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Construction of Manual Tile Cutter with Boring Saw Using Locally Sourced Materials in Anambra State, Nigeria.

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Abstract

The need to obtain a manual tile cutter that could meet users' expectations informed the quest to carry out a study on construction of a manual tile cutter with boring saw based on the operational principle of scoring and breaking. In consonance with this, the project design was drafted in accordance with the specifications and principles guiding the operation of manual tile cutters. Requisite materials were carefully selected and tested according to engineering standards so as to meet the required features of the device, in terms of, functionality and durability; such materials are mild steel, aluminium, among others. Also, appropriate engineering analyses and mathematical models were employed in determining the effect of compression forces that could basically manifest at different dimensions/points while using the machine, such as bending stress, torque, shearing stress, working stress, section modulus as well as the maximum compression stress of the cutter which equals 0.34Mpa. After assembling the cuter, the calculated maximum force was 72N, which is the threshold required of high efficiency manual cutter. Additionally, perpendicular, transverse and circular cuts were made on several tiles without breakage; which proved the cutter's ability to perform expected tasks successfully. Based on the test, the machine was rated 72.5%, which indicates an appreciable degree of efficiency. Conclusively, the result clearly showed that, the cutter could make consecutive clean cuts on tiles without fracture and therefore, recommends among others that tile layers should be sensitized and encouraged to patronize locally constructed manual cutter with boring saw in executing their jobs.

Keywords: Construction, Manual Tile Cutter, Boring saw, Locally-sourced materials

1. Introduction

Over the years, the masonry type saws that contain saw blades have been used for cutting hard masonry types of materials. For example, slates, granites, tile, marble and the likes. These saws have ever maintained the pride of place for cutting hard materials (American Society for Testing and Materials, ASTM, 1991). Unfortunately, these types of saws are limited to a certain category of individuals especially the micro industrialists. According to Gupta (2000), such masonry saws typically comprise a fixed support, a movable tray on the table, a motor, a diamond blade as well as a movable tray for both the cutting and non-cutting positions. These cutting machines produce satisfactory jobs but demand a lot of capital for their procurement (Akala, 2010; Ukoenu, 2014). This intensive capital demand restricts the use of these machines to individuals and industries that are financially buoyant and also to establishments that have high financial disposition. The effect of this has not only dimmed the creative vision of young graduates of technology (Okoye & Okoye, 2015); but also limited their willingness to applying vocational skills to conduct research and construct a cutting machine using local materials. Hence, Ezeugwu (2006) asserts that most graduates of our country's institutions of higher learning will continue to roam the streets with their highly graded certificates unless they imbibe the culture of challenging their potentials pragmatically.

Against this background, the idea of the design and fabrication of the manual tile cutter with boring saw was borne. A tile cutter unlike other masonry type saws is portable and therefore can be used in typical rural areas.

2. Materials and Methods

Design is the process of formulating a plan or scheme to assist an engineer or a technologist in creating a product. According to Wankel (2009) and Shigley (2012) design is defined as the process of devising a system, component, or process to meet desired needs. Chand (2008) maintained that design is a decision-making process in which the basic sciences, mathematics, and engineering sciences are applied to convert resources optimally to meet a stated objective. Furthermore, Wankel (2009) enlisted the following elements as fundamental design processes: establishment of objectives and criteria, synthesis, analysis, construction, testing and evaluation. Sequel to this, Brigston (2009) defined design process as a multi-step process that leads to creation or manufacturing of useful pieces of articles or machines. Machine is any device which helps an individual accomplish a job or designed objective, which ordinarily cannot be accomplished using physical hands (Okoye, 2010). Hence the manual tile cutter is a machine. Other factors worth considering when designing a system, include aesthetic value, functionality, economy, modelling, interactive adjustment and innovation or redesign of existing design (American Society for Testing and Material, ASTM, 1991).

2.1. Principle of Operation of Tile Cutter with Boring Saw

The basic operational principle guiding design and fabrication of manual tile cutter with boring saw centres on the theories of young Modulus of elasticity and momentum of a body under forces (ASME, 1995). Chapman (1972) affirmed that, achievement of accurate cutting operation by any cutting device whose operational principle lies on scribe and snap as well as break could be greatly enhanced by the application of young modulus and other related forces to provide a means of performing 3 in 1 dimensional cuts on tiles without cracking.

2.2. Performance specification/calculations of the cutter

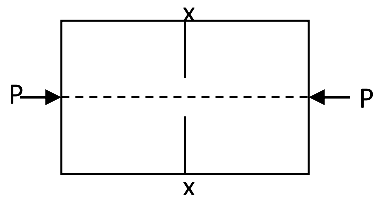
The fabrication of this project design was done in total compliance to the following standard specifications: ASTMC 720, Federal and Military Specifications and Standard –AA-50564 and MIL – F- 43402D as well as MIL – A- 3316C (Bruk, 2010; American Society of Mechanical Engineers, 1995). These standards were adopted to ensure that under certain system of forces (stress and strain) the factor of safety is guaranteed. This implies that when some external systems of forces or loads act on a body, internal forces (equal and opposite) are set up at various sections of the body, which resist the external forces. Thus, internal force per unit area which occurs as a result of cutting tiles at any section of the body is called stress, (σ).

Mathematically, stress, $\sigma = P/A$

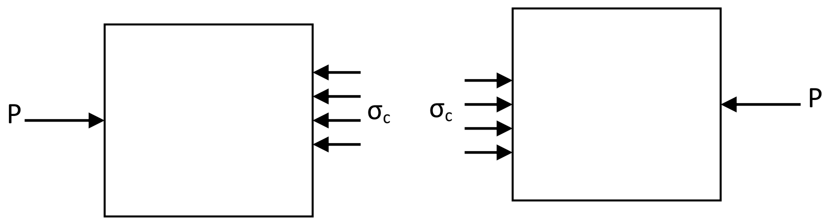
Where P = force or load acting on a body and

A = cross sectional area of the body to upon force is applied; the body experiences a compression stress, thus:

(a)



(b)



Let P = Axial compressive force acting on the body

A = Cross sectional area of the body

Young Modulus or Modulus of Elasticity

Taking cognizance of the effect of pressure on tiles subjected to certain system of forces, the application of Hooke's law is vividly justified. Thus, Hooke's law states that when a material is loaded within its elastic limit, the stress is directly proportional to strain i.e.

$\sigma \propto \varepsilon$ or $\sigma = E.\varepsilon$

$$E = \frac{\sigma}{\varepsilon} = \frac{p \times l}{A \times \sigma l}$$

Moreover, shear stress which is the force acting tangentially to resisting area becomes,

$$\text{Shear stress}, \tau = \frac{Tangential\ Stress}{\mathrm{Re}\,sisting\ area}$$

i.e P/A

where, $A = \frac{\pi}{4}(d)^2$

$\frac{\pi}{4}(0.025)^2 \qquad = \frac{3.142}{4}(0.025)^2$

$\frac{3.142}{4}(0.000625) = 0.7854 \times 0.000625 = 0.0004909 = 0.491 \times 10^{-3}\ m^2$

Stress, $\boldsymbol{\sigma}$ = P/A $= \frac{20 \times 10^3}{0.491 \times 10^{-3}} = 40.7 MN/m^2$

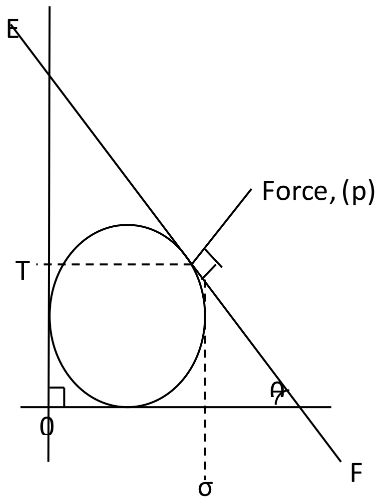
But the longitudinal tensile strain will therefore be,

$\varepsilon = \frac{\sigma}{E}$

where, $\sigma = 40.7 \times 10^6$; E = 70×10^9

$\varepsilon = \frac{40.7 \times 10^6}{70 \times 10^9} = 5.71 \times 10^{-3}$.

The percentage elongation, (0.571×10^{-3}) 100 = 0.057%



Since the maximum stress $\sigma_{max} = \sigma_c$ with respect to the shearing stress across the section EF and the maximum shearing stress $T_{max} = \sigma_c \text{Sin}\theta\text{Cos}\theta$

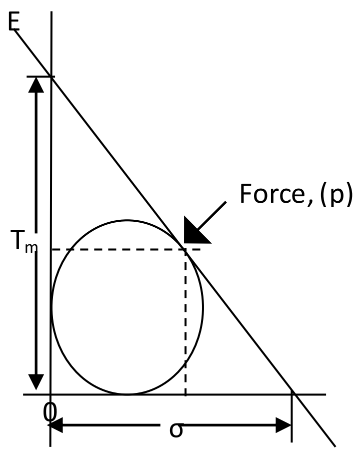
which implies that $T_{max} = (\sigma_c/2)\ \text{Sin}^2\theta$.

But, in trigonometric ratios, SinθCosθ = 1.

∴ Maximum shear stress that occurs across the hypotenuse section EF, when Sin 90 = 1, $\text{Sin}^2\theta$ = 1 and θ = 45rad.

$\therefore T_{max} = \sigma_c/2 = \frac{3.62}{2} = 1.81 MN/m^2$

Resultant stress, σ_R is given by [c]



By Pythagoras theorem

$R^2 = A^2 + B^2$

Thus, $\sigma_R^{\ 2} = \sigma_c^{\ 2} + T^2_{max}$

$\therefore \sigma_R = \sqrt{\sigma_C^{\ 2} + T^2_{\max}}$ $= 3.62^2 + 1.81^2$ $= 4.05$ N/m.

Force calculation

To determine the working stress, σ_s of the machine

$\sigma_s = \sigma_c/n$ and $\sigma_c/n = p/A$

But, $A = (t_t\text{-}t_s)_y$

Where p = force required to break the tile

A = Area occupied by the breaker on the tile

t_t = thickness of the tile

t_s = depth of score

y = length of the breaker

n = factor safety

$\therefore$ p = σ_c.A/n (since $\sigma_c/n = p/A$)

$\sigma_c\ (t_t - t_s)_y/n$

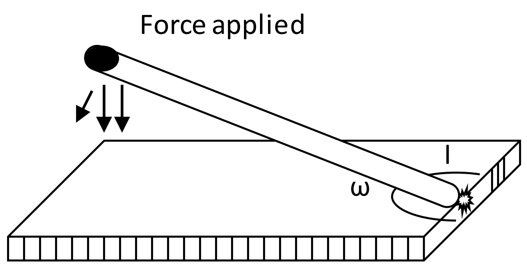
$\rightarrow \frac{\sigma_c(t_t - t_s)y}{n}$

Torque required to rotate the handle in order to cut tiles

Let the angular momentum of the handle be = I.ω

Where I = mass moment of inertia and

ω = angular motion (velocity) of the handle.



Relating operation in the diagram above to Newton second law of motion, thus torque on a rotating body is directly proportional to the rate of change of angular momentum (Shurne, (2015);

Mathematically,

Torque, T $\propto \frac{d(I\omega)}{dt}$

Since I is constant,

∴ T = I × $\frac{d\omega}{dt}$= I.α

Also, [$\frac{d\omega}{dt} = angular\ acceleration\ \alpha$]

However, work done by the machine = Force × displacement

= F × X

If the force varies linearly from zero to a maximum value of F, then,

Work done = $\frac{0+F}{2} \times x \qquad = \frac{F}{2} \times x$

Specifically, the torque causing a body to rotate at angular displacement, θ about an axis perpendicular to the plane is expressed as follows:

Power, (P) used by the machine = work done.

Thus P= torque × angular displacement. (T.θ) or P = $\frac{F}{2} \times x$

But P= torque × angular speed in rad/s

$= torque \times \omega\theta rad$

= torque ×2 $\pi n\theta rad$

Where, n $= \frac{N}{60} m/s$

$\therefore P$ = torque $\times\ 2\pi \frac{N}{60} \times \theta$ Nm

$= \ 250\ \times 2 \times 3.142 \times \frac{20}{60} \times 45rad$

= $\frac{70685.83}{3}$

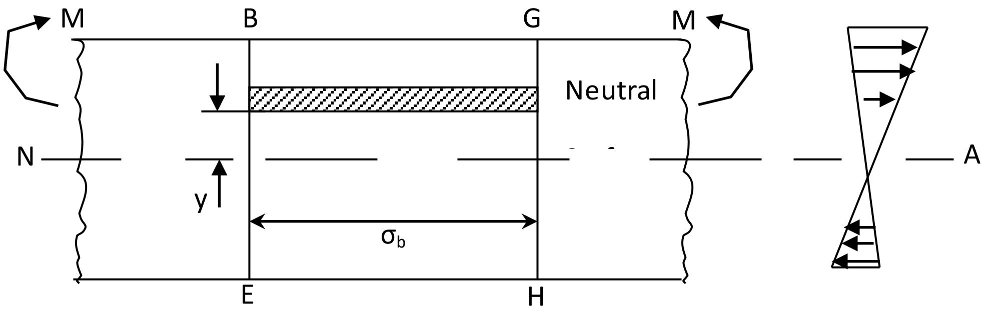
= 2, 3562

= 2.356 $\times\ 10^4$ Nm.

Design/Schematic Diagrams

Schematic Diagram for Bending Stress

Bending stress, $\sigma_b = M/Z$ (MPa)



From the bending equation

$$\frac{M}{I} = \frac{\sigma_b}{y} = \frac{E}{R}$$

Where, M = Bending moment acting at the given section

σ_b = bending stress

I = moment of inertia of the cross section about the neutral axis.

y = Distance from the neutral axis to the extreme tile.

E = young's modulus of the material

R = Radius of curvature of the plane.

From the above equation

$$\sigma_b = y \times \frac{E}{R}$$

Since E and R are constant, therefore within elastic limit, the stress at any point is directly proportional to y, i.e. the distance of the point from the neutral axis.

Also, from the above equation the bending stress,

$$\sigma_b = \frac{M}{I} \times y = \frac{M}{1/y} = \frac{M}{Z}$$

The denominator Z is the section modulus.

Where bending moment, M= 2.50 MN/m; section modulus, Z = 0.0684m^2

$= \frac{2.50 \times 10^6}{0.0684}$= 36.6MN/m^2.

2.3. Efficiency of the Machine

The efficiency of the machine is obtained after carrying out performance test on the machine by taking a certain number of cuts (Rubi, 2016). The smoothness is observed or inspected and the efficiency is evaluated, thus:

Efficiency, $\eta = w_p / w_a \times 100/1$

i.e. w_a= work done along the base ($f_1 \times d_1$)

w_p= work done perpendicular to the base ($f_2 \times d_2$)

Where, $f_1 = 10N$, $f_2 = 15N$, $d_1 = 300$, $d_2 = 145$

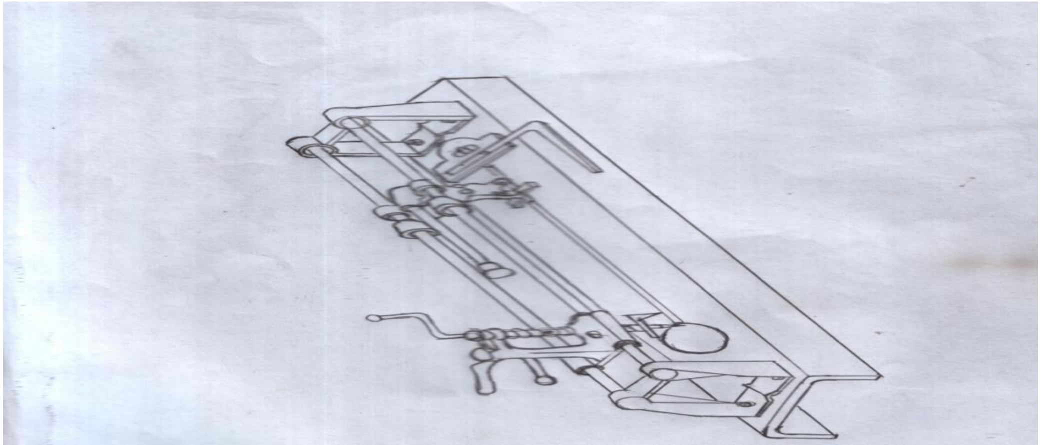
hence, $15\times 145/10\times 300 \times 100/1 = 72.5$

therefore, efficiency of the cutter is 72.5

2.4. Construction processes of the tile cutter with boring saw

The following processes were followed in the fabrication of a tile cutter: measuring and marking out, cutting out, drilling, threading, welding, grinding, assembling and polishing.

Assembly Drawing



3. Results

Assessment (Research) Question 1

How effective is this locally constructed manual tile cutter with boring saw compared with the foreign made ones?

Answer to this assessment question is presented in Table 1

Table 1: Mean and standard deviation of the extent the locally constructed manual tile cutter boring saw effectively cut tiles.

S/No	Effective performance of the cutter	Total No N	Mean X	SD	Decision
1	Capability of performing series of tile cutting operations at a stretch without tear and fatigue.	25	3.84	0.75	Effective
2	Ability to cut materials with less stress.	25	3.6	0.70	Effective
3	Ability to cut various shapes and angles conveniently unlike the imported manual type.	25	3.64	0.71	Effective
4	Ability to make sharp slits on tiles than foreign made manual tile cutters.	25	3.8	0.74	Effective
5	Ability to make holes with boring saw better than the imported type.	25	4.08	0.81	Effective
6	Ability to give accurate slits on tiles and other materials.	25	3.88	0.76	Effective
7	Ability to scribe and make snapping smoother than the imported ones.	25	3.92	0.77	Effective
8	To be easily operated by tile layers and merchants.	25	3.84	0.75	Effective
9	Capable of cutting various masonry materials satisfactorily.	25	4	0.79	Effective

From Table I, the respondents agreed that the cutter is capable of cutting series of tiles effectively at a time with less tendency of breakage at a mean rating and standard deviation of 3.84 and 0.78 respectively. They also attested that the machine can cut different shapes and angles, make sharp slits as well as make accurate slits on tiles and other masonry materials than its imported categories with mean ratings of 3.64, 3.8 and 3.88 respectively. In recommending the cutter's effectiveness, the respondents upheld that the scribing and snapping process of the cutter is smoother and it can be easily operated by tile layers and merchants with mean ratings of 3.92 and 3.84 and respectively.

4. Discussion

Execution of this project adopted various manufacturing activities summarily comprising such steps as survey into the available tile cutters, purchasing and testing of appropriate materials, measuring, marking and cutting out, turning, welding, assembling and testing as propounded by Chapman (1972), Ghand (2008), Wankel (2008) and Brigston (2009) as well as an assessment of the locally constructed manual tile cutter with boring saw using questionnaire instrument with cut-off point of 3.00 on the five-point Likert scale.

The findings from Table 1 revealed that the locally constructed manual tile cutter with boring saw can cut tiles and other masonry materials effectively with a grand mean of 3.84. The tile layers agreed that the cutter is capable of performing series of tile cutting operations at a stretched without tear or fatigue. They maintained that cutting operation is less stressful and the cutter makes sharper slit on tiles in relation to the foreign made ones which concurs with Brigston (2009) who opines that Nigerian graduates of technology education when given enabling atmosphere can perform better than the foreign expatriates. The respondents further agreed that inclusion of the boring saw rates the machine higher than the imported type which is an innovation and improvement on the existing manual tile cutters.

Technological advancement of our nation through the instrument of Technology and Vocational Education and Training (TVET) cannot be overemphasized since TVET grapples with the acquisition of creative skills and techniques needed to advance personally, nationally and internationally. With the foregoing in view, table 4 revealed that the locally fabricated manual tile cutter with boring saw is relevant to the economy while concurring to following: it arouses the creative spirit in learners and tile layers, promotes self-reliance through creative application of technological skills and validates the objectives of TVET as stipulated by UNESCO. This does not deviate at all from vision 2020 of the Millennium Development Goals (MDGs) which canvasses functional and sustainable education for all (Okoye, 2010).

5. Conclusion

To ensure that basic functional requirements of the manual tile cutter with boring saw, such as reliability, accuracy and maintainability were not compromised, the construction processes strictly adhered to requisite engineering specifications and practices. This is pertinent because of high demand of ceramic tiles in modern buildings often situated in localities where electricity could not either be accessed easily or does not exist at all. Based on the test conducted, it was revealed that the cutter could make clean cuts on tiles, whether diagonal, perpendicular or circular cuts. This was evident in the descriptive survey incorporated into the study, which also showed that the machine was highly efficient, affordable and optimally durable with less maintenance implications.

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