



**UNIVERSITI PUTRA MALAYSIA**

**DEVELOPMENT OF A CERAMIC FOAM FILTER FOR FILTERING  
MOLTEN ALUMINUM ALLOY IN CASTING PROCESSES**

**EHSAANREZA BAGHERIAN**

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**By**

**EHSAANREZA BAGHERIAN**

**Thesis Submitted to the School of Graduate Studies, Universiti Putra  
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Fulfilment of the requirement for the degree of Master of Science

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**Chairman: Dr. Mohd Khairul Anuar Mohd Ariffin,Phd**

**Faculty: Engineering**

Metal casting component are found in 90 percent of manufactured goods and equipment, from critical components for aircraft and automotive industry to home applications. However, molten metal used to produce metal casting in practice generally contains impurities and inclusions which are deleterious to final cast metal product. Currently, filtration technique by using ceramic foam filter has been accepted as a successful method of reducing inclusions from molten metal during the casting of metal parts.

The present research has been done to fabricate and improve a ceramic foam filter for using in filtration of molten metal, especially aluminium based alloys. It is an objective of the present innovation to provide a ceramic foam filter characterized by cost of raw materials. Ceramic foam filters are produced by impregnating polyurethane foam with ceramic slurry, drying, baking and finally firing the foam in the oven.

Experimental tests were carried out to the filters to measure dimensions, weight, cold compression strength, and permeability properties before



pouring process. After pouring process, the filter was cut into several sections to measure the macro and microstructure of the filter and ensure that impurity particles captured by a filter.

Thermal shock properties, obtained from pouring liquid aluminium when filter was placed in the gating system to ensure that the filters could withstand temperatures of aluminium alloys.

Further experiments were carried out to investigate and determine the efficiency of produced ceramic foam filter on quality of cast products. The result obtained in this investigation, the mechanical properties for aluminum LM6 alloy sand casting increased when ceramic foam filter was inserted into the gating system.

A produced filter by using new materials is economical to be produced. Further more, the analysis data shows present innovation filter which can be made in any shape and size, has excellent thermal shock resistance, adequate compressive strength, acceptable density and permeability properties.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia  
sebagai memenuhi keperluan untuk ijazah Master Sains

**PEMBANGUNAN PENAPIS BUSA SERAMIK UNTUK PENURASAN ALOI  
ALUMINUM CECAIR DIDALAM PROSES TUNGAN**

Oleh

**EHSAANREZA BAGHERIAN**

**September 2009**

**Pengerusi: Dr. Mohd Khairol Anuar Mohd Ariffin,Phd**

**Fakulti: Kejuruteraan**

Komponen tuangan logam ditemui dalam 90 peratus daripada barang-barang pembuatan dan peralatan, terdiri daripada komponen kritis untuk industri aeroangkasa dan otomotif hinggalah rumah aplikasi. Namun, logam cair yang digunakan untuk menghasilkan tuangan logam secara umumnya mengandungi ketidakmurnian dan inklusi yang akan merugikan produk akhir tuangan logam. Pada masa ini, teknik penapisan dengan menggunakan penapis busa seramik telah diterima sebagai satu kaedah yang berjaya bagi mengurangkan inklusi daripada logam cair semasa tuangan pada bahagian logam.

Penyelidikan sekarang dirangka untuk meningkatkan busa penapis seramik untuk digunakan didalam penapisan logam cair, khususnya pada asas aluminium aloi. Ini adalah bertujuan daripada inovasi yang hadir untuk menyediakan busa penapis seramik bercirikan oleh kos bahan asas. Penapis busa seramik adalah dihasilkan dengan mencelupkan busa



poliuretan dengan sluri seramik, pengeringan, dibakar dan akhirnya menembak busa kedalam ketuhar.

Ujian-ujian percubaan dilaksanakan untuk penapis bagi mengukur dimensi, berat, kekuatan mampatan sejuk, dan ciri-ciri ketelapan sebelum dituang proses tuangan. Selepas proses penuangan, turas akan dipotong ke beberapa bahagian bagi mengukur makro dan mikrostruktur turas dan untuk memastikan zarah-zarah bendasing itu ditangkap oleh penapis.

Ciri-ciri kejutan haba, diperolehi dari penuangan cecair aluminium apabila turas adalah diletakkan kedalam sistem pengegetan bagi memastikan bahawa penapis tersebut boleh bertahan dengan suhu-suhu pancalogam-pancalogam aluminium.

Eksperimen-eksperimen selanjutnya dijalankan bagi menyiasat dan menentukan kecekapan untuk menghasilkan busa seramik turas bagi kualiti produk tuangan. Berasaskan hasil yang diperolehi didalam siasatan ini, sifat-sifat mekanikal untuk aluminium aloi LM6 tuangan pasir bertambah apabila turas busa seramik diletakkan ke dalam sistem pengegetan.

Sebuah penapis yang dihasilkan dengan menggunakan bahan-bahan baru adalah lebih jimat untuk dihasilkan. Lebih lanjut, data analisis yang menunjukkan kehadiran inovasi turas yang boleh dibuat pada sebarang bentuk dan saiz, terdapat rintangan kejutan haba, kekuatan mampatan mencukupi, ketumpatan boleh diterima dan ciri-ciri ketelapan yang baik.

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I certify that an Examination Committee has met on 10<sup>th</sup> September 2009 to conduct the final examination of Ehsaanreza Bagherian on his Master of Science thesis entitled “DEVELOPMENT OF A CERAMIC FOAM FILTER FOR FILTERING MOLTEN ALUMINUM ALLOY IN CASTING PROCESSES” in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the student be awarded the relevant degree.

Member of the Examination Committee were as follows:

**Mohd Sapuan Bin Salit, PhD, PEng**

Professor  
Faculty of Engineering  
Universiti Putra Malaysia  
(Chairman)

**Aidy Bin Ali, PhD**

Lecturer  
Faculty of Engineering  
Universiti Putra Malaysia  
(Internal Examiner)

**Rizal Bin Zahari, PhD**

Lecturer  
Faculty of Engineering  
Universiti Putra Malaysia  
(Internal Examiner)

**Md. Mohafizul Haque, PhD**

Professor  
Faculty of Engineering  
International Islamic University Malaysia  
(External Examiner)

---

**BUJANG KIM HUAT, PhD**

Professor and Deputy Dean  
School of Graduate Studies  
Universiti Putra Malaysia

Date:



This thesis was submitted to the senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Master of Science. The members of the supervisory committee were as follow:

**Mohd Khairol Anuar Mohd Ariffin, PhD**

Lecturer  
Faculty of Engineering  
Universiti Putra Malaysia  
(Chairman)

**Shamsuddin Bin Sulaiman, PhD**

Professor  
Faculty of Engineering  
Universiti Putra Malaysia  
(Member)

---

**HASANAH MOHD GHAZALI, PhD**

Professor and Dean  
School of Graduate Studies  
Universiti Putra Malaysia

Date: 10 December 2009



## DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Putra Malaysia (UPM) or other institutions.

---

Ehsanreza Bagherian

Date:



## TABLE OF CONTENTS

	<b>Page</b>
<b>ABSTRACT</b>	ii
<b>ABSTRAK</b>	iv
<b>ACKNOWLEDGMENTS</b>	vi
<b>APPROVAL</b>	viii
<b>DECLARATION</b>	x
<b>LIST OF TABLES</b>	xiii
<b>LIST OF FIGURES</b>	xiv
<b>LIST OF ABBREVIATIONS</b>	xvi
<b>CHAPTER</b>	
<b>1 INTRODUCTION</b>	
1.1 Background of the study	1-1
1.2 Problem statement	1-3
1.3 Objectives	1-4
1.4 Thesis layout	1-4
<b>2 LITERATURE REVIEW</b>	
2.1 Introduction	2-1
2.1.1 General aspects of casting	2-1
2.1.2 Casting defects	2-3
2.2 Refining technology	2-5
2.2.1 Fluxing	2-5
2.2.2 Degassing	2-6
2.2.3 Flotation	2-8
2.2.4 Filtration	2-8
2.3 Theory and mechanism of filtration	2-9
2.3.1 Theory of filtration	2-9
2.3.2 Mechanism of filtration	2-11
2.4 History and development of ceramic foam filter	2-11
2.5 Reason for the growth in the use of filtration	2-13
2.6 Filter types	2-13
2.7 Filter application technologies	2-13
2.7.1 Filter pore size selection	2-14
2.7.2 Filter size calculation	2-15
2.7.3 Filter placement	2-16
2.8 Summary	2-17
<b>3 RESEARCH METHODOLOGY</b>	
3.1 Introduction	3-1
3.2 Fabrication of ceramic foam filter	3-1
3.2.1 Material description	3-2
3.2.2 Selection the sponge	3-4
3.2.3 Preparation the slurry	3-5
3.2.4 Immersing the sponge and removing excess slurry	3-6



3.2.5	Drying and baking ceramic slurry	3-7
3.2.6	Burning out the sponge	3-7
3.3	Analysis experimental data for pre-pouring test	3-8
3.3.1	Shape, size and dimension control	3-8
3.3.2	Weight comparison	3-8
3.3.3	Flow modification mechanism	3-9
3.3.4	Compression strength test	3-10
3.4	Casting	3-11
3.4.1	Pattern making	3-11
3.4.2	Preparation of moulding sand mixture	3-12
3.4.3	Preparation of the cope	3-12
3.4.4	Direct pour filter application setup	3-13
3.4.5	Preparation of the drag	3-13
3.4.6	Material description for casting process	3-12
3.4.7	Melting process and cast material	3-14
3.4.8	Casting fabrication	3-15
3.5	Analyse experimental data for after pouring test	3-15
3.5.1	Thermal shock inspection	3-16
3.5.2	Weight of metal contain filter and no-filter	3-16
3.5.3	Volume of metal contain filter and no-filter	3-17
3.5.4	Macrostructure of metal contain filter	3-17
3.5.5	Microstructure of metal contain filter	3-18
3.5.6	Tensile testing	3-18
3.5.7	Brinell hardness testing	3-21
<b>4</b>	<b>RESULTS AND DISCUSSION</b>	
4.1	Discussion for fabrication filter	4-1
4.2	Shape, size and dimension inspection	4-2
4.3	Weight comparison	4-2
4.4	Permeability measurement	4-3
4.5	Compression strength test	4-4
4.6	Thermal shock inspection	4-5
4.7	Weight and volume of metal which contain filter measurement	4-6
4.8	Macrostructure and microstructure of metal which contains filter	4-6
4.9	Tensile measurement	4-7
4.10	Hardness measurement	4-8
4.11	Material composition and cost analysis	4-9
<b>5</b>	<b>CONCLUSIONS AND RECOMMENDATIONS</b>	
5.1	Conclusions	5-2
5.1.1	Conclusion for fabrication of filters	
5.1.2	Conclusion for efficiency of filters	
5.2	Recommendations for future research	5-3
	<b>REFERENCES</b>	R-1
	<b>APPENDICES</b>	A-1
	<b>BIODATA OF STUDENT</b>	B-1



## LIST OF TABLES

Tables		Page
1	Estimated global filter consumption in 2003	1-5
2	Forecast of total worldwide metal casting shipments (million tons)	2-18
3	Contact angle of different refractory materials	2-18
4	Characteristic and properties of various types of filter	2-18
5	Selected filtration capacity factor	2-19
6	Materials composition used for ceramic foam filter preparation on U.S Patents	3-24
7	Materials composition used for ceramic foam filter preparation on Foseco Metallurgical Inc MSDS (Materials Safety Data Sheet)	3-25
8	Materials composition used for ceramic foam filter preparation in present research study	3-25
9	Drying and baking ceramic slurry and firing foam program	3-26
10	Chemical composition of LM6 (weight per cent)	3-26
11	Comparison weights of produced and imported filters	4-11
12	Comparison permeability of produced and imported filters	4-11
13	Comparison compression strength of imported and produced filters	4-11
14	Comparison weight of metal which contains filter	4-12
15	Comparison volume of metal which contains filter	4-12
16	Comparison maximum load of filter samples	4-12
17	Brinell values of the produced filters	4-12
18	Brinell values of the imported filters	4-13
19	Brinell values of the non-filters samples	4-13
20	Cost analysis of produced ceramic foam filters	4-13



## LIST OF FIGURES

Figure		Page
1	Schematic illustration of a sand mold, showing various features	2-20
2	Schematic illustration of a sand casting defects	2-20
3	Solubility of hydrogen in aluminum	2-21
4	Liquid and solid inclusion removal theory	2-22
5	Mechanism of filtration	2-23
6	Five possible mechanism of inclusion particle transport in deep bed filtration under laminar flow conditions	2-23
7	Filter types	2-24
8	Different porosity of ceramic foam filters	2-25
9	Calculation of effective pouring height	2-25
10	Schematic of direct pouring application	2-25
11	Schematic of indirect pouring application	2-26
12	Polymeric sponge and plastic forming method	3-27
13	Flowchart of research methodology	3-28
14	Flowchart of experimental data for pre-pouring test	3-29
15	Flowchart of experimental data for after pouring test	3-30
16	Polyurethane foam	3-31
17	Preparation the ceramic slurry	3-31
18	Immersing the sponge and removing excess slurry	3-32
19	Produced ceramic foam filter	3-33
20	Compression strength test	3-33
21	Pattern	3-34



22	Mold with filter and without filter sand mold	3-35
23	Pouring aluminium LM6 into the mold cavity	3-35
24	Fabricated parts	3-36
25	Pattern for non-filtered mold	3-36
26	Sand mold for non-filtered specimen	3-36
27	Volume measurement of metal which contains filter	3-37
28	Tensile test specimens	3-38
29	Brinell hardness testing	3-39
30	Visually inspection in surface of specimens	3-40
31	Sticky and burnt filters	4-14
32	Thickness and diameter inspection of produced and imported filter with polyurethane foam before drying, baking and sintering process	4-14
33	Flow modification test by water modelling	4-16
34	Thermal shock inspection of produced and imported filters	4-16
35	Macrostructure of metal which contains of imported and produced filters	4-17
36	Microstructure of metal which contains of imported and produced filters	4-18



## LIST OF ABBREVIATION

CFF	Ceramic Foam Filter
cm	Centimetre
CO <sub>2</sub>	Carbon dioxide
TiB <sub>2</sub>	Titanium boride
Ca	Calcium
Na	Sodium
Li	Lithium
Mg	Magnesium
ml	Millilitre
G	Gram
Si	Silicon
Cu	Copper
Mn	Manganese
Ni	Nickel
C <sub>2</sub> Cl <sub>6</sub>	Hexachloroethane
µm	Micrometre
min	Minute
AL <sub>4</sub> C <sub>3</sub>	Aluminium carbide
AL	Aluminium
AL <sub>2</sub> O <sub>3</sub>	Aluminium oxide
H	Hydrogen
ΔG	Gibbs free energy
$\gamma$	Interfacial energy
$\gamma_{MI}$	Interfacial energy between the melt and the liquid inclusion
$\gamma_{MF}$	Interfacial energy between the melt and the liquid inclusion
$\gamma_{FI}$	Interfacial energy between the filter and the liquid inclusion



ppi	Pores per inch
Da	Down sprue area (cm <sup>2</sup> )
G	Poured weight (kg)
$f$	Friction factor
$\rho$	Density (kg/dm <sup>3</sup> )
t	Required pouring time (s)
H	Effective pressure or pouring height (cm)
Cr <sub>2</sub> O <sub>3</sub>	Chromium oxide
CaO	Calcium oxide
SiO <sub>2</sub>	Silicon dioxide
MgO	Magnesium oxide
B <sub>2</sub> O <sub>3</sub>	Boric oxide
°C	Celsius degree
KN	Kilo Newton
mm/min	Millimetre per minute
MPa	Mega Pascal
Kgf	Kilogram force
D	Diameter of the ball, mm
F	Test force, N
d	Mean diameter of the indentation, mm

# CHAPTER 1

## INTRODUCTION

### 1.1 Background of the study

Metal casting is basically a process including (a) pouring molten metal into a mold patterned after the part to be manufactured, (b) allowing it to solidify, and (c) removing the part from the mold [1].

Many industrial parts and components are produced by the method of casting process such as engine blocks, crankshafts, automotive components, railroad equipment, plumbing fixtures, and power tools to home application [2]. Metal casting is a unique competitive process with other metal manufacturing processes. The most important reasons are: capable of producing complex shape components in both ferrous and non-ferrous metal, ranging in weight from less than an ounce for a single part to several hundred tons [1]. According to the recent trends with increased competition, sales of metal castings are expected to grow to US\$37.7 billion in 2008 [3].

The quality of casting basically is considered as producing casting products free of defects. Casting defects are divided into three groups [4]:

- Surface defect are due to poor design and quality of sand mould.
- Visible defect are causes of insufficient mould strength, low pouring temperature and bad design of casting.



- Internal defects found in the castings are mainly due to dirty metal. These defects also occur when excessive moisture or excessive gas forming materials are used for mould making.

Usually surface and visible casting defects can be repaired by technical operation such as welding, machining or sand blast operation, but inclusions may come from metal reaction with environment, crucible, mould materials, chemical reaction, slag and foreign material entrapped in molten metal can be reduced the strength of casting. Therefore the inclusion particles smaller than  $30\mu\text{m}$ , should be filtered out during to casting process [1, 4].

"Filtration is the process of separating solid particles from the melt, with the solid particles being captured on the filter and the liquid phase passing through the filter. In addition to solid particles, there are also semi-liquid phases of high viscosity in molten metals; this fraction is captured by the adhesion mechanism and stick to the filter walls" [5].

Filter according to mechanism of filtration divided into multi-dimensional and single-dimensional. In single-dimensional filters, only inclusion on surface can be removed and inclusion smaller than the minimum cell or hole size are passed through the filter hole size. But, the small particle in multi-dimensional filters can be trapped in the internal filter surface [6].

Filtration technology was introduced into the aluminium industry in the late 1950's [7]. Then, various filtration systems have been developed. The development of the Ceramic Foam Filter (CFF) or reticulated ceramic was in 1974 [8]. Then the application of filtration techniques expanded in the



aluminium foundry industries. In 1992, eight million metric tons of aluminium was filtered with ceramic foam filter, It equivalent to almost 50% of the total production of aluminium in the world [9]. Since now, a majority of both ferrous and non-ferrous alloy are filtered during casting. Estimated global filter consumption in 2003 is presented in Table 1. As indicated to table 1, the product type totals in 2003 is equal to more than 650 million ceramic foam filter pieces per year [10].

## **1.2 Problem Statement**

Since 1976-2007 several efforts had been done to fabricate various ceramic foam filters in foundry industry include U.S. Pat. No. 3947363 (Ceramic foam filter 1976), U.S.Pat. No. 4343704 (Ceramic foam filter 1982), U.S. Pat. No. 4391918 (Ceramic foam filter and aqueous slurry for making same 1983) and U.S. Pat. No. WO/2007/120483(Low expansion corrosion resistant ceramic foam filters for molten aluminum filtration 2007). Although all of the filters which have been fabricated in these patents have achieved acceptable ideal properties (high thermal shock resistance, adequate strength and low density), but none of them have been able to reach an acceptable price. Expensive price of these filters are related to high costs of additive raw materials such as Montmorillonite, Magnesium oxide, Chromium oxide, Calcium oxide, Boron trioxide or Silicon dioxide [11, 12, 13, 14].



### **1.3 Objectives**

The key objectives in this study are:

- (1) To fabricate ceramic foam filter for filtration of aluminium alloy with new cheaper additives materials including: Carbon, Bentonite, Silicon Carbide and sand from beach instead of Silicon Dioxide.
- (2) To investigate and determine how the designed CFF affect the quality of cast products.

### **1.4 Thesis layout**

This thesis is structured into 5 chapters and started with introduction and literature review to clarify the advantage and limitation of casting defects and refining technique. Detailed elaboration of theory and mechanism of filtration, benefit of ceramic foam filters and filters application in gating system. the Chapter 3 presents the methodology comprises the manufacturing process of ceramic foam filters which is includes: raw material preparation, selecting the sponge, slurry preparation , sponge immersing, removing excess slurry, drying and burning the sponge and other experimental tests to control the quality of filters. Results of experiments and data analysis overall discussed and explained in Chapter 4. The final conclusions of this study and recommendations for future research are in Chapter5.



**Table 1: Estimated global filter consumption in 2003 [10]**

<b>Area</b>	<b>Foam (million)</b>	<b>Extruded (million)</b>	<b>Pressed (million)</b>	<b>Total (million)</b>
<b>Europe</b>	149	16	53	218
<b>N. America</b>	55	72	102	229
<b>Japan</b>	74	7	4	85
<b>S. America</b>	40	0	6	46
<b>S. Korea</b>	36	3	1.5	40.5
<b>Other Regions</b>	10	5	20	35
<b>Product type total</b>	364	103	186.5	653.5
<b>Global consumption</b>	55.7%	15.76%	53%	100%

## CHAPTER 2

### LITERATURE REVIEW

#### 2.1 Introduction

The history of metal casting goes back to 3200 BC, through finding a copper frog which was found in Mesopotamia [15]. Since now, after 5000 years of technological advances, metal casting process plays a greater part in industry.

Global shipment of metal casting is growing at high rapid rate in the world which reached 90 million tons in 2008. Table 2 shows, shipments of metal casting worldwide are increase at an average annual rate of 2.4% from 2004 to 2008 [16]. Therefore, in this study, the selected literature is deliberated to provide knowledge on important aspects of sand casting and filtration process for refining of aluminum alloy.

##### 2.1.1 General aspects of casting process

Mold designing and manufacturing process are two steps of metal sand casting process.





(1) Mold designing is the first step of sand casting process. The sand mold is enclosed in flask which involves of two parts: cope, the upper half and drag, the lower half. The plane between cope and drag is called parting plane which consists of sprue, runner and gate as shown in Figure1 [17].

- Sprue or down sprue is the vertical passage in parting plane connected to pouring cup.
- Runner is the horizontal distribution channels in parting plane.
- Gate is the connection between the runner and cavity of parting plane to be cast.

(2) Manufacturing process of sand casting is includes (a) mold preparation, (b) melting and casting, and (c) finishing operation.

- Mold preparation: Casting technology can be divided into two board categories according to the type of mold used: (a) permanent and (b) expandable mold [18, 19]. Permanent mold is one that can be used over and over again to produce many castings. It is generally made of metal that can withstand the temperature of alloy to be cast. Expandable mold is the mold that must be destroyed after solidification. Expandable mold is made by sand with the appropriate usage of binder such as clay, organic oil, resin and silicates [20, 21].
- Melting and casting: The melting of metals can be carried out in suitable furnace such as cupola, arc, induction and etc [22]. Cupola furnace is normally used for cast iron [23]. Electric arc furnace is use

