DEVELOPMENT OF INVESTMENT CASTING MOLDS BASED ON TERENGGANU SILICA SAND FOR ALUMINIUM AND COPPER ALLOYS

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Thesis submitted in fulfillment of the requirement for the degree of Doctor of Philosophy in the school of Fundamental Science Universiti Malaysia Terengganu

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DEDICATION

This thesis is dedicated to

My parents

Allahyarham Mohd Nor bin Awang

Fatimah binti Mamat

My husband, daughters and sons

Asmawi bin Kassim

Siti Nadhirah Asmawi

Siti Nursyafiqah binti Asmawi

Siti Nur Insyirah binti Asmawi

Muhammad Amirul Danish bin Asmawi

Muhammad Aish Irfan bin Asmawi

Siti Nurdamia Hasya binti Asmawi

for their endless love and support.

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The research reported in this thesis has four main objectives. These include to investigate the chemical composition and structural properties of Terengganu local silica sand for foundry use, to develop a suitable investment casting mold formulations, to investigate the thermal and mechanical properties of the developed mold and to recommend a suitable formulation and casting procedures for both of aluminium and copper alloy. The study was conducted in two main phases, where the first phase emphasized on the development of Terengganu silica sand as a mold material while the second phase focused on the application of the developed mold in investment casting process. With the silica content more than 97% and Grain Fineness Number (*GFN*) of 57 and 49, Kuala Abang and Jambu Bongkok silica were found the most appropriate silica as they can be used directly without the need to grind first. Then, using these silica as a refractory material and plaster of paris (POP) as a binder, several formulations were developed. The compositions used were 75% silica, 25% POP and 31 - 37% water. Silica percentage was also varied from 60 - 85% with POP content changing from 15 - 40%. In the molding process, the water ratio of 31 - 37% were found suitable to produce a thick molding mixture (slurry) with the optimum

viscosity around the diameter of 7.7 - 9.6 cm (slump test). Within this range, the resulting slurry was able to flow freely to fill the empty space between the wax patterns and thus filled the flask easily. Further mold properties investigation showed that both of compressive strength and tensile strength were slightly reduced with water ratio but greatly increased with POP. Depend on the formulation, the mold strength was found to be in the range of 180 - 2800 kN/m^2 and these values are considerably higher than the strength of green sand molding with the value around 70 kN/m^2. Both of water and POP content did not influence the hardness, but slightly reduced the core hardness. Further microstructure investigation confirmed that beside the silica grain, the developed molds were also composed of needle-shape calcium sulphate crystals and pores. Thus, at a higher water content, the main causes of strength reduction were an increased porosity and a reduced number of crystals interlocking. From the TGA analysis, the decomposition temperature was found to be in the temperature range of 940 - 980 ^oC. For the process of dewaxing, the temperature of 170 ^oC was found suitable to remove the wax patterns without damaging the mold surface. The carbon burnout was successfully eliminated using the temperature of 750 ^oC for 5 hours. For copper alloy casting, the mold with 35% - 40% POP is not recommended because they produced cracks during the pouring process. Meanwhile, for aluminium alloy casting, all the developed formulations are appropriate. The results also showed that the bottom filled gating system has produced the best result of casting. Therefore, the formulations of 70 - 85% silica and 15 - 30% POP are highly recommended for both of alloys, provided all procedures of wax tree assembling, mold material mixing, dewaxing, preheating and pouring are followed properly to reduce the risk of defects.