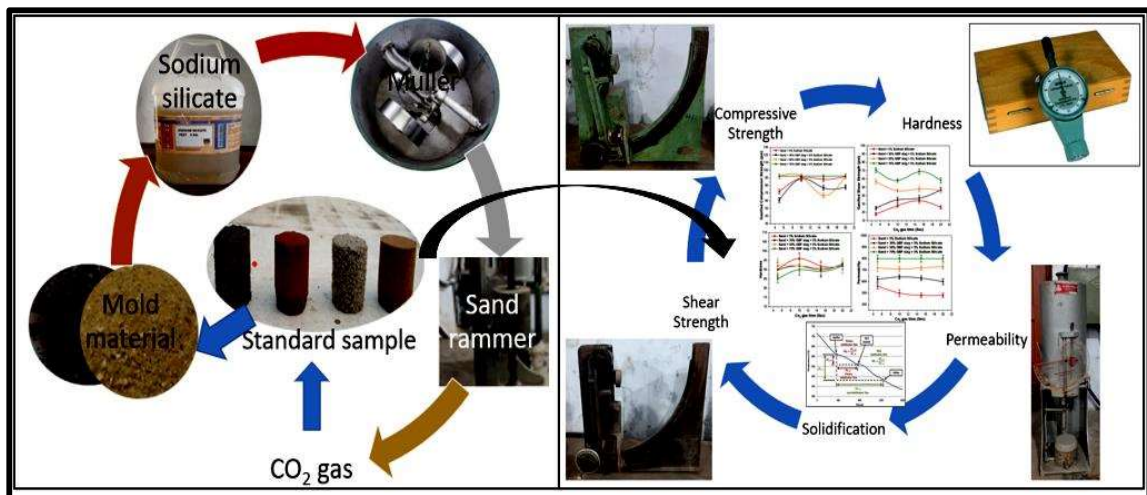


CHAPTER 4

FABRICATION OF SAND- SOLID WASTE MOLD USING CO₂ MOLDING PROCESS AND CHARACTERIZATION AS WELL AS COMPARISON OF MOLD PROPERTIES



4.1 INTRODUCTION

This chapter presents a detailed discussion of the CO₂ molding process, and mold properties such as compressive strength, shear strength, permeability, compactness, and hardness of the fabricated slag-sand mold and compared with the conventional mold properties. Casting A319 alloy in different molds and estimating the solidification rate of alloy cast in different molds with the help of a cooling curve. The details of the tests followed in the present investigation are compressive strength, shear strength, permeability, compactibility of the mold, and solidification behaviour of A319 alloy cast in different molds are also described.

4.2 MOLD PREPARATION

4.2.1 CO₂ molding process

The CO₂ molding procedure was commonly employed in Europe to harden the mold and the core. The CO₂ molding method was comparable to the traditional molding technique, which uses sodium silicate as the binder and clay-free dry sand with a moisture content of less than 3%. Different ingredients, such as starch, were employed to increase the compressive strength, while sugar, wood floor dust, and other ingredients were utilized to increase the collapsibility of the molding sand. Molding sand was rammed around the design in the mold box using the traditional method of mold preparation. With the use of the different methods of CO₂ gas passed on the mold surface are shown in figure 4.1. In accordance with equation 4.1, the CO₂ gas reacts with the sodium silicate contained in the mold to generate silica gel, which is responsible for the mold hardening, where ***SiO₂.H₂O*** Known as a silica gel.



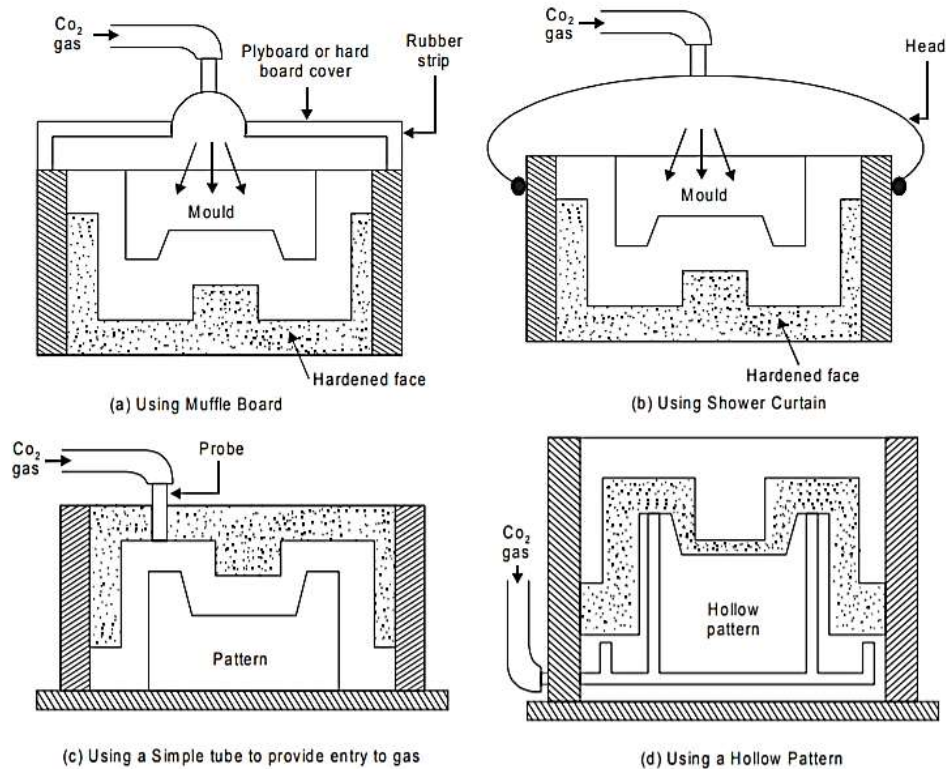


Figure 4.1: CO₂ molding processes[178]

4.2.2 Silica sand- solid waste mold

Industrial solid wastes were combined with natural sand to create a mold using the CO₂ molding technique. Silica sand (SS), alternative molding materials like red mud (RM), blast furnace slag (BS), ferrochrome slag (FS), and olivine sand (OL), as well as a binder like sodium silicate ($\text{Na}_2\text{O}/\text{SiO}_2 = 0.45$), were all used as molding sand ingredients. The conventional cylindrical specimen, which measures 2 inches by 2 inches, was created by manually combining silica sand with several other components, including blast furnace slag, red mud, olivine sand, ferrochrome slag, and 5% sodium silicate as a binding agent. 10% sodium silicate, 2% bentonite, and 2% water were added to red mud mold, and the mixture was stirred for three to four minutes. After thoroughly combining all of the materials by hand, the produced mixture was hammered three times with a sand rammer to

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achieve a standard sample size, as depicted in figure 4.2. Then, for five, ten, fifteen, and twenty seconds, respectively, standard test samples were exposed to CO₂ gas.

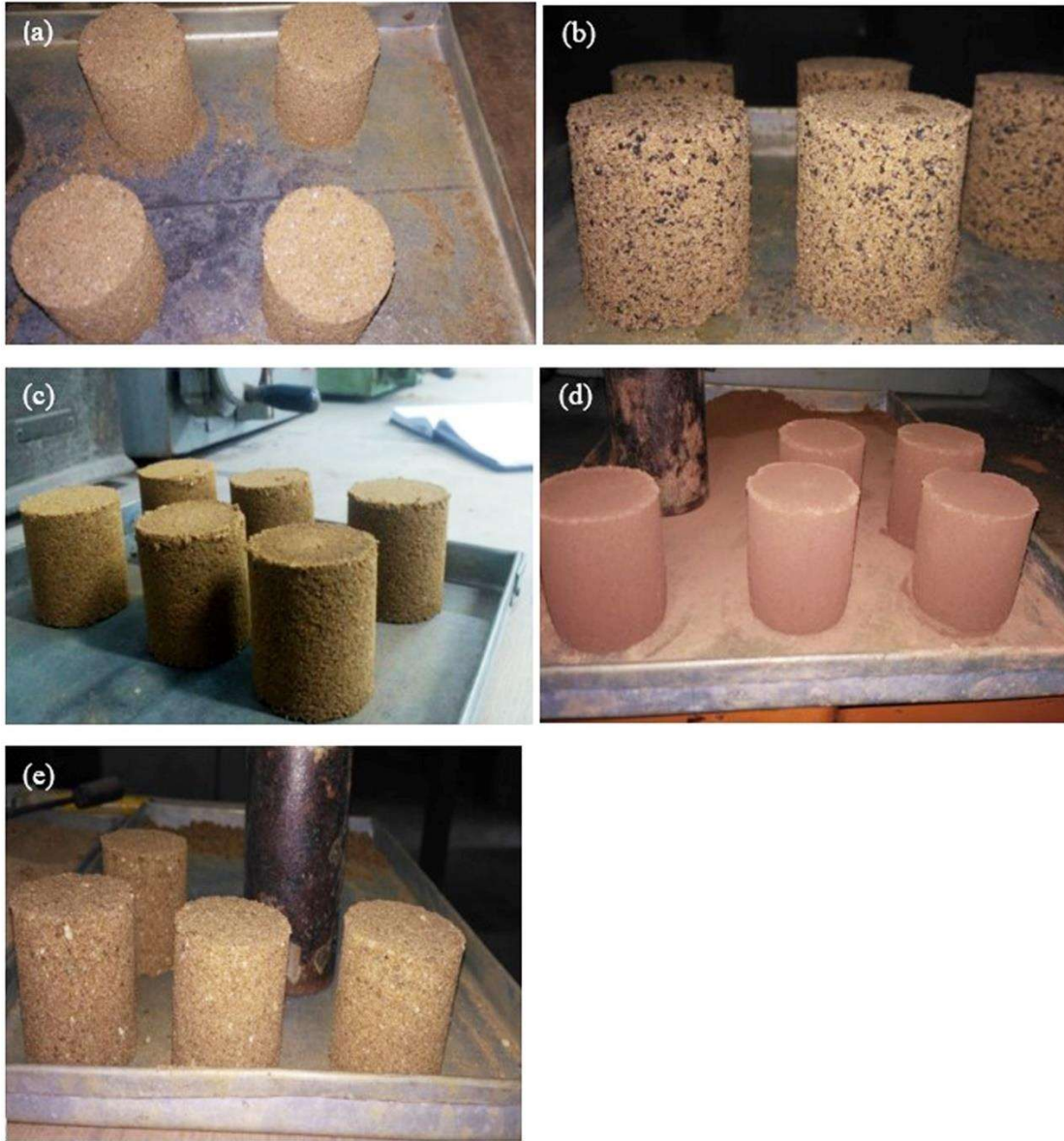


Figure 4.2: Standard size sample of (a) blast furnace slag (b) ferrochrome slag (c) silica sand (d) red mud (e) olivine sand used for the investigation of mold properties

4.3 CHARACTERIZATION

4.3.1 Mold properties

The applicability of the mold used for casting ferrous and non-ferrous alloys depends on the mold qualities. Molten metal is poured into a mold during the casting process, where it cools and solidifies. Hydrostatic pressure was applied to the mold wall during the pouring of the molten metal. Additionally, molten metal raises the mold temperature, moisture evaporates and exerts gas pressure against the mold wall, etc. In this manner, mold qualities are determined by mold properties.

4.3.2 Compressive strength

The standard sample (2inch - 2inch) after ramming was removed from the rammer. The sample was placed in the compression testing machine, where the force acts perpendicular to the cross-section of the sample, and the rate of the axial force increases with the movement of the sample holder until the sample ruptures. At the rupture point corresponding value on the measuring scale was recorded. Consecutive three tests as per standard IS11099-1984 were conducted for each combination and an average value was reported.

4.3.3 Shear strength

The standard sample was taken from the rammer after being rammed three times. The sample was placed in the shear testing machine, where forces act parallel to the cross-section of the sample, and the rate of the force increases with the movement of the sample holder until the sample is ruptured. At the ruptured point corresponding value on the measuring scale was recorded. Consecutive three tests as per standard IS11099-1984 were conducted for each combination and an average value was reported.

4.3.4 Hardness

The standard sample (2inch - 2inch) was taken from the rammer after being rammed three times. The sample was subjected to a hardness tester, where a spring-loaded ball was pressed into the compacted sand mold and the hardness of the mold surface (compaction state) was derived from the penetration depth based on the change in the spring length marked on the dial gauge as a corresponding hardness number. Record that reading consequently three times per sample and an average value was reported.

4.3.5 Permeability

The standard sample (2inch - 2inch) was taken from the rammer after being rammed three times with a sample container placed in the mercury seal of the permeability apparatus. 2000cc of air passes through the sample with the help of a knob present in the permeability meter. As the air passes through the sample, the fluid present in the manometer tube may rise to a certain height. The level of fluid in the manometer tube matches the measuring permeability dial and measures the permeability number of the mold sample. Consecutive three tests as per standard IS10498-1983 were conducted for each combination and an average value was reported.

4.3.6 Compactness

Compactability of mold directly depends on the flowability behavior of molding materials. The compactability of the mold was measured by the change in the height to achieve standard mold specimen size (2inch - 2inch). The specimen tube of dimension (120 mm height and 50 mm diameter) was filled with molding sand to a certain height to achieve a standard sample size of 2 inch - 2 inch after three consecutive ramming. The change in height of the mold sample was used to measure the compaction percentage as per standard IS1918-1966.

4.3.7 Thermal analysis

The solidification behaviour of an alloy can be represented through cooling curves. The informative of the cooling curve are liquidus point, primary solidification point, eutectic point, primary solidification time, total solidification rate, total solidification time, and solidus point as shown in figure 4.4.

Thermal analysis was carried out using a K-type thermocouple inserted in the mold so that it contacts with the cast product A319 during the solidification process as shown in figure 4.3. The data recorder was used to collect the temperature of the interval of 5sec during the solidification process. The time–temperature curve was plotted, which is generally known as the cooling curve. The primary solidification rate is defined as the change in temperature in the range of liquidus to the eutectic with respect to time. During phase transformation from liquidus to solidus, events took place which decide the morphology of primary dendrite, eutectic and secondary phases. The primary dendritic structure characterizes during the primary solidification range whereas the rest of the phase is characterized during the total solidification range. The primary solidification rate (PSR) and total solidification rate (TSR) are calculated using equations 4.2 and 4.3.

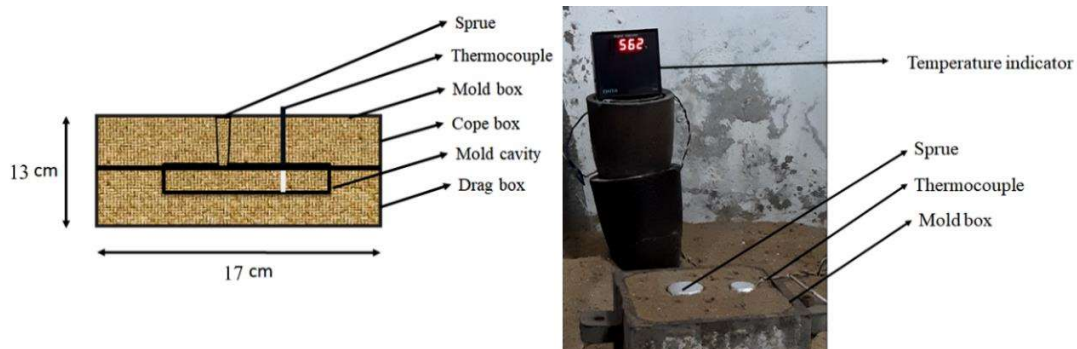


Figure 4.3: Cross sectional view of mold and recording of temperature with thermocouple

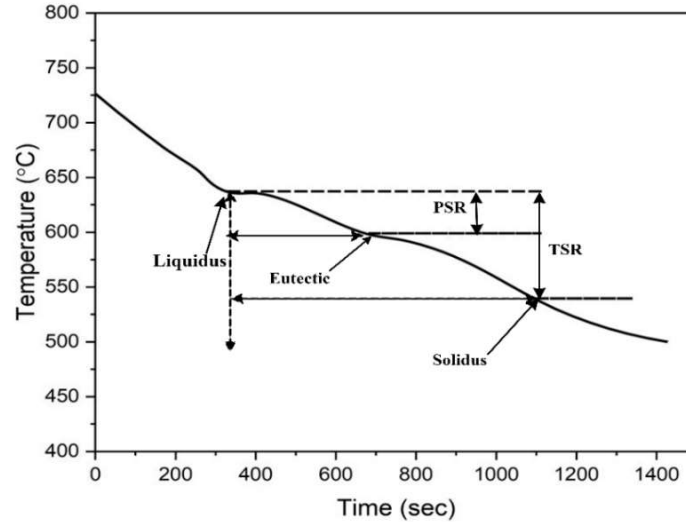


Figure 4.4: Cooling curve

$$PSR = \frac{\Delta T_{l-e}}{\Delta t_{l-e}} \quad (4.2)$$

$$TSR = \frac{\Delta T_{l-s}}{\Delta t_{l-s}} \quad (4.3)$$

ΔT_{l-e} = Temperature difference between liquid-eutectic range

ΔT_{l-s} = Temperature difference between liquid-solid range

Δt_{l-e} = Time difference between liquid-eutectic range

Δt_{l-s} = Time difference between liquid-solid range

4.4 RESULTS

4.4.1 Compressive strength

Figure 4.5 shows the compressive strength of the mold and figure 4.6 shows the rupture of the mold sample during the compressive test. It can be observed from figure 4.5 that the compressive strength of mold varies with respect to CO₂ gassing time as well as the percentage of different solid waste in silica sand mold. The compressive strength of silica sand mold with variation in the gassing time from 5 sec to 20 sec is 72 psi, 80 psi, 88 psi, and 80 psi respectively. It was observed that the minimum value of mold compressive

strength with respect to the CO₂ molding process is 72 psi. So, this is attributed to the feasibility of mold with respect to compressive strength with variation in the percentage of solid waste.

The combination of sand and blast furnace slag shows the highest compressive strength of 95 psi. The compressive strength of 30%, 50%, and 70% BS mold with respect to gassing time 5sec – 20sec were in the range of 68psi – 85psi, 80psi – 95psi, and 82psi – 92.5psi respectively. The minimum value was 61psi of 30% BS at 5sec, which is less than silica sand mold. The maximum value was 95psi at 70%BS at 10sec – 15sec, which shows the feasibility of sand-slag mold.

The combination of sand and ferrochrome slag mold shows the highest compressive strength of 92psi. The compressive strength of 30%, 50%, and 70% FS mold with respect to gassing time 5sec – 20sec were in the range of 65psi – 88psi, 78psi – 92psi, and 82psi – 92psi respectively. The minimum value was 65psi of 30% FS at 5 sec, which is less than the minimum value of silica sand mold. The maximum value was 92psi at 70% FS at 5sec – 10sec, which shows the feasibility of ferrochrome slag as mold material.

The combination of sand and red mud mold shows the highest compressive strength of 50 psi. The compressive strength of 30%, 50%, and 70% RM mold with respect to gassing time 5sec – 20sec were in the range of 40psi – 50psi, 26psi – 35psi, and 10psi – 15psi respectively. The minimum value was 10psi of 70% RM at 5sec and the maximum value was 50psi at 30% RM at 15sec which is less than silica sand mold.

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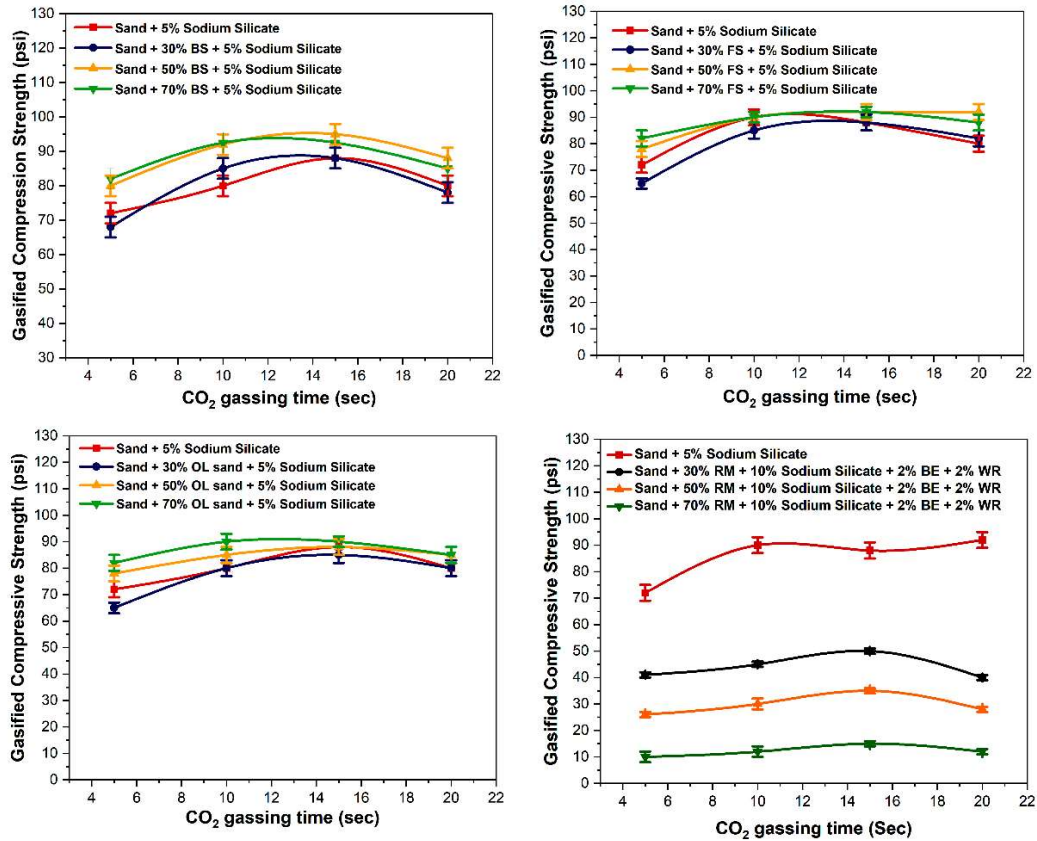


Figure 4.5: Gasified compressive strength of the mold

The combination of sand and olivine sand mold shows the highest compressive strength of 90 psi. The compressive strength of 30%, 50%, and 70% OL mold with respect to gassing time at 5sec – 20sec were in the range of 65psi – 85psi, 78psi – 88psi, and 82psi – 90psi respectively. The minimum value was 65psi of 30% OL at 5sec, which is less than silica sand mold and the maximum value was 90psi at 70% OL at 5sec – 10sec.

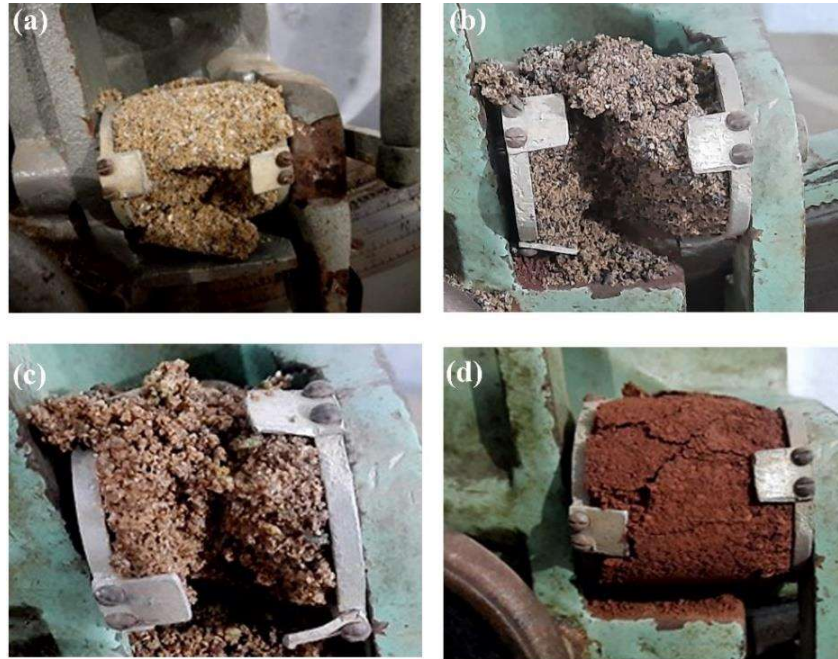


Figure 4.6: Failure of mold during a compression test

4.4.2 Shear strength

The shear strength of sand mold and the combination of sand-solid waste mold is shown in figure 4.7 and figure 4.8 show the rupture of the mold sample during the shear test. It can be observed that as the percentage of solid waste in sand mold increases with respect to gassing time there are variations in the shear strength of mold.

The shear strength of silica sand mold with the variation in the gassing time 5sec-20sec were in the range of 18psi - 34psi. The variation in the shear strength might be due to the bonding between the sand grains. The maximum value of shear strength is 34psi at 15sec gassing time whereas the minimum value is 18psi at 5sec of gassing time.

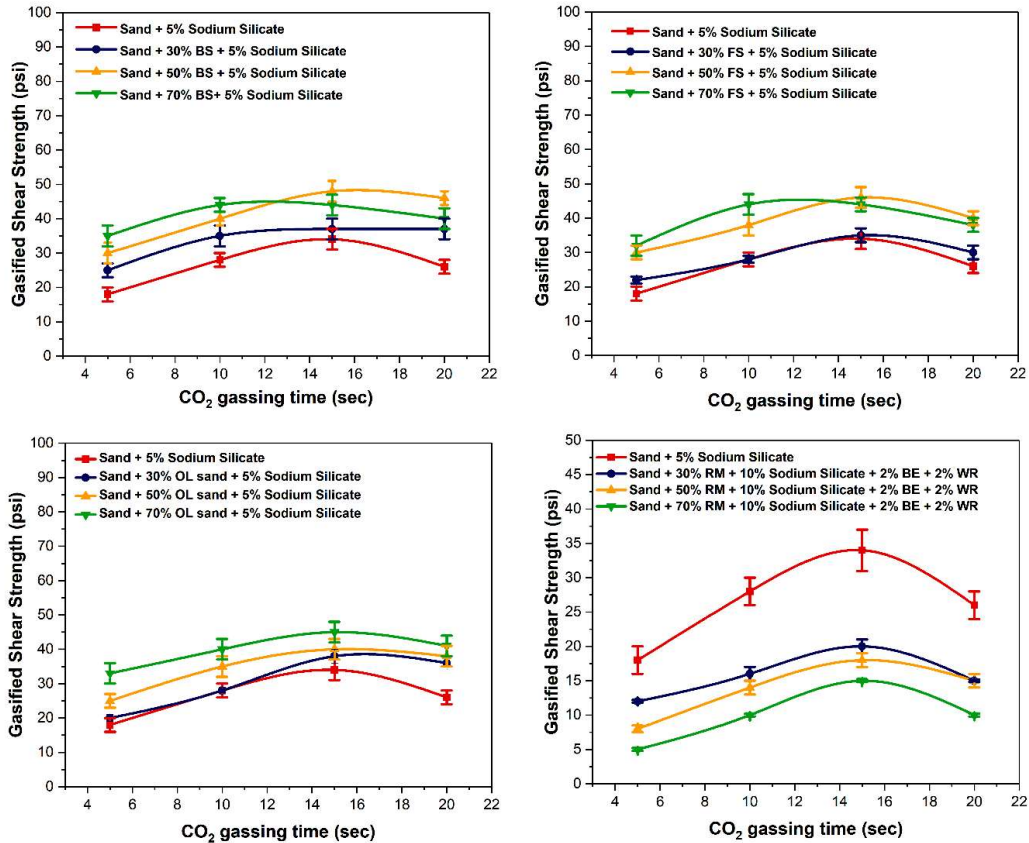


Figure 4.7: Gasified shear strength of the mold

The shear strength of sand-BS mold was in the range of 25psi – 48psi with the variation of percentage of blast furnace slag in the sand mold as well as the gassing time. The minimum value is 25psi with 30% BS at 5sec of gassing time whereas the maximum value is 48psi with 50% BS at 15sec of gassing time. The minimum value of the shear strength of the BS mold was higher as compared with the minimum value of the shear strength of the SS mold.

The shear strength of sand-FS mold was in the range of 22psi – 46psi with the variation of percentage of ferrochrome slag in the sand mold with respect to gassing time. The minimum value was 22psi with 30% FS at 5sec of gassing time whereas the maximum value are 46psi with 50% FS at 15sec of gassing time. 70% FS shows shear strength of

44psi at 10sec of gassing time. The minimum value of shear strength of combination sand-slag mold, was higher as compared with the minimum value of shear strength of sand mold.

The shear strength value of sand-RM mold was in the range of 5psi – 20psi with the varying percentage of red mud in the sand mold as well as the gassing time. The maximum value is 20psi with 30% RM at 15sec of gassing time. The maximum value of shear strength of sand-RM mold was higher than the minimum value for sand mold.

The shear strength of sand-OL mold was in the range of 20psi – 45psi with the varying percentage of blast furnace slag in the sand mold as well as the gassing time. The minimum value is 20psi with 30% OL at 5sec of gassing time whereas the maximum value is 45psi with 70%OL at 15sec of gassing time. The minimum value of shear strength of combination sand - OL mold was higher than the minimum value for sand mold.



Figure 4.8: Failure of mold during shear test

4.4.3 Hardness

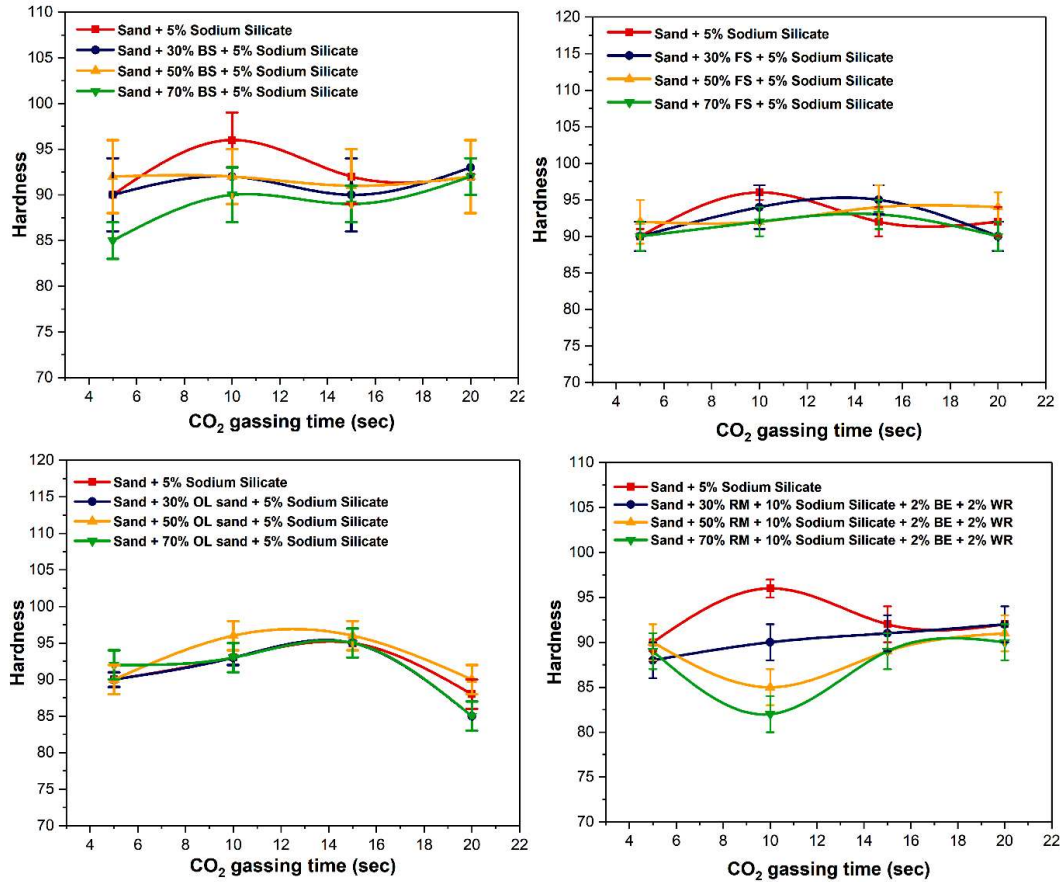


Figure 4.9: Gasified mold hardness of various mold

It has been observed from figure 4.9 that mold hardness of sand and sand-solid waste mold varies with the percentage of solid waste and CO₂ gassing time.

Mold hardness of silica sand mold with varying the gassing time from 5sec to 20sec were 90, 96, 92, and 92 respectively. It was observed that the minimum value of mold hardness with respect to the CO₂ molding process is 92. So, this attribute is towards the feasibility of mold with respect to mold hardness & with variation in the percentage of solid waste.

The combination of sand and blast furnace slag shows the highest mold hardness of 93 at 20sec of gassing time of the combination with 50% blast furnace slag in sand mold. The mold hardness value of 30%, 50%, and 70% BS mold with varying gassing times (5sec –

20sec) were in the range of 90 – 93, 91 – 92, and 85 – 92 respectively. The minimum value was 85 of 70% BS at 5sec, which is less than SS mold. The maximum value was 95 at 70% BS at 20sec, which shows the feasibility of sand-slag mold.

The combination of sand and ferro chrome slag mold shows the highest mold hardness of 94 at 20sec of gassing time of the combination with 50% ferrochrome slag in sand mold. The mold hardness value of 30%, 50%, and 70% FS mold with varying gassing times (5sec – 20sec) were in the range of 90 – 95, 92 – 94, and 90 – 93 respectively. The minimum value was 90 of 30% FS at 5 and 15sec, which is the same as the SS mold. 70% FS shows a mold hardness of 92. The maximum value was 95 at 30% FS at 20sec, which shows the feasibility of ferrochrome slag as the mold material.

The combination of sand and red mud mold shows the highest mold hardness of 92 at 20sec gassing time of the combination with 50% red mud in sand mold. The mold hardness value of 30%, 50%, and 70% RM mold varying of gassing time (5sec – 20sec) were in the range of 88 – 92, 85 – 91 and 82 – 90 respectively. The minimum value was 82 of 70% RM at 10sec. The maximum value was 92 at 30% FS at 5 - 20sec which was more than the silica sand mold.

The mold hardness value of sand-OL mold was in the range of 85 – 96 with the varying percentage of OL in the sand mold and the gassing time. The minimum value of 85 was observed with 30% OL at 20sec of gassing time whereas the maximum value is 96 with 50% OL at 10-15sec of gassing time. The minimum value of mold hardness of combination sand - OL mold, where lower than the minimum value of sand mold.

4.4.4 Permeability

The permeability of sand mold and the combination of sand-solid waste mold is shown in figure 4.10. It can be observed that the percentage of solid waste in sand mold

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increases with gassing time. The permeability of silica sand mold with the varying gassing time of 5sec-20sec was in the range of 480 - 560. The variation in the permeability might be due to the void present between the sand grains. The maximum value of permeability is 560 at 5sec gassing time whereas the minimum value is 480 at 15 and 20sec of gassing time.

The permeability of sand-BS mold was in the range of 620 – 800 with the varying percentage of blast furnace slag in the sand mold with respect to gassing time. The minimum value was 600 with 30% BS at 20sec of gassing time whereas the maximum value was 800 with 70% BS at 5sec - 20sec of gassing time. The minimum permeability of the combination sand-slag mold was higher as compared with the minimum value of sand mold.

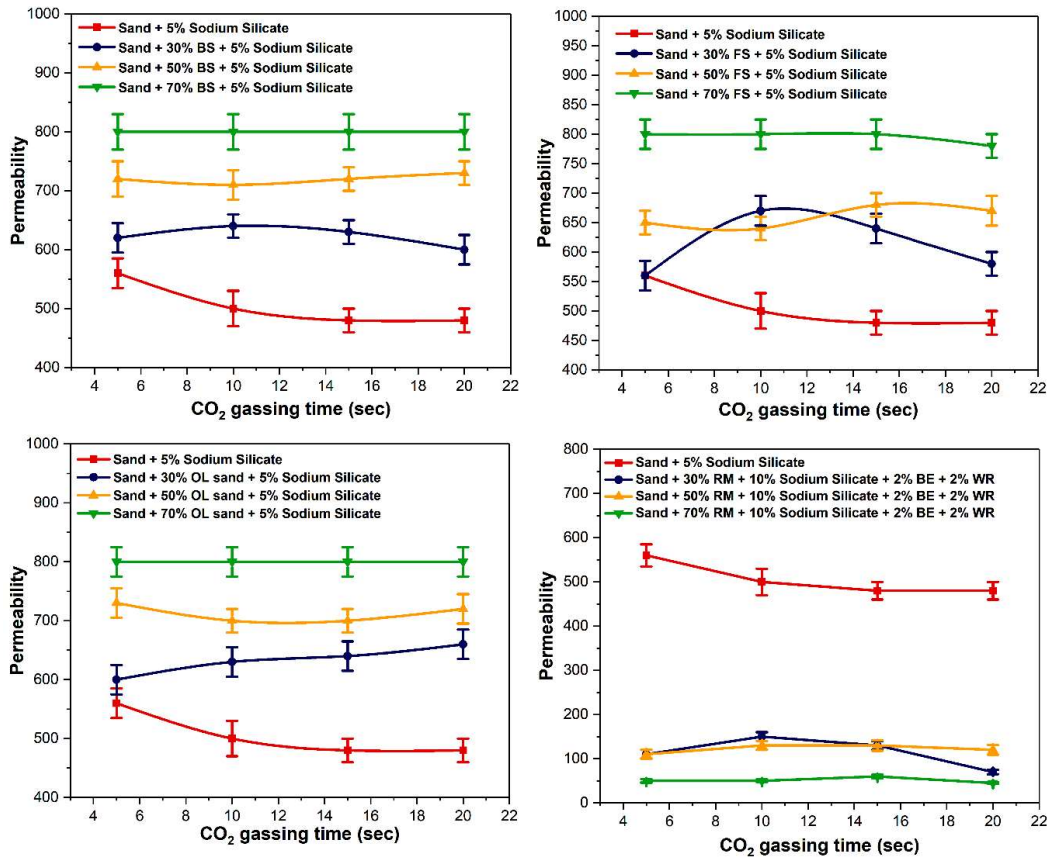


Figure 4.10: Gasified permeability of mold

The permeability of sand-FS mold was in the range of 560 – 800 with the varying percentage of ferrochrome slag in the sand mold as well as the gassing time. The minimum value was 560 observed with 30% FS at 5sec of gassing time whereas the maximum value was 800 with 70% FS at 5sec, 10sec, and 15sec of gassing time. The minimum value of permeability of sand-slag mold was higher as compared with the minimum value of sand mold.

The combination of sand and red mud mold shows the highest permeability of 150. The permeability value of 30%, 50%, and 70% RM mold with varying gassing times (5sec – 20sec) were in the range of 70 - 150, 110 – 130, and 45 – 60 respectively. The minimum value was 45 of 70% RM at 20sec. The maximum value was 150 at 30%RM at 10sec which was less than silica sand mold.

The combination of sand and olivine sand mold shows the highest permeability of 800. The permeability of 30%, 50%, and 70% OL mold with varying gassing time (5sec – 20sec) were in the range of 600 – 660, 700 – 730, and 800 respectively. The minimum value was 600 of 30% OL at 5sec, which is more than the minimum value of permeability of silica sand and the maximum value was 800 at 70% OL at 5sec – 20sec.

Figure 4.11 shows the SEM image of a silicate bridge formed between grains of mold materials such as sand-sand, BS-Sand, FS-Sand, and RM-sand mold. There are stages in the hardening process of sodium silicate such as hydration of sodium silicate, silicate gel formation, and network formation with bonding of silica gel. The bond between grain present in the mold decides the strength of the mold, which attribute to the nature of the adhesion of the bond to the surface of the grains as well as the cohesion of the materials forming the bond.

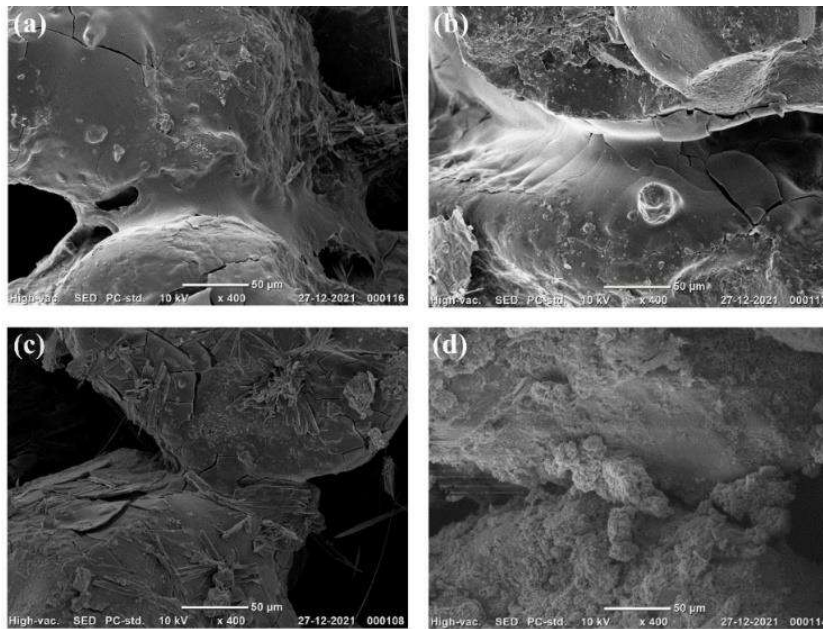


Figure 4.11: Bonding between the grains of mold materials

From the above result, it was observed that initially, the strength of mold increases with the gassing time, and beyond a certain level of gassing time it decreases, the decrease in strength might be due to the over-gassing that results from releasing water that has been trapped in capillaries below a specific level, causing the gel to shrink and develop cracks[179]. The 70% BS and 70% FS mold compressive strength, shear strength, hardness, and permeability were higher as compared to that of silica sand mold. This attribute that the increase in the percentage of slag may provide a wide range of particle size distribution, which also provides better interlocking between the grains, which gives rise to the enhancement in mold properties. The compressive, shear strength, hardness, and permeability of RM decreases due to having higher GFN and HSC value which attribute to the decrease in the strength of RM mold.

The permeability of the RM mold decreases with an increasing percentage of RM in a sand mold with respect to CO₂ gassing time while for the case of 20 sec of gas time permeability is decreased by increasing the RM content. The decrease in permeability is due to the

occupancy of voids by RM with the binders. The void present in the mold is the factor that influences the permeability of the mold. Even though, size of the voids had not been measured but it was expected that its size is somewhat greater than red mud grain. This gave rise to the filling of void spaces by red mud, resulted into a lesser permeability. The void may arise between two neighbouring particles that may be due to sand-sand interaction, sand-slag interaction, and slag-slag interaction. In the sand-sand interaction, the voids generated may be occupied by slag particles which reduced the void in the mold and hence decrease the permeability. In the sand-slag interaction, the voids generated may not be occupied by Slag, which may be the cause of enhancement in the permeability as well in the case of slag-slag interaction also enhanced permeability at a certain level of slag content beyond this level may be permeability decreased.

4.4.5 Compactness

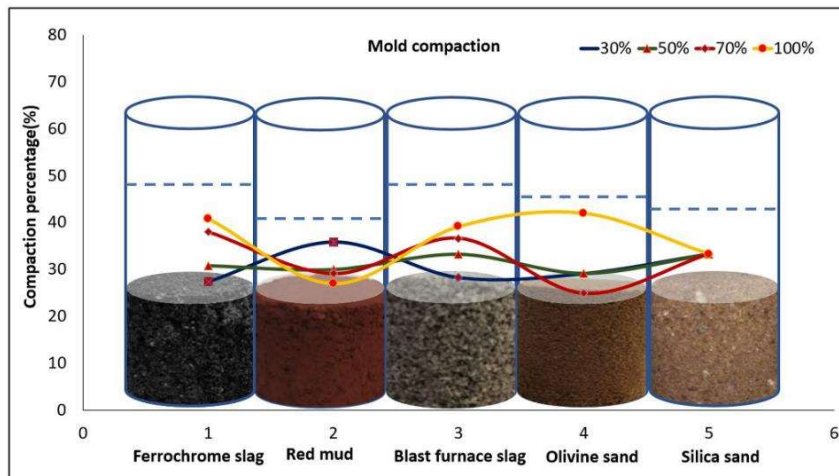


Figure 4.12: Compactability of different mold

Figure 4.12 shows the compaction percentage as a function of solid waste content in silica sand mold. The result revealed that as the percentage of blast furnace slag, ferrochrome slag, and olivine sand increases, the compactibility percentage also increases, which is due to the high flowability behaviour of these materials. The 5BS and 5FS show

quite similar results with the SS mold. As per the literature, there is no limiting value to compactibility of the mold assigned. So, blast furnace slag and ferrochrome slag can be a better alternative for silica sand mold.

4.4.6 Melting and casting

A319 alloy was melted in an electric pit furnace at 720°C in a crucible made of graphite, and its chemical composition was listed in table 4.1. The magnesium chloride and potassium chloride salt were used as a flux to eliminate the formation of the oxide. This salt has a low melting temperature of about 450°C - 490°C, which form a layer above the molten alloy due to having a low density. During the pouring of molten alloy, a salt layer was skimmed off from the melt surface as well as to clean the melt surface of dissolved hydrogen gas, oxide, etc., hexachloroethane powder (0.5%) was also employed for degassing. After melting the alloy was poured into the mold of different compositions listed in table 4.2. Mold was prepared using the CO₂ molding process with sodium silicate as a binder. The process of mold fabrication is listed below.

- Mixing of sand-solid waste-binder to make mold mixture.
- A wood pattern is used to create a cavity in the drag part of the mold.
- The pattern was placed in the drag part of the mold and the mold mixture was filled around the pattern.
- Sprue is incorporated in the cope part of the mold.
- Removable of pattern
- Venting was done on the mold.
- Molten metal was poured into the cavity through the sprue.
- Break the mold to remove the Cast product.

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The mold fabrication, casting, and cast product of various molds are shown in figure 4.13, 4.14, and 4.15. Same size riser is used and Caines's method has been utilized to design the Riser.

Table 4.1: Chemical composition of A319 alloy

Element	Si	Mn	Cu	Fe	Mg	Zn	Ti	Sr	Al
Wt.%	6.5	0.55	4.09	0.20	0.16	0.60	0.12	0.11	rest

Table 4.2: Mold composition

Molding materials	Mold composition	Binder (Sodium silicate and Bentonite)	Represents
SS	100%	5% sodium silicate	SS
BS	30%BS + 70%SS	5% sodium silicate	3BS/30BS
	50%BS + 50%SS		5BS/50BS
	70%BS + 30%SS		7BS/70BS
FS	30%FS + 70%SS	5% sodium silicate	3FS/30FS
	50%FS + 50%SS		5FS/50FS
	70%FS + 30%SS		7FS/70FS
RM	30%RM + 70%SS	10% sodium silicate + 2% bentonite + 2% water	3RM/30RM
	50%RM + 50%SS		5RM/50RM
	70%RM + 30%SS		7RM/70RM
OL	30%OL + 70%SS	5% sodium silicate	3OL/30OL
	50%OL + 50%SS		5OL/50OL
	70%OL + 30%SS		7OL/70OL

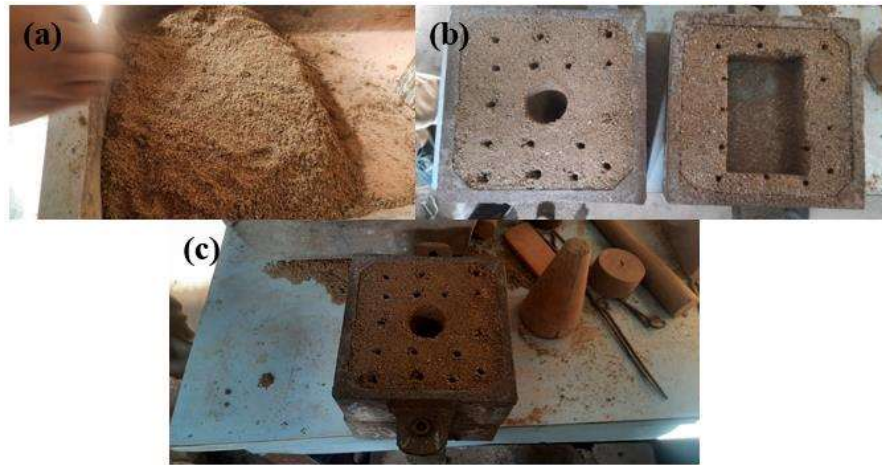


Figure 4.13: Mold fabrication process (a) Mold ingredient mixed in proportion (b) Cavity and venting hole in mold (c) Placing of cope and drag in position



Figure 4.14: Casting of A319 alloy in various mold

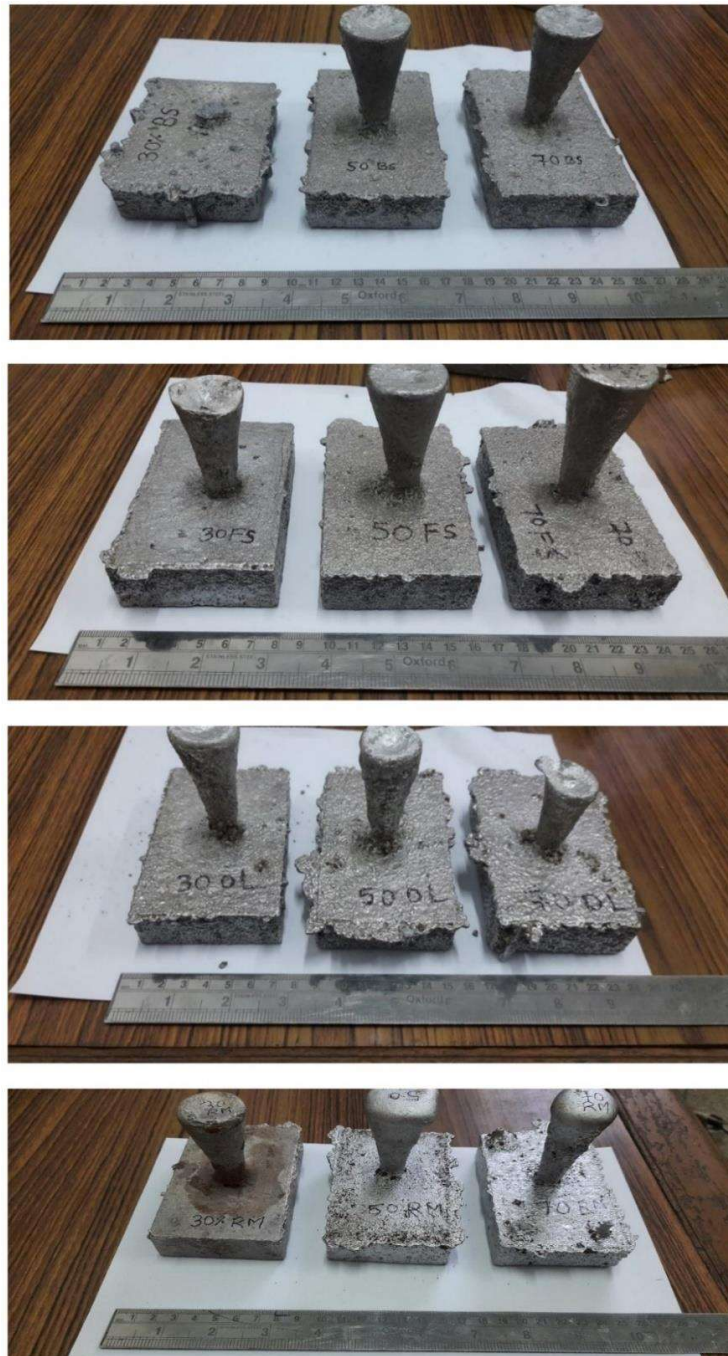


Figure 4.15: Cast product of various mold

Surface topographies of all the sample cast in silica sand (SS) mold, silica sand + 70% blast furnace slag (7BS) mold, silica sand + 70% ferrochrome slag (7FS) mold, silica sand + 70% olivine sand (7OL) mold and silica sand + 70% red mud (7RM) mold are shown below which depicts the surface quality of cast sample as shown in figure 4.16.

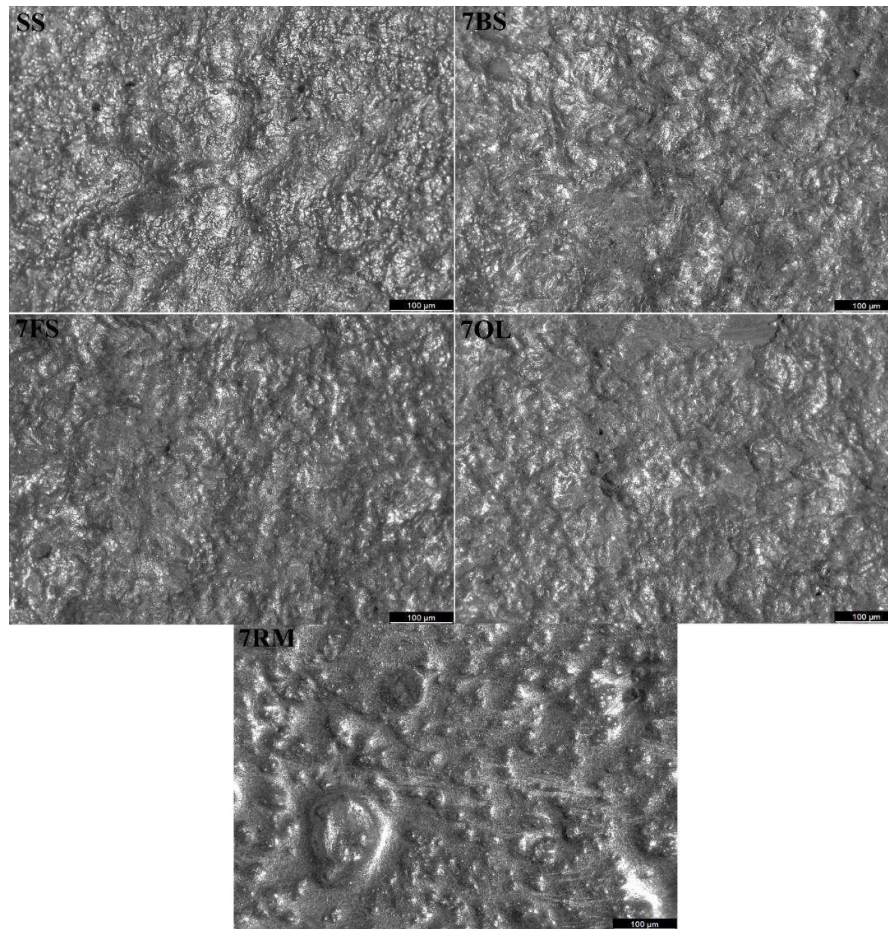


Figure 4.16: Surface micrograph of cast sample

4.4.7 Thermal analysis

Figure 4.17 shows the cooling curve of A319 alloy cast in different molds, the cooling curve of A319 alloy is distinct into three stages in the range of solidification temperature. These three stages belong to the nature of solidification as metallurgical transformation occurs during solidification.

$T_e < T < T_l$: nucleation and growth of α -Al dendritic structure

$T_e = T$: nucleation and growth of Al-Si eutectic

$T_e < T < T_s$ = nucleation and growth of secondary phases such as Al₂Cu, β -Al₅FeSi, etc.

Solidification rates such as primary and total solidification rates of A319 alloy cast in various molds are shown in table 4.4 depicts on the basis of temperature gradient and eutectic temperature. The total solidification rate of A319 alloy cast in the sand mold was 0.55(°C/sec).

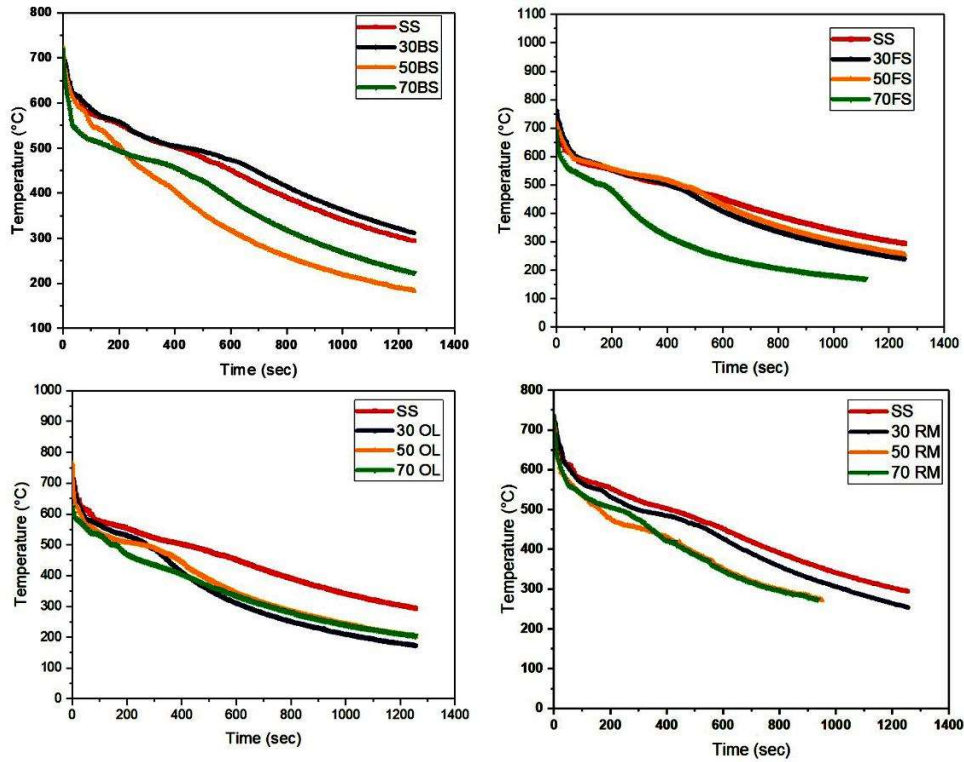


Figure 4.17: The cooling curve of A319 alloy cast in a different mold

As the percentage of blast furnace slag in sand mold increases, the solidification rate also increases. 50BS and 70BS mold show a 5.45% and 9.09% increase in solidification rate whereas 30BS shows a similar characteristic of solidification behaviour with sand mold. It was also observed that as the percentage of slag in the mold increases, the cooling curve shows steeper as compared with the sand mold.

50FS and 70FS molds show a 1.81% and 9.09% increase in solidification rate whereas 30FS shows similar characteristics of solidification behavior. It was also observed that the 30 and 50FS mold shows similar characteristics of the nature of the cooling curve as per

sand mold, whereas the cooling curve of 70FS shows steeper as compared with the sand mold. 50OL and 70OL mold shows a 3.63% and 7.27% increase in solidification rate whereas 30OL shows similar characteristics of solidification behaviour. It was also observed that the as a percentage of olivine in the mold increases, the cooling curve shows steeper as compared with the sand mold but the nature of cooling 30OL, 50OL, and 70OL are quite similar behaviour, and 50RM and 70RM shows similar behaviour as shown in figure 4.17 but steeper curve as compared with the SS mold.

The solidification behaviour of casting is attributed to the evolution of microstructure, mechanical and physical properties of Al-Si alloy. From the above results, it can be concluded that the total solidification rate of A319 alloy cast in BS, FS, and RM mold is higher than sand mold, which states that these mold facilities have higher heat transfer rates as compared with sand mold. This might be due to the thermal conductivity of these mold materials listed in table 4.3. The slag mold shows a higher solidification rate as compared to the rest mold. In spite of the high thermal conductivity of red mud, the solidification rate was not high, which is due to having a low permeability level of mold that creates a layer of gas between the mold wall and cast product which resists the transfer of heat to the mold surface. The solidification rates of the cast in slag mold were higher, which enhanced the mechanical properties of a cast alloy.

Table 4.3: Thermal conductivity of materials

Mold materials	Thermal conductivity (W/m. k)
Sand[180]	0.25
Blast furnace slag	1.2
Ferrochrome slag[181]	1.3
Red mud[182]	11.7
Olivine[183]	3-4

Table 4.4: Experimental solidification parameter

Mold Materials	Primary Solidification rate (°C/sec)	Total Solidification rate (°C/sec)
Sand	0.46 ± 0.04	0.55 ± 0.06
30BS	0.48 ± 0.04	0.55 ± 0.06
50BS	0.50 ± 0.04	0.58 ± 0.06
70BS	0.50 ± 0.04	0.60 ± 0.06
30FS	0.46 ± 0.04	0.55 ± 0.06
50FS	0.48 ± 0.04	0.56 ± 0.06
70FS	0.48 ± 0.04	0.60 ± 0.06
30OL	0.47 ± 0.04	0.55 ± 0.06
50OL	0.48 ± 0.04	0.57 ± 0.06
70OL	0.48 ± 0.04	0.59 ± 0.06
30RM	0.47 ± 0.04	0.55 ± 0.06
50RM	0.48 ± 0.04	0.57 ± 0.06
70RM	0.48 ± 0.04	0.57 ± 0.06

4.5 CONCLUSIONS

The following conclusions are drawn-

- 70% blast furnace slag mold shows 15% enhanced compressive strength at 10 sec gassing time and 29% enhanced in Shear strength at 15 sec gassing time w.r.t sand mold. The mold hardness of 70% blast furnace slag was in the range of 85-92.
- 70% ferrochrome slag mold with 15 sec gassing time showed compressive strength and shear strength enhanced by 4.5% and 30% respectively w.r.t sand mold. The mold hardness of 70% ferrochrome slag mold was in the range of 90-93.

- Mold properties such as compressive strength, shear strength, permeability, hardness, and compactness increase with the addition of solid waste except for red mud.
- The compressive strength of mold increased by 6%-15% with the addition of 70% BS in sand mold and 70% FS in a sand mold with respect to gassing time.
- Permeability of mold was enhanced by 65% with the addition of 70% BS in sand mold and 70% FS in sand mold with respect to gassing time whereas by the addition of 30% RM in sand mold, the permeability of mold decreased by 70%.
- The mold hardness value of different molds falls in the range of 70-90.
- A319 alloy cast in 7BS and 7FS mold enhanced the solidification rate of the alloy by 10%.