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HIGH TEMPERATURE CASTING OF PYROPHYLLITE USING CALCIUM OXIDE AND ZIRCONIA ADDITIVES AND SUBSEQUENT COMPARISON WITH CAST BASALT TILES

Prepared by

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A dissertation submitted to the Faculty of Engineering and the Built Environment, University of the Witwatersrand, Johannesburg, in fulfilment of the requirements for the degree of Master of Science in Engineering.

18 January 2021

DECLARATION

I declare that this dissertation is my own unaided work. It is being submitted for the degree of Master of Science in Engineering to the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination to any other university.



Tichaona Nyasha Marongwe

18th day of January in the year 2021

ABSTRACT

A fundamental part of the petrurgy industry is the use of materials such as basalt, which have considerably low melting points as compared to other alumino-silicates. These materials, however, are available in some regions but scarce in others including South Africa. Pyrophyllite ($Al_2Si_4O_{10}(OH)_2$), a material abundant in South Africa, has the potential to be a substitute for casting of basalt due to its favourable material properties. From the ternary phase diagrams of the SiO_2-Al_2O_3-CaO system, calcium oxide additives formed from decomposed calcium carbonate were used to lower the melting point of pyrophyllite ($Al_2Si_4O_{10}(OH)_2$) powder. The mixed powders were successfully molten at a temperature of 1400°C, approximately 350°C lower than the melting point of pyrophyllite. The molten powders were cast into pyrophyllite sand moulds and produced amorphous samples with fracture toughness values comparable to cast basalt but with a lower hardness. Heat treating the samples at 900°C for phase separation and 1040°C to crystallise them produced samples with hardness and fracture toughness values comparable to cast basalt. Using an additional 1 wt. % yttria-stabilized zirconia as a nucleating agent, crystallised samples of pyrophyllite with comparable hardness and fracture toughness to the cast basalt were produced using a single heat treatment step at 1100°C. XRD analysis indicated gehlenite was the major phase formed, together with phases of anorthite and wollastonite. This final material had a density of 2,83g/cm³ with hardness and fracture toughness values of 6,18 GPa and 1.12 MPa.$m^{1/2}$ respectively and therefore, in conclusion, crystallised samples of pyrophyllite with comparable hardness and fracture toughness to the cast basalt were indeed produced using calcium oxide and zirconia additives. In addition to this further work may be done to explore additional additives to eliminate the nucleation step entirely and produce crystallised samples as cast.