A FRAMEWORK FOR LOCAL PRODUCTION OF A LOW COST PLASTIC INJECTION MOULD SYSTEM

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ABSTRACT

The development of a framework for the local production of low-cost injection moulds, using inputs and technical skills available within a typical Nigerian city is the focus of this study. The plastic casing of an auto-battery has been used as the case study product. Product analysis of the casing and casing mould were carried out to identify features amenable to simplification. For the injection mould design an injection pressure of 83MPa was used for the strength of material analysis. Materials availability survey and analysis were carried at the multipurpose metal and machinery market located in Agodi, Ibadan. Oyo State, Nigeria. A survey of metal fabrication related skills was carried out in the same market to identify artisans with skills relevant to the proposed production processes. A production process framework supportable by the identified local skills and materials was thereafter developed. Scrap medium carbon flat sheet was identified as a suitable material. Oxy-acetylene welding was identified as suitable for cutting while arc welding was found adequate for joining. The local artisans were found to be capable of producing the required product if given close supervision. An exploratory evaluation of the mould system was carried out using an improvised low pressure manually operated injection mould. Test, using locally available recycle plastic materials, indicated better plastic formation with a homogeneous polypropylene plastic than heterogeneous polypropylene plastic. It is concluded that plastic mould system is feasible for local fabrication.

Keywords: Plastic, Injection mould, auto battery, polypropylene

INTRODUCTION

Injection moulding is a manufacturing process for producing parts from both thermoplastic and thermosetting plastic materials (Berins, 1991). Plastics are used extensively by many key industries. The monetary value of a given mass of plastic is greatly more enhanced when used as casings of products in some engineering products than when used for common household utensils.

The Nigerian plastic industries presently produce plastic items like buckets, combs and cups requiring the use of off the shelf moulds while huge foreign exchange is spent on the importation of many high valued engineering plastic items that require custom made moulds. The nation's lack of capacity to produce customised plastics injection moulds is major factor in our inability to manufacture plastic casings for products like battery, electric kettle, calculator, television and radio casings. The objective of this study the development of a framework for the local production of low cost injection mould, using inputs and technical skills available within a typical Nigerian city.

The design and manufacture of injection mould is a time consuming and expensive process and traditionally require highly skilled tool and mould maker (Yesim, 2006; Douglas, 1996). Most of the recent work in mould design has been directed to the application of expert systems, knowledge based system and artificial intelligence to supplement the vast amount of human expertise required in traditional design process. Koelsh et al (1999) employed group technology technique to reduce mould design time. Kwong et al (1998) developed a computational system for the process design of injection moulding based on the expert system, which includes mould design production scheduling, cost estimation and determination of injection moulding parameters. Several studies have been made on improving the design of specific components of an injection mould.

DESIGN AND DEVELOPMENT OF FRAMEWORK

A process design framework that considers, evaluate and select alternatives designs based on a balanced between standard requirements, and what is available in terms of materials, local skills and possible product simplification has been adopted. In other words, the mould design was carried out based on a production framework and a production process supportable by available local skills and materials which may require a simplification of the product (mould) design. The alternative process design and product design modules receive information inputs form a number of factors. For instance the manufacturing capabilities of relevant production shops in the Ibadan market were analysed. Raw material availability in relevant markets within the Lagos-Ibadan axis as well as the consumer acceptance of the final product was put into consideration. This framework described above is illustrated in schematic model of Fig. 1.

The injection mould and product analysis

The case study item to be produced from mould is a plastic casing of an automobile battery. The product dimension has been obtained using product specifications in (Oladokun and Adekunle, 2008). The cavity and core mould are shown in Fig. 2. The product analysis yields the product tree of Fig. 3.

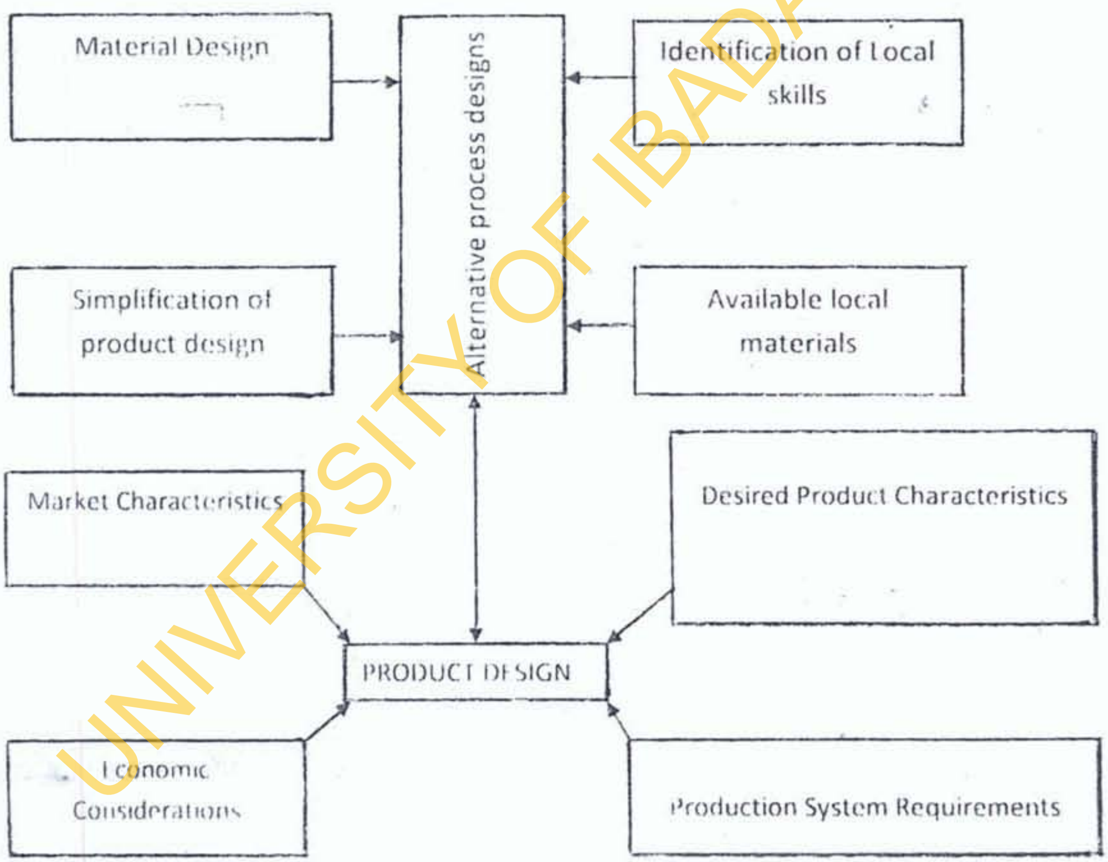

Fig. 1: Production framework of Mould system

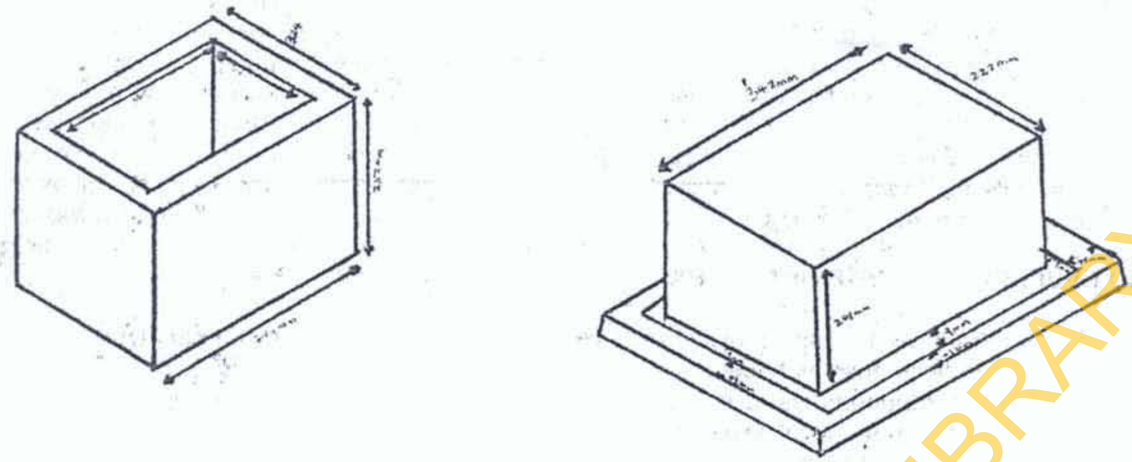

Fig. 2: The cavity and core of mould

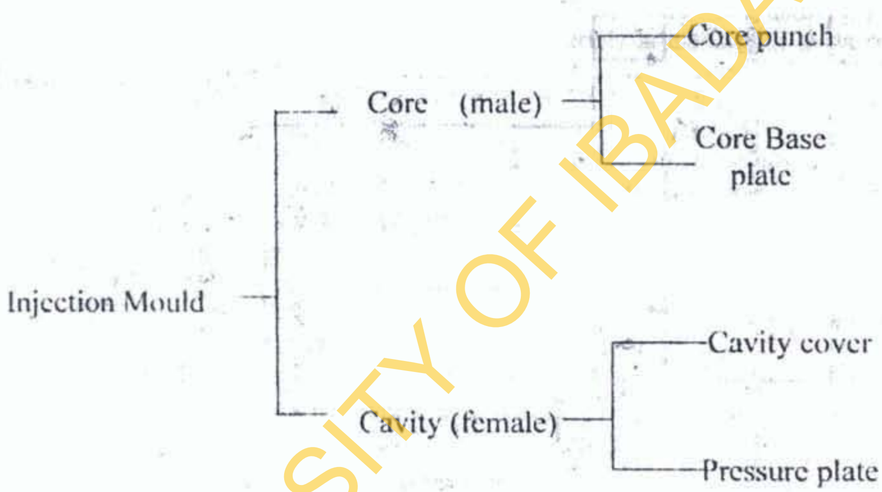

Fig. 3: Injection Mould product Tree

A bill of materials of Table 1 incorporating the make/buy decision was developed based on factors such as cost, availability of raw material, weldability and machinability of the materials.

Steel components specifications

Using the product specifications as shown in Fig 4, a design analysis was carried out to determine the appropriate dimensions of the input flat steel materials.

Calculation of thickness t of mould wall was based on using medium carbon steel plate of a tensile strength δ = 720N/mm^2. Based on literature a plastic pressure P = 83N/mm^2 (Jerrylee, 2008) has been adopted.

Hence the maximum force F in mould cavity, induced by pressure P acting on the largest projected area A is given by:

$F = PA = 83\times10^6 N/m^2 \times 0.0864m^2$ = 7,171,200N

Where $A = L\times B = 0.36\times0.24 = 0.0864m^2$

Therefore for equilibrium in cavity walls of thickness t

$$F = \delta \times t \times l \text{ i.e. } t = \frac{F}{\delta \times l}$$

Where $l = 2(L+B)$ is the total length of the mould material

$$t = \frac{7{,}171{,}200}{720 \times 10^{6} \times 1.2}$$

$$t = 0.0083m, \; t \approx 9mm$$

Hence the following specifications were used:
Steel type plate - Medium carbon steel
Plate thickness 9mm

Plate yield strength (shear) - 145MPa
Tensile strength of steel - 720N/mm^2

Cost Reduction Framework

Simplification of Product Design by Using Extra Assembly Operations was adopted by increasing the assembly requirement and necessitating some parts joining using heated tongs. Also use of alternative production process validated by appropriated strength of analysis and welding analysis is proposed. Ideal process flow for general mould making and proposed modified process flow for specific mould are shown in Fig. 5 and Fig. 6 subunits.

Table 1: Product Bill of material

Product Name Auto battery casing plastic Mould					
BOM Number BOM BC120					
S/N	Part No	Part Name	Qty	Material	Make or Buy Decision
1	B120	Core	1	Mild steel	Make
2	B130	Core Plate	1	Mild steel	Make
3	B140	Cavity cover	1	Mild steel	Make
4	B150	Pressure Plate	1	Mild steel	Make
5	C160	Clamp strip	2	Mild steel	Make
6	C170	Clamp screw	4	Mild steel	Buy
7	C170	Clamp nut	4	Mild steel	Buy

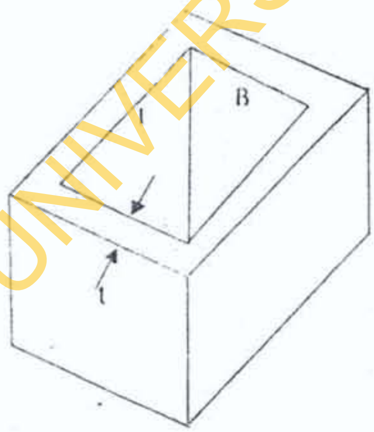

Fig. 4: Steel materials specification

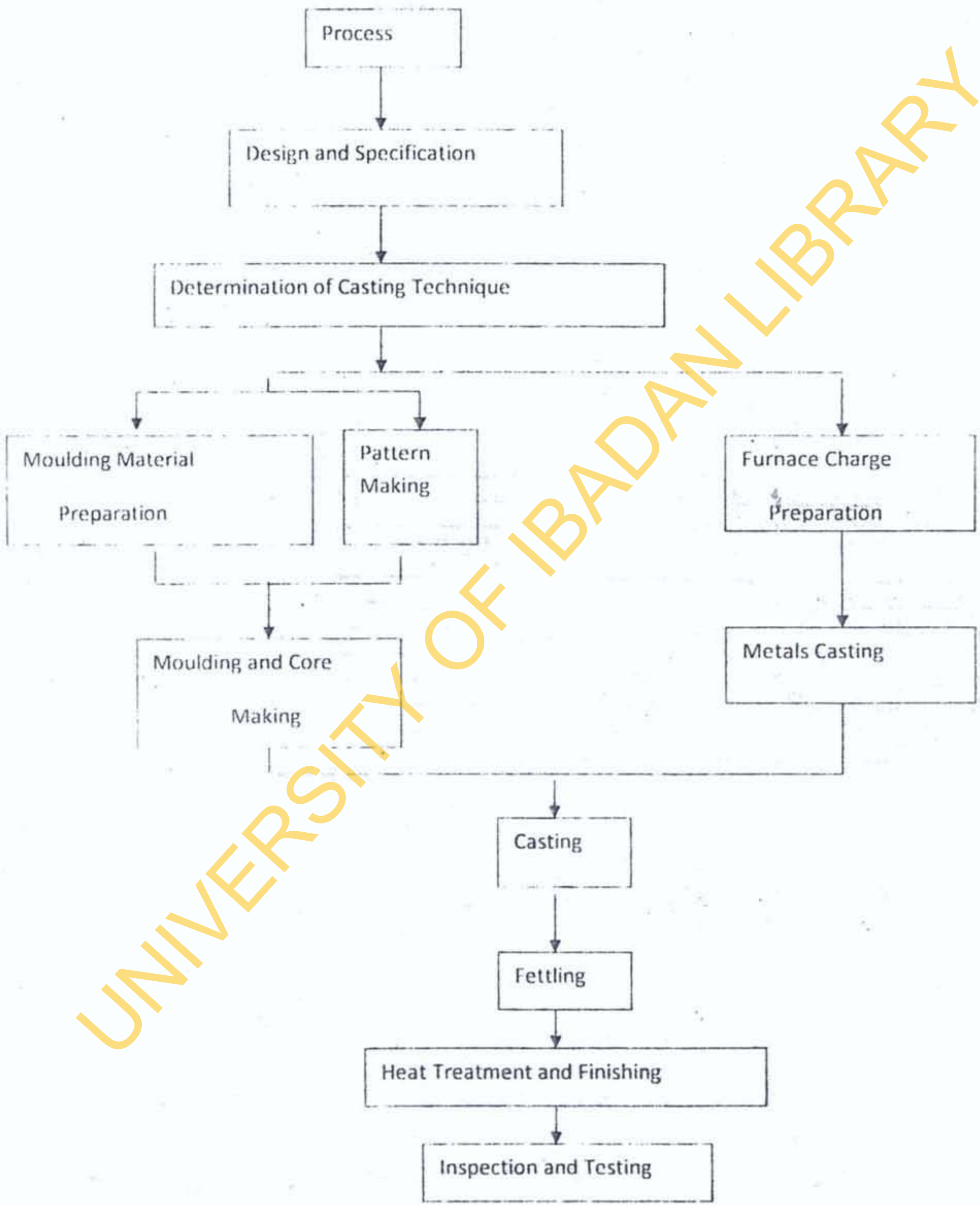

Fig. 5: Conventional Process Flow for General Mould Making

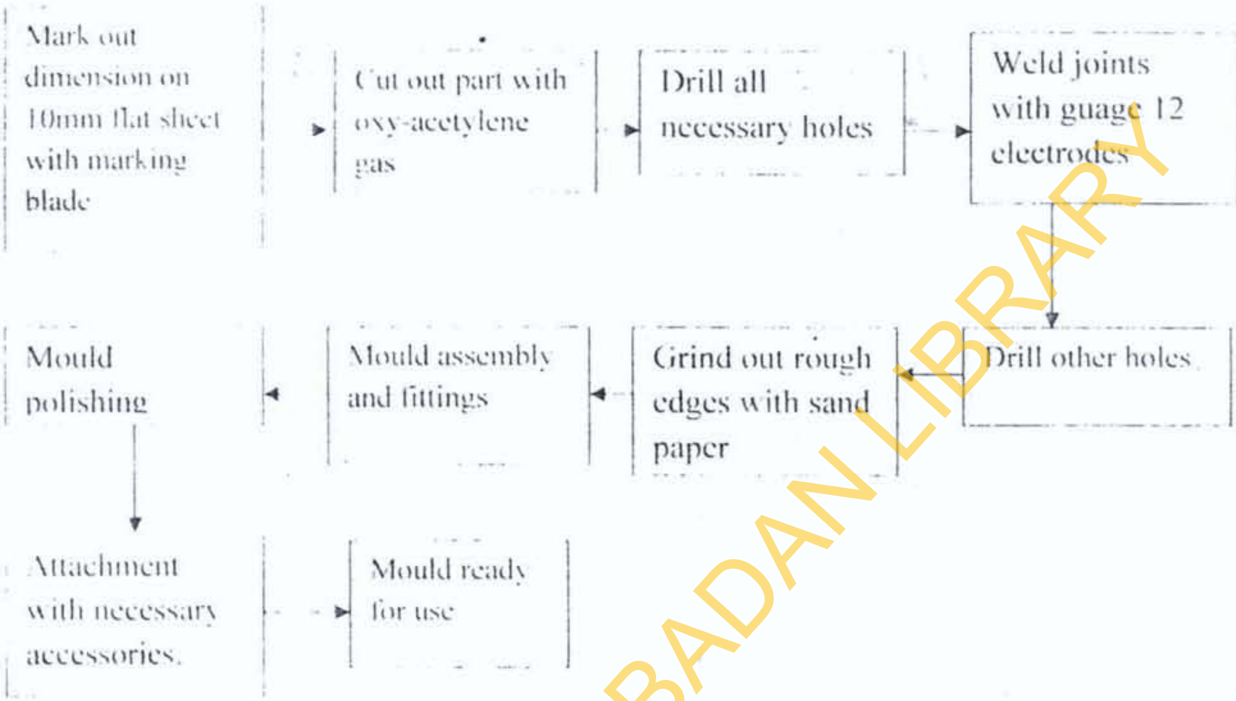

Fig. 6: Proposed Modified Process Flow for the Specific Mould

RESULTS AND CONCLUSION

Scrap medium carbon flat sheet was identified as a suitable material. Oxy acetylene welding was identified as suitable for provide cutting while arc welding was found suitable for joining. The local artisans were found to be capable to produce required product if given close supervision. The Agodi Gate multipurpose metal and machine parts market Ibadan was identified and survey of metal fabrication related skills was carried out to identify and characterize those relevant to proposed production process. A mould within the range of N70 000 and N80 000 was produced.

An exploratory evaluation of the mould system was carried out using an improvised low pressure manually operated injection mould. Tests were carried out using plastic granules of different mixes. Specifically plastic granules made from mixtures of different wastes plastic materials (heterogeneous polypropylene) and granules from single plastic type were used. Test indicated better plastic formation with a homogeneous polypropylene plastic than heterogeneous polypropylene plastic. Cracking observed due to the manual mould separation and absence of filler. It is concluded that plastic mould system is feasible for local fabrication. The injection mould system developed here was designed for small scale users using locally available engineering materials.

ACKNOWLEDGEMENT

This work is part of project supported by senate research grants No SRG/FTEC/2006/1A, University of Ibadan.

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