

# Design and Construction of an Aluminium Mould for the Production of a Motorcycle Brake Lever.

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### ABSTRACT

This work focused at designing and fabricating of an aluminium mould for the production of motorcycle brake lever. The pattern making, sand mould and the casting are the major step used to achieve the work. The thermal stress exerted on the mould stood at 0.67GPa which did not exceed the permissible thermal stress for aluminium. In the design of the motorcycle brake lever, it was discovered that a force of 0.58N is required to operate the lever at an effective length of 9cm from the motorcycle head. It shows that the production of motorcycle brake lever can be done locally since aluminium is largely available in the country and hence recommends that more effort should be put in by the Nigerian government for sustainability and development in this area.

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### Introduction

Moulds are made of different shapes and sizes depending on the constructional patterns it was set – up for. A mould has been defined as a pattern constructed for the production of the same type of the prototype. Therefore, a mould for a motorcycle brake lever creates a pattern which activates the brake mechanism, causing the motorcycle to slow down or stop. Brake levers need to possess properties such as hardness, stiffness, lightness and resistance because these levers support an extreme hand-push operation without breaking or deforming. Since brake levers for motorcycles are an essential item, the lack of local production outfit has made the importation of these levers paramount, affecting our economic development in the face of soaring foreign exchange rate. Therefore, packaging and production of brake lever locally using aluminum mould will improve the market system whereby making it less expensive for the users and will also enhance job opportunities in our nation. By setting up aluminum mould industries, the high foreign exchange cost in the importation of moulds and different machines parts could be saved for the nation. The different machines that are usually abandoned due to lack of spare parts are easily moulded and constructed since the material construction is known. The needs of setting up of mould producing industries will have a positive effect on all facets of projects associated with lack of spare parts and accessories. Hence, the aim of this study is to design and construct an aluminium mould for the production of a motorcycle brake lever. The objectives of the study includes: development of cost effective and efficient pattern making, sand moulding, and casting processes, determination of the thermal stresses induced in the mould, determination of the operating force and effective length of the lever.

### Research Elaborations

Aluminum is one of the few metals that can be cast by all of the processes used in casting metals. These processes, in

decreasing order of amount of aluminum casting, are: die casting, permanent mould casting, sand casting (green sand and dry sand), plaster casting, investment casting, and continuous casting. Other processes include lost foam, squeeze casting, and hot isocratic pressing, [1]. There are many factors that affect selection of a casting process for producing a specific aluminum alloy part. The most important factors for all casting processes are feasibility and cost factors, and quality factors. In terms of feasibility, many aluminum alloy castings can be produced by any of the available methods. For a considerable number of castings, however, dimensions or design features automatically determine the best casting method. Because metal moulds weigh from 10 to 100 times as much as the castings they are used in producing, most very large cast products are made as sand castings rather than as die or permanent mould castings [2]. Small castings usually are made with metal moulds to ensure dimensional accuracy.

Quality factors are also important in the selection of a casting process. When applied to castings, the term quality refers to both degree of soundness (freedom from porosity, cracking, and surface imperfections) and levels of mechanical properties (strength and ductility).

However, it should be kept in mind that in die casting, although cooling rates are very high, air tends to be trapped in the casting, which gives rise to appreciable amounts of porosity at the centre.

The pattern is the principal tool during the casting process. It is the replica of the object to be made by the casting process, with some modifications. The main modifications are the addition of pattern allowances, and the provision of core prints. If the casting is to be hollow, additional patterns called cores are used to create these cavities in the finished product. The quality of the casting produced depends upon the material of the pattern, its design, and construction.

According to [3], functions of a pattern include:

- A pattern prepares a mould cavity for the purpose of making a casting.
- A pattern may contain projections known as core prints if the casting requires a core and need to be made hollow.
- Runner, gates, and risers used for feeding molten metal in the mould cavity may form a part of the pattern.
- Patterns properly made and having finished and smooth surfaces reduce casting defects.
- A properly constructed pattern minimizes the overall cost of the castings.

Pattern Material may be constructed from variety of materials. Each material has its own advantages, limitations, and field of application. Some materials used for making patterns are: wood, metals and alloys, plastic, plaster of Paris, plastic and rubbers, wax, and resins. In a study on manufacturing processes, [4] opines that for a pattern to be suitable for use, the pattern material should be:

- Easily worked, shaped and joined
- Light in weight
- Strong, hard and durable
- Resistant to wear and abrasion
- Resistant to corrosion, and to chemical reactions
- Dimensionally stable and unaffected by variations in temperature and humidity
- Available at low cost

#### Casting in metal moulds

This uses a metal mould instead of sand. The moulds are made of steel or cast iron. The mould can be of solid type or split type. In the split type mould casting removal is easy. The moulds are coated with ceramic based coating agent. The mould is dried and preheated before molten metal is poured. The crucible is removed from the furnace and the dross is removed. The melt temperature is taken and the melt is poured in the mould cavity. After solidification the casting is removed.

Shrinkage happens because during solidification there is a volume contraction. The shrinkage area is machined away by cutting on a power saw and the rest of the casting can be used. In die casting molten metal is injected into the mould under high pressure resulting in a better part with good dimensional accuracy.

#### Properties of Aluminium Moulds

Moulds made of aluminum possess special properties. The properties of aluminum mould are low density, low weight, high strength, easy machining, excellent corrosion resistance, superior malleability, and good thermal and electrical conductivity are amongst aluminium's most important properties.

The properties of aluminum mould are therefore related to the properties of the aluminum used for the construction work. Properties of the aluminium mould according to [5] include:

- **Weight:** One of the best known properties of aluminum is that it is light, with a density one third that of steel, 2,700 kg/m<sup>3</sup>. The low density of aluminum account for it being light weight but this does not affect its strength.
- **Strength:** Aluminum alloys commonly have tensile strengths of between 70 and 700MPa. The range for alloys used in extrusion is 150 – 300MPa. Unlike most steel grades, aluminum does not become brittle at low temperatures. Instead, its strength increases. At high temperatures, aluminium's strength decreases. At temperatures continuously above 100°C, strength is affected to the extent that the weakening must be taken into account.

- **Linear expansion:** Compared with other metals, aluminum has a relatively large coefficient of linear expansion. This has to be taken into account in some designs.
- **Machining:** Aluminum is easily worked using most machining methods – milling, drilling, cutting, punching, bending, etc. Furthermore, the energy input during machining is low.
- **Conductivity:** Aluminum is an excellent conductor of heat and electricity. An aluminum conductor weighs approximately half as much as a copper conductor having the same conductivity.
- **Reflectivity:** Another property of aluminum its ability to be a good reflector of both visible light and radiated heat.
- **Corrosion resistance:** Aluminum reacts with the oxygen in the air to form an extremely thin layer of oxide. This layer is dense and provides excellent corrosion protection. The layer is self-repairing if damaged.

#### Materials and Method

The choice of material for the construction of the mould is aluminium, because factors that determine the selection of mould construction materials such as cost, stability, ductility, strength, availability, good machinability, corrosion resistance etc. [6], favour the choice of aluminium.

#### Pattern Making

The pattern used to prepare the mould cavity for the purpose of making a casting was made of cream hardener and filler.

The cream hardener and filler were mixed together in equal ratio, in order for it to solidify and take the shape of a rectangle. Then an electric discharge machine (EDM) was used to form the shape of a motorcycle brake lever in the pattern according to the dimension and design of the lever. After this was achieved, sandpaper was used to smooth the surface of the pattern.



Figure 1. Pattern for motorcycle brake lever.

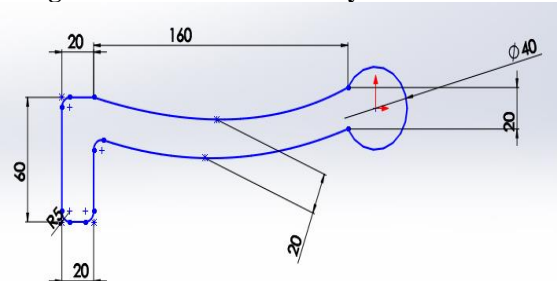


Figure 2. Diagram of a motorcycle brake lever.

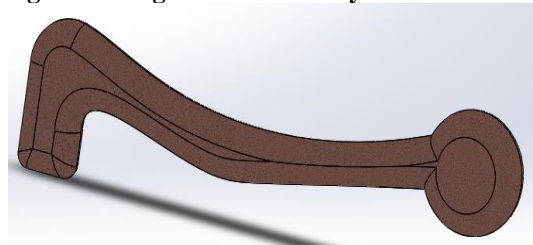


Figure 3. 3D model of a motorcycle brake lever.

### Sand Moulding

Among the sand casting processes, moulding is most often done with green sand. Green sand also known as tempered or natural sand was used in sand moulding preparation. A box of Length 34m and width 27m was selected which can accommodate the pattern, riser, gating system and also allow some space around it for ramming of sand. After the mould is achieved, the cope is then clamped with drag and the mould is ready for pouring of the molten metal.



Figure.4. Sand mould.

Molten aluminium metal alloyed with silicon is poured into the cavity in the sand mould. The aluminium mould is formed when the molten metal solidifies, machining of the mould is carried out properly. After then, testing of the aluminium mould is done by melting aluminium at a temperature of 680°C and then poured into the mould which has been pre-heated to avoid sputtering of the molten metal. Solidification of the molten metal in the mould gives the product.

### Design Analysis

#### Effective Length ( $L_{eff}$ )

This is the distance from the motorcycle head to the applied force that will cause a turning effect on the lever.

$$L_{eff} = \frac{0.5 \times W \times L}{F} \quad (1)$$

#### Stresses in the Mould

##### Thermal Stress

The thermal stress induced in the aluminium mould during casting is given by:

$$\sigma = E\alpha(T_f - T_i) \quad (2)$$

Where  $\sigma$  is the thermal stress in MPa

E is the modulus of elasticity of the aluminium material = 68.3GPa

$\alpha$  Is the coefficient of thermal expansion in m/m°C = 0.000023 m/m°C

$T_f$  and  $T_i$  Are the initial and final temperatures of the mould, respectively in °C

#### Deformation due to temperature changes

$$\delta_T = \alpha L \Delta T \quad (3)$$

### Results and Discussion

#### Operating force and Effective Length of the Brake Lever

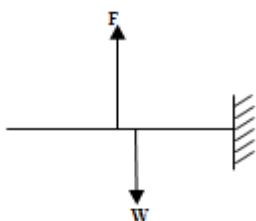


Figure 5. vertical force loading diagram of lever.

Considering the diagram in figure 5,  $F=W$  at equilibrium.

Where  $F$ = force applied on the brake.

Mass of the brake lever,  $M$

Mass of the brake lever is

$$M = D(V) = 2.70 \times 0.0219 = 0.059g$$

Therefore, force applied on the brake

$$W = Mg = 0.059 \times 9.81 = 0.58N$$

Force applied on the brake is 0.58N, Since  $F = W$ .

$$\text{EffectiveLength } (L_{eff}) = \frac{0.5 \times W \times L}{F} = 0.5 \times 180 = 90mm$$

m

$$\text{Effective Length } (L_{eff}) = 90mm \text{ or } 9cm$$

#### Thermal stress in the Mould

From equation 2,

$$\sigma = E\alpha\Delta T$$

Where  $\alpha = 0.000023$  m/m°C,  $T_i = 25^\circ\text{C}$ ,  $T_f = 453^\circ\text{C}$ , E is 68.3GPa

$$\Delta T = 453 - 25 = 428^\circ\text{C}$$

$$\sigma = 68.3 \times 0.000023 \times 428 = 0.67GPa$$

$$\sigma = 0.67GPa$$

Therefore,

#### Deformation due to temperature changes

$$\delta_T = \alpha L \Delta T$$

$$\delta_T = 0.000023 \times 0.24 \times 428 = 0.0024m$$

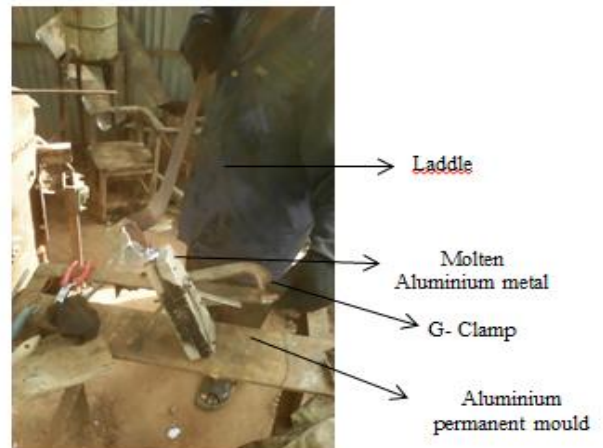


Figure 6. Pouring of the molten metal into the mould.



Figure 7. Product formation after solidification.

### Discussion

This project was fabricated successful taking into consideration the entire safety requirements for its safe operation. The project designed a permanent mould using aluminium. The motor lever was design to be operated by a force of 0.58N at an effective length of 9cm. To achieve this, a permanent mould of area  $155.76cm^2$  and a volume of  $934.56cm^3$  was sand casted. The study shows that thermal stresses are set up in the mould as a result of temperature gradient. The thermal stress associated with the casting of the brake lever is 0.67GPa as a result of this, the deformation experienced by the mould is 0.0024m.

This deformation was not adequate to alter the dimension of the motorcycle brake lever because the thermal stress induced was not beyond the permissible thermal stress for aluminium which is 43.5GPa.

#### **Conclusion**

The study carried out a design and construction of aluminium mould for the production of motorcycle brake lever. In order to achieve this, a pattern was constructed according to the specification of the motorcycle brake lever drawing. The pattern was made with cream hardener and filler, after which the mould was casted. Aluminium-Silicon alloy was used as a material for the mould. The reason for the alloy was to create a difference in the freezing/solidification temperature between the aluminium mould and aluminium motorcycle brake lever, so that removal of the cast motorcycle lever from the mould can be achieved. The study revealed that the thermal stress of the mould did not exceed the permissible thermal stress for aluminium thereby leading to a negligible deformation in length of the mould. The mould produces a light motorcycle brake lever that could be operated by a force of 0.58N at an effective length of 9cm.

As a result of the negligible deformation induced by the thermal stress, the aluminium mould is expected to have a very long service life and be able to withstand high working temperature by the reason of it been alloyed with silicon.

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