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Some studies on olivine fines and clay mixtures

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ABSTRACT

Olivine is a mineral composed of forsterite (2 $MgO.SiO_2$) as major and fayalite (2 $FeO.SiO_2$) as minor phases. During processing of olivine minerals for foundry and other uses, lot of fines (around –100 mesh) are generated. The present study has been carried out on the olivine fines collected from the Salem district of Tamil Nadu to explore the possibilities of converting these fines into value added ceramic products by reaction sintering with clay. Different combinations of olivine fines and clay have been formulated and the mixtures are heated at various temperatures in the form of pellets. The sintering kinetics and physical properties have been studied and discussed in this paper. XRD & SEM and studies are also carried out to confirm the phases formed.

INTRODUCTION

Mineralogically, olivine is composed of around 94% forsterite (2 $MgO.2SiO_2$) and 6% fayalite ($2FeO.SiO_2$) and the first known effective use of olivine as a refractory was in Norway in the mid 1800's. In the early 1930's, olivine band refractory products were first marketted in U.S.A. Then the European refractory manufactures and industrial end-users began to exploit the broader range of post-effective applications for Oliving based refractoriess sometimes during mid 1950's. An early thinking of refractory application was possible as olivine possesses many advantageous refractory properties such as high refractoriness (around 1760°C), no free silica, good hot crushing strength and creep resistant, high relatively resistance to iron and steel, essentially hydration free, inert and requires no calcination prior to use, very good insulating values due to very low heat conductivity and low cost.

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Richardson's spider web diagram provides many useful informations to convert olivine into other various ceramic products besides refractory applications by reaction sintering with clay, MgO. To name a few, low loss electro ceramic body, cordierite ceramics for saggers, tiles, insulators, spark plug etc. could be manufactured using olivine as one of the major raw material. Although, the material, olivine is known to all ceramic technologists, its full capabilities and usage has yet to be adequately developed.

An attempt has been made in the present study to understand the behaviour of clay and olivine mixture on heating. The physical properties and the various phases formed by heating different combination of clay and olivine have been determined and the results are discussed in this paper. The scanning electron microscopy studies have also been carried out on the fractured surfaces of few sintered specimens to confirm the microstructure.

EXPERIMENTAL

The raw materials used in the present study were Indian sources of olivine fines (Salem Area of Tamil Nadu) and Kaolin type of clay minerals. The chemical analysis of these raw materials are given in Table 1 : The olivine fine in as it is form was characterized by XRD studies.

Table 1 : Chemical Analysis of Olivine fines & clay

Constituents (Wt %)	Olivine fines	Clay
SiO_2	38.52	46.06
Al_2O_3	2.78	36.40
Fe_2O_3	11.04	1.85
CaO	-	0.35
MgO	42.78	0.49
TiO_2	-	0.10
L.O. I.	2.18	13.51

As received olivine fines (-100 mesh powder) and clay minerals were wet mixed and ground for a specified time as per the batch compositions given in Table 2.

The wet slurry was dried and powered. The pellets of 2" dia were prepared from the powder by compaction in a hydraulic press. The compaction pressure was kept uniform at 300 kg/cm^2 for all the samples. The compacted pellets were dried and sintered in the temperature range of 1250-1450°C for a constant soaking period of 30 minutes. The pellets of composition "A' were further sintered in the temperature range of 1500-1600°C (60 min soak) to study the behaviour of only olivine samples at high temperatures.

Table 2 : Batch compositions

Raw materials(wt.%)	Composition code				
	A	B	C	D	E
Olivine	100	95	90	85	80
Clay	Nil	5	10	15	20

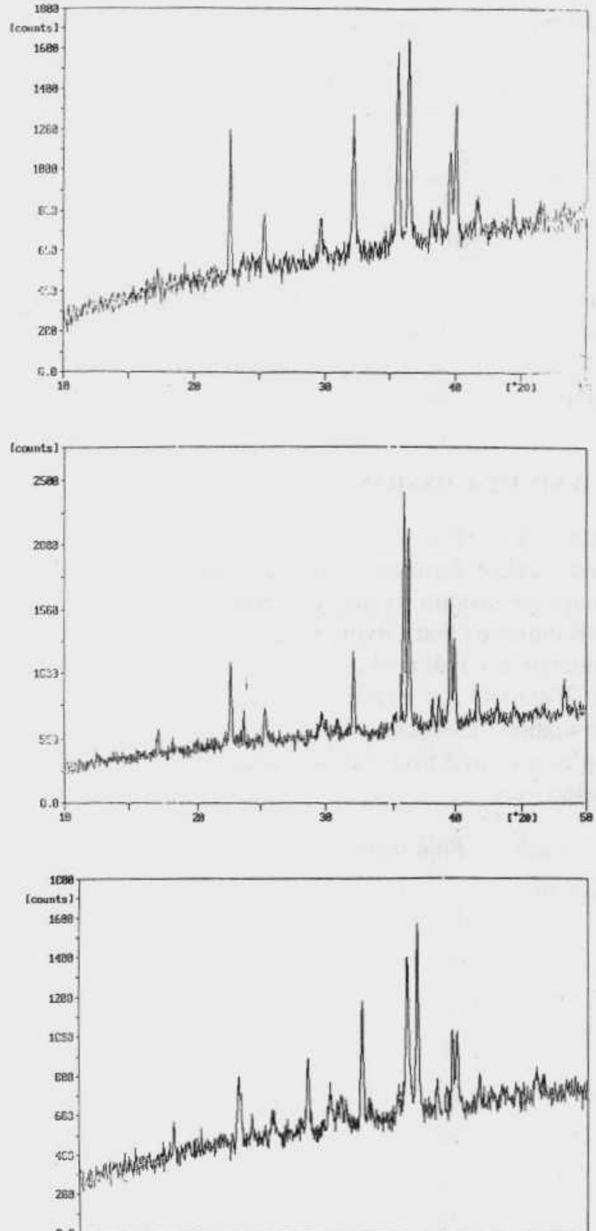
The physical properties such as density, percent water absorption values were determined using standard techniques. The various phases formed on the sintered specimen (only on selective samples) were identified by XRD studies. SEM technique was adopted to study the microstructure of few sintered samples.

RESULTS AND DISCUSSION

The XRD pattern (Fig. 1a) of raw olivine fines indicates the presence of forsterite and fayalite. Further, it may be noted from Fig. 1a that some of the phases belongs to fayalite having compositions 2FeO. SiO_2 and (Fe^{2+}, Mg)$_2$ SiO_4. Fig. 1b indicates that olivine when heated at high temperature (1600°C) does not undergo any major phase transformation. However, (Fe^{+2}, Mg), SiO_4 converts to 2FeO.SiO_2 an heating by releasing MgO to take part in further forsterite formation. The bulk density and percent water absorption of of the heated samples prepared from various compositions are given in Table - 3 and Table 4 respectively.

Table 3: Bulk density (B.D.) of the heated samples

Heating temp (0°C)	B.D. (gms/cc)				
	A	B	C	D	E
1250	2.28	2.38	2.40	2.48	2.51
1275	2.40	2.44	2.46	2.65	2.71
1300	2.41	2.53	2.46	2.66	2.72
1325	2.41	2.59	2.47	-	-
1375	2.56	2.77	2.49	-	-
1450	2.68	2.78	-	-	-
1500	2.77	-	-	-	-
1550	2.87	-	-	-	-
1600	2.89	-	-	-	-



(a)

(b)

(c)

Fig. 1 XRD pattern (a) raw olivine sample as received, (b) 1600°C heated olivine sample,(c) 1325°C heated sample of composition 'C'.

Table 4 : Percent water absorption (%W.A.) of the heated samples

Heating temp (0°C)	%WA				
	A	B	C	D	E
1250	12.20	10.03	9.75	7.90	5.97
1275	10.07	9.45	8.59	5.01	3.04
1300	10.00	8.45	6.96	2.21	1.01
1325	10.00	6.65	5.06	-	-
1375	8.64	1.73	1.57	-	-
1450	6.38	1.33	-	-	-
1500	4.77	-	-	-	-
1550	1.15	-	-	-	-
1600	0.88	-	-	-	-

From the table 3 & 4 it may be noted that with the increase in heating temperature, bulk density increases and water absorption values decreases due to obvious reason of more sintering at higher temperatures. Further, it is observed that additions of clay to olivine causes more sintering. Compositions D&E with 15 & 20% clay gets almost sintered at around 1300°C where as compositions B&C with 5&10% clay requires about 1400°C for complete sintering. 100% oblivine samples without clay additions requires as high as 1600°C for maximum sintering.

The reaction products of clay + olivine mixtures (composition-C) heated at 1325°C were identified by XRD studies (Fig. 1c) where the formation of cordierite enstetite, sapphirine are observed. This indicates a possibility of producing cordierite bodies from olivine and clay mixtures. The XRD results are also comparable with the cordierite body produced from conventional raw materials such as talc, alumina and clay. The SEM photograph of this sample is shown in Fig. 2a to confirm the microstructure. The sample of 100% olivine heated at 1600°C was also subjected to SEM study and the photomicrograph is shown in Fig. 2b. These microstructures consists of both crystalline and glassy phases. No big pores or cavities are seen in the matrix.

CONCLUSIONS

The findings of the present work indicates many scopes of developing various types of ceramic products from olivine and clay mixtures particularly in the area of cordierite bodies. Although olivine is known to all refractory manufactures, its full capabilities and usage in combination with other materials has yet to be adequately developed for other ceramic products.

(a)

(b)

Fig. 2 : SEM photographs taken on the fractured sufrace of the specimen (a) sample of composition 'C' heated at 1325°C, (b) sample of 100% olivine heated at 1600°C.

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