FORMULATION AND CHARACTERIZATION OF PORCELAIN BALLS FROM MALAYSIA CLAYS

by

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Thesis submitted in fulfilment of the
requirements for the degree of
Master of Science

December 2016

ACKNOWLEDGEMENTS

Bismillahhirrahmanirrahim. Alhamdulillah, with the granted from Allah S.W.T, this thesis can finally be completed.

My most sincere appreciation is to my supervisor Prof. Dr. Hj. Zainal Arifin Ahmad for supervision, encouragement, valuable advices and enthusiastic support throughout the research work. His guidance helped me in all time of research and writing of this thesis. Besides my supervisor, I would like to thank my co-supervisor: Assoc. Prof. Dr. Mohd Roslee Othman for his continuous support through their suggestion and guidance in the research.

I would like to thank to Public Service Department (JPA) for their sponsorship throughout my study under HLP Scholarship Scheme. I would like also to thank JPA officers for their excellent service. I would like to thank to Director of Minerals Research Center, Minerals and Geoscience Department, Ipoh, Perak for study leave and laboratory supports.

I would like to convey my special thanks to Dean, Deputy Dean, lecturers and other staffs of School of Materials and Mineral Resources Engineering, USM for their kind assistants and supports. Without their kind cooperation, this study could be not completed on time.

Unforgettably, I would like to thank my colleagues in the Lab 0.36 for their contributions to this research and their friendship. I would particularly like to thank Dr. Nik Akmar Rejab, Dr. Wan Fahmin Faiz Wan Ali, Dr. Abdul Rashid Jamaludin, Mr. Fariz Ab Rahman, Mr. Johari Abu, Mrs. Fatin Khairah and Mrs. Rosyaini Afindi Zaman.

Finally, I would like to express my highest gratitude to my mum, dad, family and all friends for their care and supports. A very special thank you to my wife, Marniyati Mamat Noor, for her patience during the hours I was caught up in my own world in thought, analysing data and compiling this thesis.

Hamdan Bin Yahya

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~	approximately
Å	Angstrom
a*	Degree of reddish
b*	Degree of yellowish
Dv	Volume distribution particle size
GoF	Goodness of fit
H_v	Hardness Vickers
L*	Degree of lightness
Mt	million tonne
N_c	Critical speed
$R_{Exp.}$	R expected (error factor)
R_P	R profile (reliability factor)
R_{WP}	Weighted R profile
S_{BET}	Specific surface area
wt.%	weight percent
W_D	Dry weight
W_I	Immersed weight
W_S	Soaked weight
λ	Wave length

LIST OF ABBREVIATIONS

AP	Apparent density
API	Active pharmaceutical ingredients
ASTM	American Society for Testing and Materials
BC	Bidor clay
BD	Bulk density
BET	Brunauer-Emmett-Teller method
CDSCO	Central Drugs Standard Control Organization
CE	Current era
CFDA	China Food and Drug Administration
CIE	International Commission on Illumination
CIP	Cold Isostatic Press
CVD	Chemical vapour deposition
DCA	Drug Control Authority
DTA	Differential thermal analysis
EMA	European Medicines Agency
FESEM	Field Emission Scanning Electron Microscopy
GPa	Giga Pascal
HK	High grade kaolin
ICDD	International Centre for Diffraction Data
ICH	International Conference on Harmonization
ISO	International Organization for Standardization
KC	Kg. Coldstream clay
KFDA	Korea Food and Drug Administration
kgf	kilogram force

LK	Low grade kaolin
LL	Liquid limit
LOI	Loss of ignition
MCAZ	Medicines Control Authority of Zimbabwe
MHRA	Medicines and Healthcare Products Regulatory Agency
MLCC	Multilayer ceramic condenser
MPa	Mega Pascal
PAHO	Pan American Health Organization
PBB	Porcelain Ball Bidor
PBC	Porcelain Ball Coldstream
PBP	Porcelain Ball Simpang Pulai
PBS	Porcelain Ball Selendang
PBT	Porcelain Ball Trong
PI	Plastic index
PKKMCP	Perbadanan Kemajuan Kraftangan Malaysia Cawangan Perak
PL	Plastic limit
PSZ	Partially stabilized zirconia
QPA	Quantitative phase analysis
RM	Ringgit Malaysia
rpm	rotation per minute
SAG	Semi-autogenous
SC	Selendang clay
SP	Simpang Pulai clay
TC	Trong clay
TEOS	tetraethyl orthosilicate
TGA	Thermogravimetric analysis

TZP	Tetragonal zirconia polycrystal
UOP	Universal Oil Product
USFDA	United State Food and Drug Administration
USP	United State Pharmacopeia
VHN	Vickers hardness number
WA	Water absorption
WHO	World Health Organization
WI	Whiteness Index
WIC	Whiteness index CIE
WIPO	World Intellectual Property Organization
WTO	World Trade Organization
XRD	X-ray diffraction
XRF	X-ray fluorescence
Y-TZP	Yttria stabilized tetragonal zirconia polycrystal

FORMULASI DAN PENCIRIAN BEBOLA PORSELIN MENGGUNAKAN LEMPUNG-LEMPUNG DARI MALAYSIA

ABSTRAK

Kajian yang dijalankan ini adalah bertujuan untuk menghasilkan bebola seramik sebagai media pengisar pada suhu pensinteran rendah yang mempunyai sifat-sifat mekanikal dan fizikal yang unggul berbanding media pengisar sama yang didapati secara komersil. Kebanyakan media pengisar yang digunakan ialah bebola keluli terutamanya untuk pemprosesan mineral bagi pengurangan saiz partikel, walau bagaimanapun ia tidak sesuai untuk industri farmaseutikal dan kosmetik kerana pencemaran besi. Oleh itu, bebola seramik adalah salah satu media alternatif yang boleh menggantikan media pengisar daripada keluli disebabkan kestabilan kimia dan ketahanan haus yang tinggi. Walau bagaimanapun, industri-industri di Malaysia adalah semata-mata bergantung kepada bebola seramik yang diimport. Oleh itu, kajian ke atas penghasilan bebola seramik tempatan menggunakan tanah liat Malaysia yang siap proses dimulakan. Kajian ini dibahagikan kepada tiga bahagian iaitu Bahagian I adalah pencirian ke atas lima tanah liat Malaysia yang siap proses terpilih, Bahagian II adalah penilaian lima formulasi jasad porselin tempatan iaitu PBT, PBC, PBP, PBS dan PBB yang masing-masing menggunakan lempung-lempung dari Trong, Kg. Coldstream, Simpang Pulai, Selendang dan Bidor. Bahagian III berkenaan dengan sifat-sifat pengisaran bebola porselin tempatan terpilih (PBT) untuk ujian haus dan lusuh bagi menentukan prestasi pengisarannya dan dibandingkan dengan bebola porselin komersil. Keputusan menunjukkan bahawa sifat-sifat fizikal dan mekanikal jasad porselin tempatan meningkat dengan suhu pensinteran di mana jasad porselin PBT yang disinter pada 1270 °C menunjukkan kekerasan (7.32 GPa) dan kekuatan mampatan (381.6 MPa) yang paling tinggi. Keputusan prestasi pengisaran menunjukkan bahawa bebola PBT mempunyai lima kali lebih hebat rintangan haus

iaitu hanya 2.44% kehilangan berat berbanding 13.49% bagi CPB (bebola porselin komersil) dan 10% lebih baik prestasi pengisarannya bagi pengurangan saiz partikel berbanding CPB. Kajian ini membuktikan bahawa bebola porselin yang dihasilkan secara tempatan mempunyai sifat-sifat unggul berbanding bebola porselin yang terdapat di pasaran.

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ABSTRACT

The aim of this research is to fabricate locally produced low sintering temperature porcelain balls as grinding media with superior mechanical and physical properties than the similar commercially available grinding media. The mostly used grinding media is steel balls especially for mineral processing for reduction of particles sizes; however, it is not suitable for pharmaceutical and cosmetic industries due to contamination of iron. Therefore, porcelain balls are one of the alternative media that can substitute this steel grinding media due to its high chemical stability and wear resistant. However, Malaysian industries are solely dependent on the imported ceramic balls. Therefore, this research on locally produced ceramic balls using processed Malaysian clays was initiated. The research is divided into three parts i.e. Part I is on characterization of the five selected processed Malaysian clays, Part II deals on the evaluation the five formulated local porcelain bodies based on PBT, PBC, PBP, PBS and PBB, which used clays from Trong, Kg. Coldstream, Simpang Pulai, Selendang and Bidor, respectively. Part III deals with the grinding properties of the selected local porcelain body formulation (PBT) which was tested for wear and tear tests for milling performance and compared to the commercial porcelain balls. Results showed that physical and mechanical properties of local porcelain bodies were increased with sintering temperature whereby PBT body sintered at 1270 °C shows the highest hardness (7.32 GPa) and compressive strength (381.6 MPa). The milling performance results showed that PBT balls has five times greater wear resistance is only at 2.44% whereas 13.49% for CPB (commercial porcelain balls) and 10% better milling performance of particles size reduction than CPB. This research proves that locally

produced porcelain balls have superior properties than the commercially available porcelain balls.

CHAPTER ONE

INTRODUCTION

1.1 Research background

Grinding is crucial industrial operation that is used to reduce the size of the materials and release of valuable minerals from their matrices. Size reduction is critical step in many of the procedures by which raw materials are transformed into finished product. In mineral beneficiation, size reduction materials by grinding process is also use the most energy (Ozkan et al., 2009). Grinding cost is approximated 30-50% of common mining operating expenditures (Aldrich, 2013). Therefore, research efforts have been conducted continuously to reduce the costs. Costing during grinding process can be reduce by using suitable grinding media balls. Two types of grinding media balls in the market are metals and non-metals (Aldrich, 2013). Non-metal balls are made of ceramic materials such as alumina, silicon carbide, zirconium oxide and porcelain. Metal balls that commonly used are steel, stainless steel, carbon steel and chrome steel.

Metal balls such as steel-based grinding media ball are widely used in mineral processing industry for reduces ore mineral particles and others industry such as paper, paint, pharmaceutical and cosmetic manufactures. Steel balls are possess great impact toughness although less hardness. This make them more relevant to milling environments where large impact and rough grinding is needed, such as milled of hard gold ores (Aldrich, 2013). However, high wear and iron (Fe) contamination during grinding for long times, usage of steel-based grinding balls have been restricted in the production of sensitive products such as pharmaceuticals and cosmetics.

Currently, the operating benefits of grinding with fully inert ceramic media at plant scale has been termed as (i) improved selectivity against sulphide gangue mineral components, (ii) increased recovery of fine value mineral particles, and (iii) reduced collector consumption, amongst other benefits (Pease et al., 2006). The development of milling technology, utilising fully inert grinding media, efficiently avoids contamination of mineral surfaces from grinding media sources. Others field, pharmaceutical and cosmetics manufactures also used ceramic ball as grinding media to prevent contamination occurs.

Pharmaceutical and cosmetic manufacturers are very sensitive areas which involve human health and the most highly regulated industries worldwide. Every country has its own regulatory authority, which is responsible to enforce the rules and regulations and issue the guidelines to regulate drug development process, registration, manufacturing, licensing, marketing and labelling of pharmaceutical products. The regulatory authority of pharmaceutical products such as United States Food and Drug Administration (USFDA), China Food and Drug Administration (CFDA), Medicines Control Authority Zimbabwe (MCAZ), Medicines and Healthcare Products Regulatory (MHRA, UK), Central Drugs Standard Control Organization (CDSCO, India), Korea Food and Drug Administration (KFDA) and Drug Control Authority (DCA, Malaysia) are the few regulatory agencies and organizations established in respective countries (Fahmi et al.,2015; Hussain et al., 2015; Flick et al.,2016). World Health Organization (WHO), International Conference on Harmonization (ICH), World Intellectual Property Organization (WIPO), Pan American Health Organization (PAHO) and World Trade Organization (WTO) are some of the international regulatory agencies and organizations which also play an important role in all aspects of pharmaceutical regulations (Khanam et al., 2013; Simopoulos et al., 2000;