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# Design and Construction of a Bench Tool-Type Grinder

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**LIST OF SYMBOLS**

A – Area
Ip – Moment of inertia
D – External diameter
D – Internal diameter
T – Thickness of wheel
R – Radius
∑ - Moment of inertia of ring
6d – Direct stress
6b – Bending stress
W – Weight
e – Eccentricity
Z – Section modulus
Kg – kilogram
T – Thickness
$N/m^2$ – Newton per metre square
$6_{max}$ – Maximum stress
$6_{min}$ – Minimum stress
Dx – Shaft thickness
Lx – shear stress radius
Dt – Turning moment of turning force
Y – Stress
∫ - Integration
ϴ – Angle of twist
L – Length of shaft
C – modulus of rigidity
$Y_{max}$ – Maximum stress
$T_{mean}$ – Mean thickness of wheel
τ – Allowable shear stress
$T_{max}$ – Maximum thickness of wheel
≈ – Approximation
F – Force
6all – Allowable stress
lp/R – Polar modulus of the shaft

***ABSTRACT***

*A bench grinder is a type of bench-top grinding machine used such as those used for sharpening our knives, cutting tools, clean or polish work-pieces, grinding softer metals, like aluminium and perform other rough grinding. This study therefore is aimed at designing a* *bench tool grinder with good efficiency, better versatility for better productivity. The bench tool type grinder was constructed with the use of an adjustable electric motor. The fabrication of all the parts of this machine was done using fabrication technique such as welding and brazing. And the software prototype presented herein was designed using the AutoCAD. The use of mild steel was preferred in the design of the bench type grinder because it's cheap and wide varieties are available with different properties. The result presents that welding carbon steels with carbon content greater than 0.3% requires special precautions to be taken. However, welding carbon presents for fewer problems than welding stainless steels. While the corrosion resistance of carbon steel is poor (i.e they rust), mild steel is therefore found to be more corrosion resistance. The construction of the designed machine was simple, and they are cheap to maintain hence, its acquisition is affordable to all scale of users, ranging from the work-shops to even the wood-working shops. The use of high strength materials ensures its long life and durability. The use of goggle is highly recommended for engineer as safety measures while constructing bench type grinders as wielding can easily cause damage to the eye if not protected.*

***Keywords:-****Design, Bench, Machine Tools, Technology.*

## INTRODUCTION

The basic bench grinder may be a machine, that's made from little quite an induction motor with an abrasive wheel mounted at each end of the motor's shaft. Homeowners-grade and small-shop grinders come sized for either 6-or 8-inch wheel. Considering the Nigeria economic system, the 6-inch handle basic grinding chores just fine and it is relatively cheaper. Bench grinders usually have two wheels of different grain sizes for roughing and finishing operations, and secured to a workbench. It is used for shaping tool bits or various tools that need to be made or repaired and can also be used for making high cuts on metals and other materials. Bench grinders are manually operated and their wheels which differ in sizes and grains are made up of a variety of stones, diamonds, and other inorganic materials.
The bench grinder to be described is a six-inch bench grinder, equipped with all the handy fixing to be formed in a modern machine. The grinder can be operated by means of electricity to a very good advantage. Bench grinders are handy for sharpening mower blades, drill bits, gardening shears and more. Additionally, a bench grinder can be homing and shaping metals where modifications are need.

The essence of this project is to device a means to enhance better versatility of this machine for better productivity. It also seeks to analyse the importance of technology in developing countries such as ours Nigeria.

Therefore, This project can be a technological advantage to Nigerians, which invariably is essential to the development of any economy.

In this section, we will review the history of a bench grinder right from inventions and the alternative sources used before the inventions and improvement done on it till present day time.

Grinding machines are high precision tools. They have been used since the beginning of the $19^{th}$ century and are designed for final shaping of preprocessed machine parts. They ensure high surface quality and exceptional dimensional accuracy. Precision processing played a decisive role within the standardization of machine elements. They ensure high surface quality and exceptional dimensional accuracy. In 1838, the American, J.W stone, developed surface grinding machine with a horizontal grinding spindle. This design was also used in Europe for decades, In 1855, W. Maris & co in Manchester invented a tool grinding machine for sharpening milling cutters, lathe tools, knives and blades. Twenty years later, which was precisely in1875, Brown and sharpe, USA, carried out with a circular grinding machine, which permitted a cutting accuracy of 0.01millimeters.

In 1890, C.H. Besly & co. in Chicago introduced the first Automatic surface grinding machines. These machines offered exceptional grinding performance, high precision and outstanding surface quality. For the first time ever. Synthetic abrasives such as aluminium oxides were used instead of natural ones such as sandstone.

A bench grinder can vary depending on the application, where heavy usage is required. An 8-inch grinding wheel is preferable to the 6-inch wheel and heavy duty grinding may not have frills such as mounted heights. No matter what our specific application are, we must opt for a grinder that is well balanced, both for durability and sound reduction.

In general, a quieter motor indicate less fraction in the assembly and that result in more work over a longer period of time, A grinder should never be operated without mounting it securely as the torque of the motor could cause the grinder to move about considerably without proper mounts. Additionally grinders will cause sparks, so an operator must wear proper safety gears and do not operate the grinder near potential fuel sources. You should have a fire extinguishers close to your place of operations.

There are various types of grinders and they include:

1. Belt grinder
2. Bench grinder
3. Cylindrical grinder
4. Surface grinder
5. Tool and cutter grinder
6. Jig grinder

**A Bench Tool Grinding Machine and its Parts According to Functionality**

Figure 1 below is a diagrammatical representation of a bench tool type grinder and its various parts.

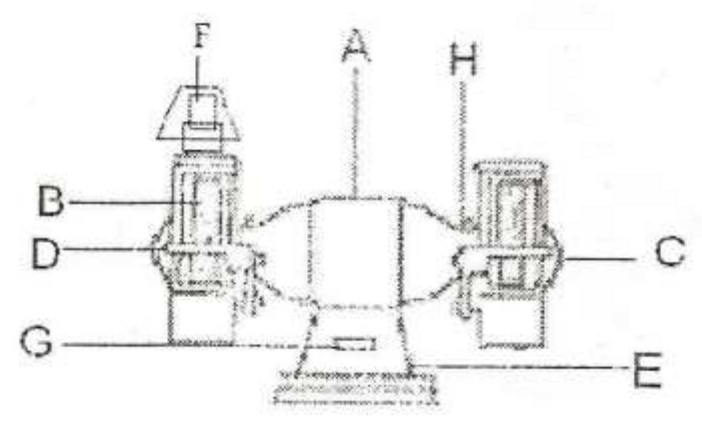



***Fig.1:-****Bench tool type grinder*

A. Electric motor (150W, 220) (Adjustable)
B. Grinding wheels X2 (150mm in diameter)
C. Wheel covers X2
D. Tool rest X2
E. Base stand/ pedestal
F. Protective eye shield
G. On/off switch
H. Drive shaft

I. With Reference to Figure 1:
Secured to and supported on the base is a 220 volts electric motor (A) provided with an electric cord assembly for connecting to a power outlet junction (not shown). An on-off (G) switch for connecting power to the motor assembly mounted at the front face of the pedestal for ready and convenient access. A pair of coaxial drive shafts (H) and projecting laterally from opposed sides of the motor support a pair of rateably-mounted motor-driven grinding wheels or tool elements (B).

Important advantages provided in the grinder stem from improvements in tool rest (D), Configuration and manipulation of the pivotally-adjustable protective shields (F). The tool rest assembly includes a rewardly and forwardly adjustably positionable two component side bracket component one of which is fasted to the inner wall and of the protective housing assemblies (C), and at lower zones thereof, slid ably secured within the remote bracket component is a co-operating bar-like bracket and lockable in selectable retracted and extended modes by means of stub shaft carried lock nut. The bench grinder is fitted with a pair of protective shields (F) and of transparent plastics compositions. The shield and interposed between the grinder wheels and the machine operator to protect the operator from flying debris generated during rise of the grinders as shown in Figure 2

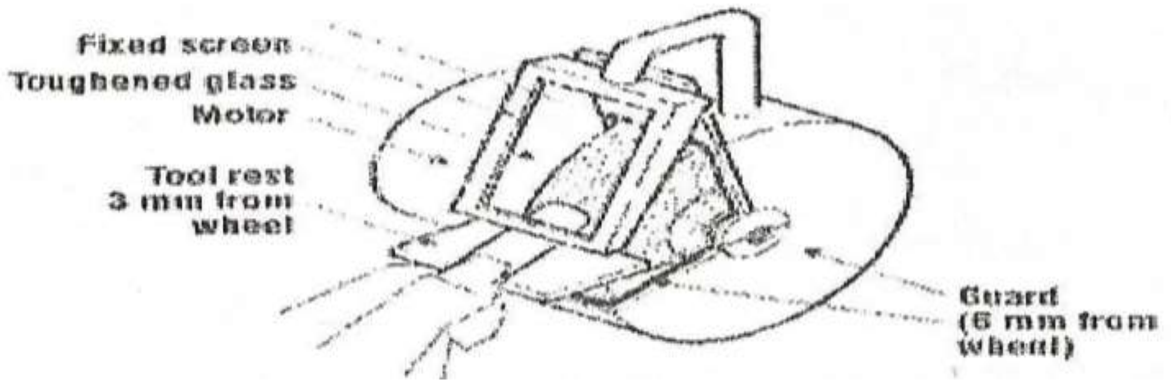


***Fig.2:***-*Wheel casement*

A bench grinder can also be referred to as a pedestal grinder that has a pedestal and sometimes a regulator for speed control. Most of the features in a bench grinder are similar to that of a pedestal grinder. The Figure 3 relates to the different component that shapes a bench grinder into a pedestal grinder.

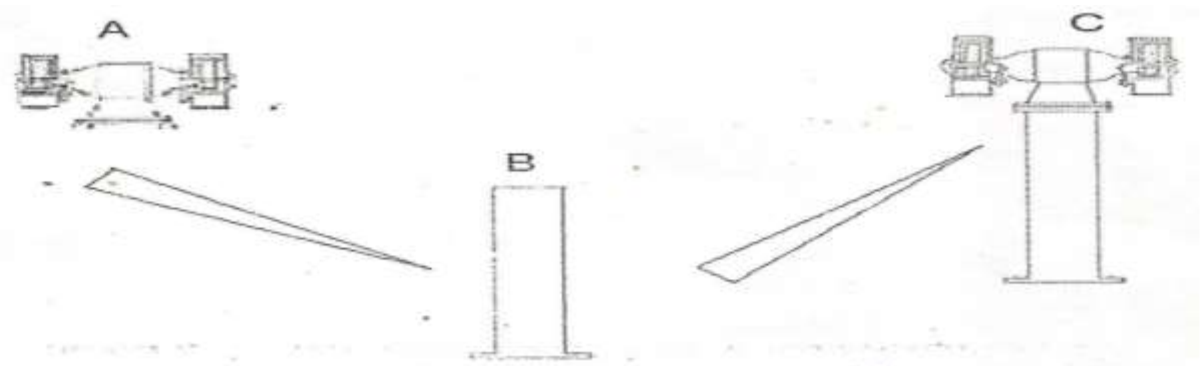


***Fig.3:***-*Bench tool grinder basement or pedestal*

Bench grinders are used for all kinds of general off-hand grinding and for the sharpening of drills, chisels, tool bits and other small tools. They are ideal for sharpening scissors, garden shears, mower blades, even the edge of a garden spade will benefit from a pass over a coarse wheel. Additionally, a bench grinder can be used for forming and shaping metal objects when modifications are needed. Sharpening is not only thing they do. Grinding is the fastest way to deburr a sharp corner or dress the end of threaded rod or bar stock that been cut to length. Bench grinder can also be used as a wood working tool.

## METHODOLOGY

This refers to the methods and technique or the process used in order to arrive at the desired result. Therefore for this project to be completed, I intend to use the following methods.

1. Design the product with AUTOCAD software and other relevant formulas: This involves using a suitable CAD program (i.e AUTOCAD) to design the different parts of the bench grinder showing how they will be assembled together and using relevant formulas to design various parts taken into consideration the stresses that they will be subjected to and the torque that will be transmitted through them.
2. Sourcing for/ collection of materials: This involves buying the items required from the market and bringing them together in a workshop were the construction or fabrication will be done.
3. Fabrication of required parts: After gathering the needed materials, we would fabricate all the parts of this machine that needs to be fabricated using fabrication technique such as welding, brazing. Etc.
4. Assembling of the various parts: This is the joining together of all the parts previously fabricated. In this process, all the various parts of the bench grinders are fitted together so they can perform as one (1) single unit or entity. This joining would involve temporary joining processes such as using bolts and nuts, and screws to assemble the products.
5. Coating and Finishing: After the full assembling of the bench grinder, it would be coated with paint to avoid corrosion and also improve the aesthetics of the products and then final inspection will be carried out on this product to ensure that all the parts are well fitted and aligned properly and that the bench grinder is working satisfactorily.

### Working Principles of the Bench Tool Grinder

A bench tool grinder works by using electromagnetic force to rotate a shaft, electromagnetic force is possible by rolling copper wire around a metal and when the two end is connected to an electric current, the metal will become magnetic. The more electric current is supplied to it, the more magnetic force we will get. With that in mind a bench tool grinder works with the help of an electric motor powered by an AC current. The above description also tell how an electric motor works but for better understanding, electric motor works with two opposite electromagnetic force N and S, when this two force comes close to each other, the force pulls away from each other, so the motor use this this force of the N and S to produce rotation. The rotation is used to do work as we have in a bench tool grinder.

### The Workings of Motor Speed Regulator

The speed regulator works by using a step down transformer to step down 240 volt down 80 volt. The transformer has three output which is 150 volt and 220 volt. When the speed regulator is set to speed one 80 volt will be sent to the motor.

When it set at speed two 150 volt will be sent to the motor and when the speed regulator is set at speed three 220 volt is sent to the motor. The more the current sent to the motor, the more the power it gives out and the more the speed of the abrasive wheel.

**Estimated Total Cost of Project**

After due consultation with experts in this area of fabrication discovered that to design, construct and complete this project, an estimated total of #65,000 would be spent. Thus, this is however on the high side.

**Estimated Time to Finish This Project**

The major impediment or constrain to the quick finish of this project is the cost of financing it, but however, if we are able to overcome this challenge, and the finance to achieve this purpose is realized, it would be possible for me to complete this project in another four (4) to five (5) months.

**Design Calculation**

Design calculation is an essential part of any project fabrication, as it helps to guide the designer on the size capacity, type and gravity of the components to be designed. It also helps in the selection of right materials during fabrication.

**Components of the Bench Tool Type Grinder [Figure 4 and 5]**

Ac motor
The grinder abrasive wheel
The grinder abrasive wheel covers or housing
An electric cable or power cable (power supply)
The tool rest or motor basement (Bench)
Protective eye shield (glass)
Drive shafts
Stubs shaft lock nuts
Step down transformer
Power button
Speed regulator
Transformer box

**DESIGN PARAMETERS**

Voltage – 220V
Power – 2206W
Speed – 2950
Cycles – 50/60Hz
Wheels – 210mm in diameter
Base length – 17cm
Base width – 12cm
Thickness – 2.3cm
Number of wheels – 2
Height from base – 13
Length from wheel to wheel – 32cm
Weight of machine – 42.2Ib

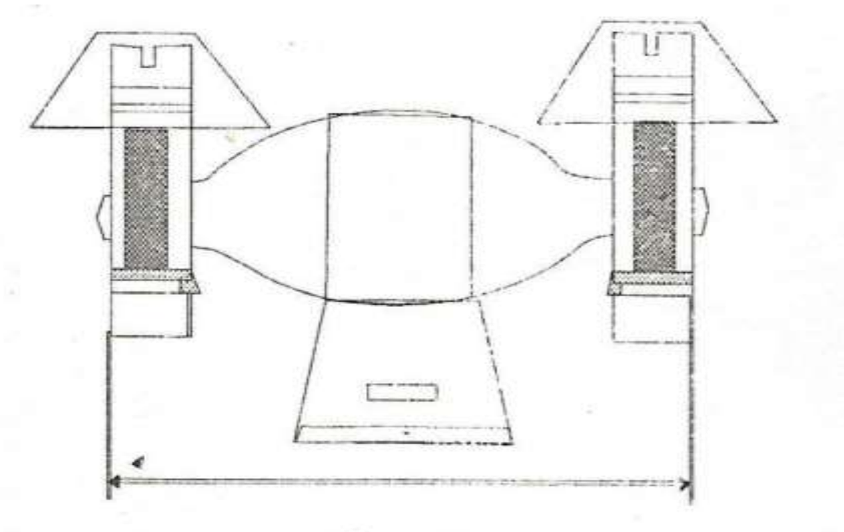


***Fig.4:-****The Grinding Wheels*

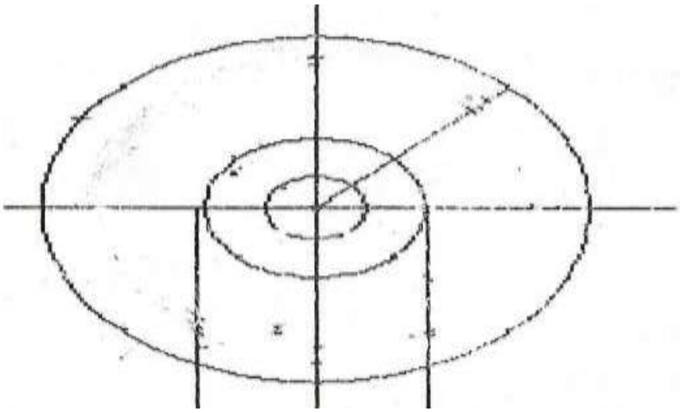


***Fig.5:**-Grinder wheel*

Let D = External diameter
d = internal diameter
D = 210mm
d = 20mm

Area of wheel = $\frac{\pi}{4}(D^4 - d^4)$

$= \frac{\pi}{4}(210^4 - 20^4)$

$A = 34326.35mm^2$

**Moment of Inertia**

The polar moment of inertia (Ip) = polar moment of inertia of the bigger circle – polar moment of inertia of the smaller circle.

$I = \frac{\pi}{64}(D^4 - d^4)$

$= \frac{\pi}{64}(210^4 - 20^4)$

$= 95.5\times10^6\ mm^2$

**Moment of Inertia Considering the Thickness of the Wheel**

T = Thickness, 23mm
D = 210mm; R=105mm
d = 20mm; r =10mm

$Ip = dAR^2 \equiv r^2\sum dA$

$= R^2\times2\pi rt$

$= (105)^2\times2\times\pi\times105\times2\times3$

$= 167\times10^6\ mm^3$

**Stress on the Grinding Wheel During Work**

a. Direct stress,6d = $^w/_a$

b. Bending stress,6b = $\underline{^{w\times e}/_z}$

**Direct stress,(6d)**

Considering this equation, we assumed a test load of 100kg subjected to the grinding wheel and the Area of the entire wheel is 2πrt, Where

$\pi = 3.142$

R = radius = 105mm

t = thickness = 23mm

Area of rotating wheel = 2πrt

Area = (2 × 3.142 × 105 × 23)mm =15175.86mm$^2$

Direct stress 6d = $\frac{(100\times10)}{(15175.86)}$ N/mm

$= 0.066N/mm^2$ or $66N/m^2$

**Bending Stress (6b)**

6b = $\frac{w\times e}{z}$; where e = $\frac{Z}{A}$ for no tensile stress

$\frac{w\times e}{z} = \frac{W}{A}$

$6b = \frac{100\times10}{15.17566}$

$= 65\ N/m^2$

Stress $6_{max}$ = 6d + 6b

Where 6d = 66N/m$^2$

6b = 65N/m$^2$

$6_{max}$= (66 + 65) N/m$^2$

$6_{max}$= 131N/m$^2$or 0.131N/mm$^2$

Stress $6_{min}$ = ( 6d – 6b )

= 1 N/m$^2$ or 0.001N/mm$^2$

**Electric Motor**

Power of the electric motor = 2206watts

Shaft rotation speed = 2950rpm (equal on both side)

**Shaft of the Electric Motor**

Considering the shaft (solid) of thickness dx at a radius x and let the shear stress at this radius be lx.

The turning force on the elementary ring is j =Tx.2πx.dx

And the turning moment due to this turning force is dT=Yx.2π.dx (x)

To get the total turning moment, we integrated both side

$\int dT = \int_0^r Tx.2\pi x.dx\ (x)$

$\int dT = 2\pi\int_0^r Tx.2\pi x.dx = 2\pi\int_0^r Y.x.x.dx/R$

[Where Y/R =YX/X]

The strength of the solid shaft is;

$T_{max} = \frac{\pi}{16} \times \tau \times D^3 (1-K^4)$

[Where $Ip = \frac{\pi}{32} \times D^4 = \frac{\pi}{2} \times R^2$]

$T = \frac{I}{R} \times \frac{\pi R^4}{2} = \frac{I}{R} \times Ip$

$\frac{T}{Ip} = \frac{Y}{R}$

And from Torsion equation, we have;

$\frac{T}{R} = \frac{C\Theta}{L}$

$\frac{I}{Ip} = \frac{Y}{R} = \frac{CA}{L} \equiv$ Torsion equation.

And from the relation; we have;

$\frac{I}{Ip} = \frac{Y}{R}$

$T = Y \times \frac{Ip}{R}$

For a given shaft [shaft of the electric motor], Ip and R are constants and Ip/R is thus a constant and is known as polar modulus of the shaft.

T = Y× 2p

T = T× 2p where 2p = polar modulus

Calculating for the modulus of rigidity of the shaft

Recall $\frac{Y}{R} = \frac{C\Theta}{L}$, where Y = stress

R = radius of rigidity

C = modulus of rigidity

Θ = Angle of twist

L = length of shaft

And for torsional rigidity;

$\frac{T}{Ip} = \frac{C\Theta}{L}$

$\Theta = \frac{TL}{CIp}$, making Θ subject

Since C, L and Ip are constants for the shaft, θ the angle of twist is directly proportional to the twisting moment;

$\frac{CIp}{L}$ = torsional rigidity and is denoted by K or M

$K = \frac{CIp}{L} = \frac{I}{\Theta}$

The shaft material used is a solid steel shaft subjected to torque, and the modulus of rigidity (C) from standards table is; C =84GPa = for solid steel.

**ANGLE OF TWIST**

$\frac{T}{J} = \frac{C\Theta}{L}$

$\Theta = \frac{TL}{JC}$

Torque, $T = \frac{P60}{2\pi N}$

$T = \frac{2206 \times 60}{2 \times 3.142 \times 2950}$

$T = 7.141\ N/m \equiv 7.141 \times 10^3\ N/mm$

$J = \frac{\pi}{32}\ (D^4 - d^4)$

$J = \frac{\pi}{32}\ (210^4 - 20^4)$

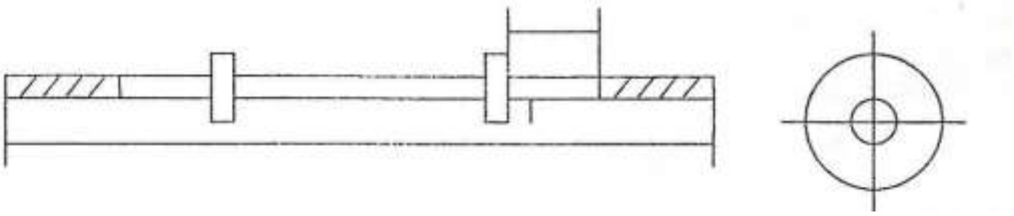
$J = 191 \times 10^6\ mm^4$

Recall that modulus of rigidity, C for a solid shaft is 84 GPa

$\Theta = \frac{7141 \times 240}{191 \times 10^6 \times 10^3 \times 84}$

Θ = 0.00000011 rad

## DIAMETER OF SHAFT



Power to be transmitted =3hp = 2206 watts
Speed , N = 2950 rpm
Allowable shear stress, $\tau = 131\ N/m^2$

$T_{max} = T_{mean}$

$$T_{mean} = \frac{P \times 60}{2\pi N}$$

$$= \frac{2206 \times 60}{2 \times \pi \times 2950}$$

$T_{mean} = 7.141\ N/m \equiv 7141\ N/mm$

Since $T_{max} = T_{mean}$
Therefore, $T_{max} = 7141\ N/mm$

$$T_{max} = \frac{\pi}{16} \times \tau \times D^3 \left( 1 - K^4 \right)$$

$$7141 = \frac{\pi}{16} \times 0.131 \times D^3 \left( 1 - 0.02/0.21 \right)$$

$$16 \times 7141 = \pi \times 0.131 \times D^3 \times 0.9999$$

$$D^3 = \frac{16 \times 7141}{\pi \times 0.131 \times 0.9999}$$

D = 65.24mm

**Efficiency of the Machine**

$$\text{Efficiency} = \frac{\text{work input}}{\text{Work output}} \times 100\%$$

Work input corresponds to the force

$$\text{Since stress} = \frac{\text{force}}{\text{Area}}$$

Force = stress × Area
= 0.131 × 15175.86
Force = 1988N = Work input

$$\text{Efficiency} = \frac{1988}{2206} \times \frac{100}{1}$$

= 90.12%

## RESULT [Table 1]

***Table 1:-*** *Materials and Specifications*

| MATERIALS | SPECIFICATION |
|---|---|
| Mild steel (low carbon steel) | 60mm x 300mm |
| Polymeric materials (thermosetting) | 25mm x 25mm |
| Silicon carbide and aluminium oxide | Bought |
| Cast iron | 250mm x 100mm |
| Sheet metal | 2mm |
| Fibber glass | |
| Ac motor | 3 h p |
| Step down transformer | 1 input 3 output |
| Paint | 1 cup |
| Electrode | |
| Speed regulator | 1 |
| Ply wood | 4 |
| Wooden facing board | (2cm×2cm) |
| Bolt and nut | 10mm and 17mm |

## CONCLUSION

Fortunately, bench grinders are relative in-expensive even the best Models available should cost not more than #65,000 and are often much less. But for the exception in this case which part of the modification is an adjustable electric motor which is expensive and will make this machine cost much more than the afford-mentioned amount. But in all the minimal cost should encourage every machinist or even wood worker to add bench grinder to their assortment. Most of the materials used in the construction of the bench grinder is easy to find and are manufactured locally. The construction is simple, and they are cheap to maintain hence, its acquisition is affordable to all scale of users, ranging from the work-shops to even the wood-working shops. The use of high strength materials ensures its long life and durability.

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