

**DEVELOPMENT OF A FRAMEWORK TO
ENCOURAGE INJECTION MOULD
REMANUFACTURING IN SRI LANKA**

Buddhima Karuni Wanaguru

198429U

Master of Engineering in Manufacturing Systems Engineering

Department of Mechanical Engineering
Faculty of Engineering

University of Moratuwa
Sri Lanka

March 2023

**DEVELOPMENT OF A FRAMEWORK TO
ENCOURAGE INJECTION MOULD
REMANUFACTURING IN SRI LANKA**

Buddhima Karuni Wanaguru

198429U

Thesis/Dissertation submitted in partial fulfilment of the requirements for the degree
Master of Engineering in Manufacturing Systems Engineering

Department of Mechanical Engineering
Faculty of Engineering

University of Moratuwa
Sri Lanka

March 2023

DECLARATION

I declare that this is my own work and this thesis/dissertation does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or Institute of higher learning and to the best of my knowledge and belief, it does not contain any material previously published or written by another person except where the acknowledgement is made in the text. I retain the right to use this content in whole or part in future works (such as articles or books).

Signature:

Date: 2023-03-13

The above candidate has carried out research for the Master's thesis/dissertation under my supervision. I confirm that the declaration made above by the student is true and correct.

Name of the supervisor: Dr. J.R.Gamage

Signature of the supervisor:

Date:

ACKNOWLEDGEMENT

First and foremost, I am extremely thankful to my supervisor, Dr J.R. Gamage, Senior Lecturer of the Department of Mechanical Engineering at the University of Moratuwa for his immense support and advice given to me with this research. I am also grateful to Mr. Janaka Mangala for helping me when constructing the interview and allowing me to visit the die and mould laboratory at the University of Moratuwa.

I would also like to acknowledge Mr. Janath Priyankara, for involving in the validation of my framework and for sharing his knowledge and experience. Without his enthusiastic participation and feedback, the validation could not have been successfully conducted.

I would like to express my gratitude to my parents for motivating and encouraging me all the time. Without their tremendous support and understanding in the past three years, it would be impossible to complete this study.

I would also like to thank my cousin sister Ms. Jayathri Kalinga for generously providing her knowledge and expertise to make this thesis grammatically error-free.

Last but not the least, I would like to thank my sister, aunt, cousins and friends who helped me in numerous ways.

ABSTRACT

The global mould manufacturing market amounts to USD 26.21 billion in 2020 and is expected to increase to USD 38.62 billion in 2025 at a Compound Annual Growth Rate (CAGR) of 8%[1]. This growing demand for moulds urges to develop sustainable methods to recover used moulds. Remanufacturing of moulds offers a promising solution in the industry which extends the useful life of end-of-use moulds. However, there is a lack of evidence that mould remanufacturing is used to reap its potential benefits in the Sri Lankan ‘Small and Medium-sized Enterprises (SME)’.

The purpose of this research is to develop a framework to promote mould remanufacturing in Sri Lanka. This research was conducted within organizations that are already remanufacturing moulds, manufacturing moulds and which have the potential to remanufacture moulds. Semi-structured interviews of 09 organizations were conducted to ascertain relevant data to develop the framework to promote mould remanufacturing. Literature review and semi-structured interviews were used to establish the current knowledge, to identify barriers, and to identify key elements in developing the framework.

The presented framework is in the format of a three-by-three matrix that is developed to help promote mould remanufacturing. The three columns address, 1) barriers and challenges, 2) technologies or methods, and 3) process steps and essential factors. These three factors are fused with three phases as shown in the rows of the framework namely, the initial stage, process stage, and market stage. This framework would be beneficial for the stakeholders of mould remanufacturing. Future research can be directed to further fine-tune the framework and make it available in a more accessible form such as a web or a mobile application. Additionally, the research can be extended to include other types of moulds such as blow moulds, and compression moulds as the data were mostly sourced from plastic injection mould (re)manufacturing.

Keywords— Mould Remanufacturing, Mould remanufacturing in Sri Lanka, Remanufacturing Framework

TABLE OF CONTENTS

DECLARATION	i
ACKNOWLEDGEMENT	ii
ABSTRACT.....	iii
TABLE OF CONTENTS.....	iv
LIST OF FIGURES	vi
LIST OF TABLES	vii
LIST OF ABBREVIATIONS	viii
1. INTRODUCTION	1
1.1. Aim and Objectives	4
1.2. Methodology	4
1.3. Scope of the Project.....	5
2. LITERATURE REVIEW	7
2.1. The Context of Mould Remanufacturing in the World.....	8
2.2. Mould Remanufacturing Technologies	9
2.3. Mould Remanufacturing Methods and Strategies	9
2.4. Challenges and Limitations of Remanufacturing.....	10
2.5. Qualitative Data Collection Methods	11
2.6. Available Frameworks and Framework Development.....	14
2.7. Research Gap.....	15
3. METHODOLOGY	16
3.1. Literature Review Method.....	16
3.2. Interview Method	17
3.3. Pilot Study and Sample Data Analysis.....	19
3.4. Semi Structured Interview preparation.....	21

3.5.	Semi Structured Interviews	25
3.6.	Framework Development Method.....	26
4.	DATA COLLECTION AND ANALYSIS.....	27
4.1.	Sample Question 01	27
4.2.	Sample Question 02.....	27
4.3.	Sample Question 03.....	28
4.4.	Case Studies	28
4.5.	Challenges	30
5.	RESULTS AND DISCUSSION.....	31
5.1.	Semi-Structured Interview Results.....	31
5.1.1.	General Information.....	31
5.1.2.	Extent of Mould Remanufacturing	31
5.1.3.	Mould Remanufacturing Technologies	32
5.1.4.	Methods and Strategies	33
5.1.5.	Challenges of Mould Remanufacturing.....	33
5.2.	SWOT Analysis of Mould Remanufacturing in Sri Lanka	35
5.3.	Conceptual Framework	36
5.4.	Justification of Elements in Framework.....	37
5.5.	Validation of the Framework	38
6.	CONCLUSION.....	43
	REFERENCES.....	45

LIST OF FIGURES

Figure 1.1 US Trade in Tools, Dies and Industrial Moulds [3]	2
Figure 2.1 Pertinent Literature on Mould Remanufacturing by Year	7
Figure 2.2 Essential and Supportive Factors in Remanufacturing [33]	10
Figure 2.3 Sub phases of framework development	14
Figure 3.1 Questionnaire Flow Chart	18
Figure 3.2 Revised Questions Flow Diagram	20
Figure 3.3 Questionnaire Flow Diagram	22
Figure 5.1 SWOT analysis for mould remanufacturing in SMEs in Sri Lanka	35
Figure 5.2 Conceptual Framework	37
Figure 5.3 Validated Framework	39

LIST OF TABLES

Table 1.1 Problems Associated with Sri Lankan Mould Manufacturing Industry [4].	2
Table 1.2 Objective-Method Mapping.....	5
Table 1.3 Defining SMEs in Sri Lanka [10]	5
Table 2.1 Data Collection Research Methods.....	12
Table 2.2: Interview Methods	12
Table 3.1 : Question - Objective Mapping.....	24
Table 3.2 : Mapping the Interview Questions with the Expected Information to be Gathered	25
Table 5.1 : Problems Associated with Mould Remanufacturing in Sri Lanka.....	34

LIST OF ABBREVIATIONS

OEM – Original Equipment Manufacturer

CMM – Coordinated Measuring Machine

SME – Small to Medium Scale Enterprises

LSR – Liquid Silicone Rubber

CNC – Computer Numerical Control

EDM – Electrical Discharge Machining

WEDM – Wire Electrical Discharge Machining

TIG – Tungsten Inert Gas