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FOREWORD

Mineral processing is an art of treating raw ores in order to separate valuable minerals from the waste rock as well as preparing mineral products for specific needs. It is the first process that most ores undergo after mining in order to provide concentrated material for the downstream metallurgical processes. The primary operations are comminution and concentration, but there are other important operations in a modern mineral processing plant, including sampling and analysis and dewatering. In mineral processing, a number of unit operations are required to prepare and classify ores before the valuable constituents can be separated or concentrated and then forwarded on for use or further treatment. Mineral processing education at the Istanbul Technical University has started as a division of the "Mining Engineering Department" which was founded as a part of the Mining Faculty in 1953. The division was re-organized as a Mineral Processing Engineering Department of the same faculty in 2007, in order to meet the requirements of engineering education. It is the first and only one in Turkey.

The first Balkan Mineral Processing Congress was held in Varna, Bulgaria in 1973. The “XVIIth Balkan Mineral Processing Congress – BMPC 2017” is organized by ITU Mineral Processing Engineering Department and the Turkish Mining Development Foundation between November 1 and 3, 2017, in Antalya-Turkey. “BMPC 2017” will bring together a large number of academicians from Turkey and many other countries as well as the authorities from the companies that are operating in the mining, mineral processing, and extractive metallurgy industries in order to create an opportunity to evaluate the future of the sector. In this context, BMPC represents a technical platform for the safe and sustainable future of the mining and mineral processing industries in Balkan Countries. We are inviting you to become a part of this global challenge by attending our congress through participation, presentation, exhibition and supporting our activities. In this respect, Antalya with its dynamism and diversity presents a unique opportunity for the attendees. We assure you that we will provide all means to make you enjoy and benefit from this extraordinary event.

The Congress will gather over one hundred professionals and academics from all over the world to exchange knowledge and experience, to present the results of scientific research and to discuss innovations in the mineral processing industry. Universities specializing in mineral processing, a number of important mining companies, major leading providers of services and technologies will participate in the Congress.

We are very pleased to welcome you to attend and we are sure you will enjoy the Congress from both scientific and social points of view. Looking forward to meeting you in Antalya!

Prof. Dr. Fatma Arslan | Prof. Dr. Ayhan Ali Sirkeci

FOUNDATION'S FOREWORD

As Turkish Mining Development Foundation, we are happy to be organizer of 17. Balkan Mineral Processing Congress. I would like to express my sincere thanks to the Balkan Scientific Committee, Turkish Organization Committee, to the Sponsors, exhibitors and all the attendees. Our special gradidute to Istanbul Technical University, Mining Faculty and Mineral Processing Department.

We wish successful and fruitful congress and sunny days in Antalya.

With kind regards,

Prof. Dr. Güven Önal

President of Turkish Mining Development Foundation

Balkan Scientific Committee Member

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EFFECT OF MICRONIZED GRINDING ON THE QUALITY OF THE FILLERS BASED ON CORDIERITE, MULLITE AND ZIRCON

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ABSTRACT

This study presents the results of an investigation of high temperature materials – refractory filler based on cordierite, mullite and zircon for the synthesis of new refractory pattern coating and application in foundry. In order to obtain better properties of refractory fillers, special attention in the research was devoted to the preparation of fillers by grinding and mechanical activation. The application of the fillers for the synthesis of refractory pattern coatings and use in the new EPC casting process for obtained aluminum alloys and steel casting was shown positive results.

Key words; filler, talc, mica, cordierite, mullite, mechanical activation, castings

1. INTRODUCTION

Refractory pattern coatings are an integral part of industry casting production. The basic role of refractory coatings is to provide an efficient refractory barrier between the mould substrate and liquid metal flow during the phases of casting, solidification and final formation of the castings (Gökce et al., 2011, Dong et al., 2009, Hirano and Inada, 1993, Jacas-Rodriguez et al., 2005, Santillan et al., 2007). This ideally provides a smooth and clean surface for the casted component, with no adhered sand or defects due to metal penetration into the mould (e.g. lumps, dents, rough surfaces or other imperfections). Depending on use, contemporary coatings are made from refractory materials (fillers) mixed with a solvent and added suspension and binding agents (Andric et al., 2001, Aćimović et al., 2011, 2012, Trumbulović et al., 2004). Refractory coatings enable improvements to existing casting methods and development of new ones, an important example of which is expandable and meltable pattern casting (the EPC casting process and precision investment casting, respectively) (Aćimović et al., 2012). Coating development involves systematic research to determine optimum coatings and casting methods, and appropriate types of castings for different alloys. At the same time, all relevant economic and quality indicators for the casting production should be monitored. Coating properties are strictly defined by standards (Serbian Standards). It is very important to make the choice, preparation, and application of coatings under actual foundry working conditions. Special attention was applied to preparation of fillers by grinding and mechanical activation. Grinding and fine grinding of refractory fillers was done in mill with balls of Cr- Ni steel, capacity 20 kg/h, with mill load of 70% and grinding time 45-60 minutes. Important characteristics of refractory fillers are: high melting temperature; low heat spread coefficient; it does not soak up liquid metal; it does not produce gases in contact with liquid metal.

2. EXPERIMENTAL PROCEDURE

The cordierite ($2MgO\cdot 2Al_2O_3\cdot 5SiO_2$) used in experiment (marked: C) was the product of synthesis of the following raw materials: kaolin, alumina, quartz and sepiolite. Initial materials, were blended in the ratio $2MgO:2Al_2O_3:5SiO_2$. Sintered temperature was 1350 ^oC /over the time of 8 hours in a laboratory oven with oxidation atmosphere. Mullite samples ($3Al_2O_3$ $2SiO_2$) used in experiment (marked: M) was product of synthesis the mixture of kaolin and alumina with presence of mineralizers 1% NaF. Alumina is added in the quality to satisfy the stoichiometric ratio 3:2 of mullite. Sintered temperature was 1200 ºC/ time of 8 hours. Zircon silicate ($ZrSiO_4$) was obtained by mechanical processing of refractory mineral raw materials – zircon sand, purification methods and milling (mark zircon samples in the experiment: Z). Cordierite, mullite and zircon samples as refractory materials are selected for making refractory coatings in according with their properties, Table 1.

Table 1. Properties of refractory fillers based on cordierite, mullite and zircon

Cordierite ($2MgO{\cdot}2Al_2O_3{\cdot}5SiO_2$)	**Mullite** ($3Al_2O_3{\cdot}2SiO_2$)	**Zircon** ($ZrSiO_4$)
Density: 2.2 kg/m^3	Density: 3.2 kg/m^3	Density: 4.56 kg/m^3
Melting point :1380ºC	Melting point :1850ºC	Melting point :2500 ºC
Refractoriness:14SK/1300ºC	Refractoriness:34SK/1750ºC	Refractoriness:34SK/1750ºC
Mosh hardness: 7	Mosh hardness: 7.5	Mosh hardness: 7.5
Coefficient of linear expan. at 25°C (cm/cmºC): 1.7 $\cdot 10^{-6}$	Coefficient of linear expan. at 25°C (cm/cmºC): $6{\cdot}10^{-6}$	Coefficient of linear expan. at 25°C (cm/cmºC): $7.2{\cdot}10^{-6}$
Coeffic. of thermal cond. at 27°C (W/cm K): 2.3-2.9	Coeffic. of thermal cond.at 27°C (W/cm K): 1.3	Coeffic. of thermal cond. at 27°C (W/cm K): 0.227
Max.service temp.: 1350ºC	Max service temp.:1700ºC	Max service temp.: 1750ºC

For quality of refractory fillers an important factor is the size and shape of the grains. In order to establish filler and binding agent's distributions, refractory pattern coating suspension was analyzed on the polarized microscope for transmitted light (Carl Zeiss-Jena, Germany). Measurements of the filler grain size and shape were carried out with 4000 grains, while the analysis was conducted by means of the software application package OZARIA 2.5 (interval 0-1). For characterization of the refractory fillers, X-ray diffraction analysis was applied in the X-ray diffractometer PHILIPS, model PW-1710. The microstructure of the samples was characterized by scanning electron microscopy method (SEM) using a JOEL JSM-6390Lv microscope. Properties of the obtained refractory pattern coatings were examined pursuant to the norms [10,11]. To assess the quality of the refractory pattern coatings obtained, simple, plate shaped castings were casted with aluminum alloys and steel. Dry quartz sand with grain size 0.36 mm was used as a material for the mold involved in the EPC casting process. Polymer patterns used in the experiment were made of polystyrene with density of 19 kg/m^3 and with mean grain size of 0.5-1 mm.

3. RESULTS AND DISCUSSION

Table 2 shows the composition of the synthesized fillers based on cordierite, mullite and zircon, which was mechanically activated and then used for production of refractory coatings.

Table 2. Chemical composition of refractory fillers based on cordierite, mullite and zircon

Compound	Cordierite (%)	Zircon (%)	Mullite (%)
SiO_2	51.01	32.5	25.18
Al_2O_3	30.09	0.03	70.33
MgO	13.50	-	5.20
Fe_2O_3	1.20	max 0.05	0.98
CaO	3.20	-	0.80
ZrO_2	-	min 66	-
TiO_2	-	max 0.05	-
NaCl+K_2O	0.02	0.001	0.58

Figure 1 shows XRD and SEM microphotograph of cordierite samples. On the X-ray graph for the synthesized sample C indicating a prevailing presence of cordierite. To a lower extent, presence of corundum, quartz, spinel, periclase is also noted. Based on semi quantitative chemical analysis, it was found that the analyzed sample C contains smaller amounts of K, Ca and Fe apart from the main cations Mg, Al and Si. SEM microphotograph of the filler C it clearly indicates the grains of irregular forms and different sizes.

Figure 2 shows XRD and SEM microphotograph of mullite samples. XRD gave certain proof that dominant mineral phase in investigated samples is mullite. There was also a smaller presence of α-corundum. Microphotography of synthesized mullite sample indicates that this mineral occurs in irregular forms and different dimensions.

Figure 3 shows XRD and SEM microphotograph od zircon samples. XRD gave certain proof that dominant mineral in investigated samples is zircon. It shows clearly expressed pikes characteristic for high purity zircon. Microphotography of starting zircon sample indicates that this mineral occurs in irregular shapes with characteristic shell split and different dimensions.

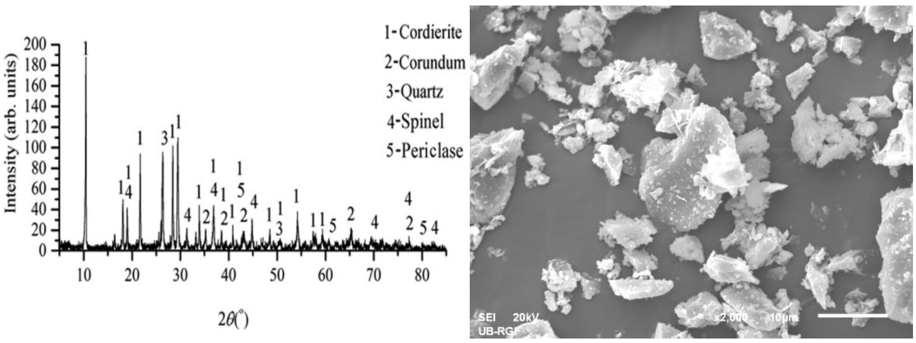

Figure 1. XRD and SEM microphotograph of cordierite samples

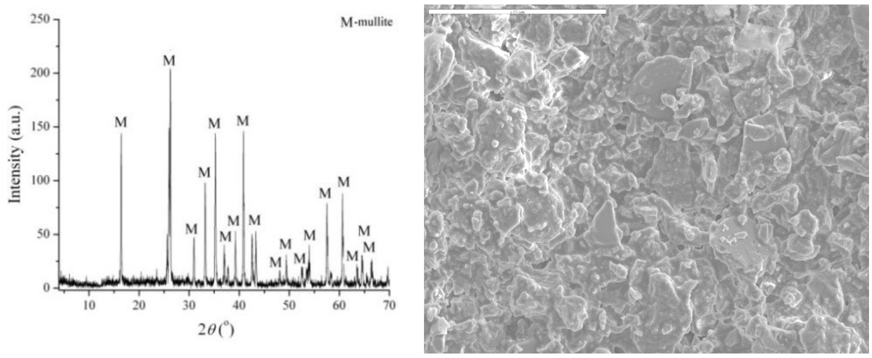

Figure 2. XRD and SEM microphotograph of mullite sample

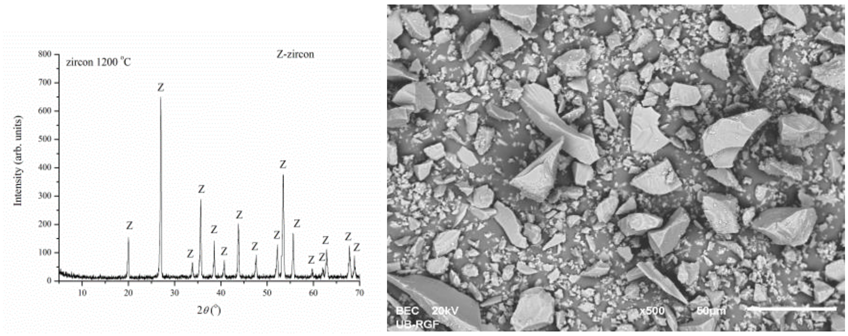

Figure 3. XRD and SEM microphotographs od zircon samples

The microphotographs of all the samples: C; M; Z show that the grains of fillers indicate that they are suitable for use as fillers for the synthesis of various refractory materials. One can predict that in the pressing of the samples powder and formation of various products in practice will be able to achieve uniform packing of particles in a volume of the body. Also, one can expect to obtain dense ceramic body at the appropriate, pre-defined sintering temperatures. An analysis of grain size and grain shape factor showed that the mean grain size of all samples was about 15 µm and that the grain size factor was 0. 69. Based on the data on the shape factor, the C; M; Z filler grains are classified in the category of rounded grains. Based on the data on the filler mean grain size, it may be expected that the lower grained fillers will precipitate slower in suspension of refractory pattern coating; they will keep their dispersed state longer and the coating suspension will homogenize more easily.

From the obtained samples C, M, Z, refractory pattern coatings were made on water and alcohol basis, (mark suspension: A and B, respectively). The coating compositions are shown in Table 3. Design of refractory pattern coatings and choice of production method were carried out in accordance with analysis of the influence of mechanical activation of nonmetallic mineral raw materials on the filler's quality, i.e. on the grain size and shape of the filler, according to the works [7, 10,11]. Tests of sedimentation stability of the A & B series refractory pattern coatings showed that the amount of precipitated matters was 5%. Layers of coating on polymer patterns were uniform thicknesses, without cracking and poisoning after drying. This film was homogenous and constant. According to the norms [10,11], the results of the quality of the A and B suspensions were satisfactory.

Table 3. Compositions of the A & B series refractory pattern coatings (%)

	Type A:	**Type B:**
Refractory filler	C; M; Z, grain size 15 μm, quantity 93%	C; M; Z, grain size 15 μm, quantity 95%
Bonding agent	Bentonite 1.5-2.5% Bindal H 1-1.5%	Colophony resin 2-3%
Suspension maintenance agent	$Na_3P_3O_3$ 2.5 % CM cellulose 0.5%	Bentone 25 1.5 %
Solvent	Water	Iso-propyl alcohol
Density- (kg/m^3)	2000	2000

After visual inspection of the surface casted according to the EPC casting process, it was noted that application of both types of coatings together with the fine grained polystyrene patterns led to production of castings with fine and smooth surfaces.

4. CONCLUSION

As a result of this investigation, the composition of refractory pattern coatings for use in the EPC casting process is defined. Refractory fillers based on cordierite, mullite and zircon were prepared by grinding and mechanical activation (grain size 15 microns, grain shape factor 0.69). The resulting coatings were applied to the polymer pattern by immersion in a tank with coating suspension. Sedimentation of the suspension of the coating was found to be below 5% which meets the coating standards. The application of these coatings has contributed to obtaining high quality castings obtained with the EPC casting process.

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