Drill Saw

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Abstract: This paper presents a device which can be attached to any hand drill machine and can be converted into a reciprocating jig saw machine. This device is compact, light and cost efficient, simple to design and manufacture. The Drill Saw is a prototype designed and engineered to reduce human effort and increase efficiency in work. This attachment is designed for converting rotational motion to reciprocating linear motion. It can be used as external attachment for power drills. There are several Application of this device like in wood shop to cut woods and intricate shapes, in Plumbing for cutting PVC Pipes, elbows, Steel pipes, etc. This device is specially made for Hand drill machine which is commonly available with every fabricator, carpenters, Plumbers, even in every household, etc.

Key words – **Drill Saw, Rotational to reciprocating motion, Power drill attachment, saw attachment, jig saw, Saw Blade, Drill saw attachment, Drill saw device, cutting attachment.**

1. INTRODUCTION

The professional use of power tools has been around quite a while now, in industries, small scale businesses and households. Power tools such as hammer drill, jigsaw, sander, angle grinder are pretty common and inexpensive in today's market, yet one needs special tools to get the job done. In this case of study, conventional power tools for cutting a sheet of various materials are available in the market, these products are expensive, heavy and consume electricity or on the other hand manually cutting with a hacksaw and a lot of muscle. This is where Drill Saw comes in picture. The Drill Saw attachment can cut through sheets and pipes of PVC, wood and metal effortlessly. This is achieved by rapidly reciprocating a blade over a short stroke length. This product is cost efficient, light in weight and consumes no electricity.

2. LITERATURE REVIEW

Bílek, O & Baďurová, J. (2018). FEM analysis of saw blade. [1]

Article deals with identification of the critical points of the saw blade designed for wood cutting which teeth are made from stellite material. Cutting parameters and shape of blade were under investigation. FEM analysed the influence of cutting speed, size of cutting forces, clamping and geometry of saw blade. Factors that significantly affect the strength of the saw blade have been identified and can contribute to identification of

critical conditions leading to the destruction of the saw blade. The results can also be applied when sawing wood with a band saw.

Mehta, Viraj & Patel, Vimal. (2017). Performance Evaluation of Jigsaw Machine with Kinematic and Stress Analysis. [2]

Hand tools play a major role in machining and manufacturing processes. Jigsaw is the widely used portable power tool useful to cut straight or curved slots or parting off soft material effectively. It can also make bevel cuts. In addition to wood cutting, jigsaws can cut steel, fiberglass and aluminium etc., which make jigsaws very versatile tool and valuable tool in workshop. Purpose of the whole study is to evaluate the performance of jigsaw machine in different conditions on the basis of power requirement analysis and the stress analysis. Here three criteria have been considered to solve this problem. 1.Maximum power criterion 2. Maximum von mises stress criterion in slotted bar 3. Maximum von mises stress criterion in cutting saw. The present investigation evaluates performance of a jigsaw machine using kinematic and stress analysis for cutting metals as well as different types of wood of different thicknesses. It is essential to analyse the mechanism with respect to the rotation of motor while designing, as the velocity, acceleration, active and constraint forces and torque tend to change with respect to angular position of rotating crank, which in turn changes inertia forces and stresses in the mechanism. The findings of the present investigation indicate the maximum von mises stress values and maximum input power requirement which are compared with the material properties and specifications of the jigsaw machine respectively and performance of the machine has been evaluated.

Shelare, Sagar & Thakare, Prafull & Handa, C. (2012). COMPUTER AIDED MODELLING AND POSITION ANALYSIS OF CRANK AND SLOTTED LEVER MECHANISM. International Journal of Scientific & Technology Research. 1. 7-10[3]

The paper is discussed about crank and slotted mechanism that converts rotary motion into reciprocating motion at different rate for its two strokes, i.e., working stroke and return stroke. Time ratio has been calculated for constant length of stroke with specified dimensions. A CAD model has been prepared to simulate the mechanism and to specify the accurate path of the mechanism. Also the analytical method which can be used to define the various position of crank and

respective position of slider in quick return mechanism is discussed.

Haus, Richard. (1996). Converting rotary motion to linear motion. 22. 72-74. [4]

 Linear motion systems driven by rotating electric motors commonly employ one of three mechanical systems: ball screws, belt drive, or Acme screw. Ball screw actuators are ideal in many applications, as they offer high speed, high efficiency, and long life. Belt drive systems offer nearly all the advantages of ball screws, fewer moving parts, without the `critical speed limit' that leadscrew-driven systems impose. In contrast, Acme screws are often used when a load must remain locked in position after motion stops, such as in vertical lifting. Making the right choice saves time, costs, and gives optimum results.

Domblesky, Joseph & Widera, G. & James, Thomas. (2006). Experimental investigation of reciprocating sawing. Transactions of the North American Manufacturing Research Institute of SME. 34. 531-538. [5]

As part of an effort to model cutting and optimize blade design, an investigation was undertaken to study material removal in reciprocating sawing. Using an experimental cutting fixture, results showed that linear cutting rates increase with reciprocating rate and thrust force though the data suggests that thrust force may be more effective in optimizing cutting. It was also found that blade can't results in an angled cut and induces a dynamic thrust force that alternately opposes and assists the user. Material removal was found to predominate during the cutting stroke where approximately two-thirds of the chips are generated.

Domblesky, Joseph & James, Thomas & Widera, G. (2008). A Cutting Rate Model for Reciprocating Sawing. Journal of Manufacturing Science and Engineering-transactions of The Asme - J MANUF SCI ENG. 130. 10.1115/1.2976143. [6]

In the present paper, the reciprocating sawing process is analysed, and a model for linear cutting rate is developed. The resulting model is based on an orthogonal approximation of cutting at individual teeth and accounts for elastic and plastic indentation. Cutting rates obtained from an instrumented sawing fixture show good agreement with predicted results for the range of conditions considered. Cutting rate was found to be proportional to thrust force and reciprocating rate though this behaviour is influenced by edge radius and flow stress at higher levels. While it was not possible to decouple the effect of pitch and blade set, it was confirmed that coarser pitch blades do provide higher cutting rates.

James, Thomas & Domblesky, Joseph. (2010). Study of Blade Wear in Reciprocating Sawing. ASME International Mechanical Engineering Congress and Exposition, Proceedings (IMECE). 3. 10.1115/IMECE2010-38819. [7]

Previous work has resulted in an analytical model for linear sawing processes which incorporates key process parameters and is capable of predicting cutting rate. While this provides useful information to guide saw design and cutting, rapid blade wear has a pronounced effect. It is necessary to characterize this effect of cutting edge wear on sawing rates. In the present study, work was conducted using the reciprocating sawing process to assess geometric changes of individual blade teeth and how this affects cutting rate. Geometric changes resulting from blade wear were analysed and an expression was developed that allows the edge radius to be predicted as a function of cutting conditions and time. The cutting rate model predicts that as edge radius increased, cutting rate would fall exponentially and this was confirmed by experiment. Predicted edge radius values in conjunction with the cutting model were found to provide good agreement with experimentally obtained cutting rate results.

Miller, H.. (1962). Band Saw and Jig Saw. 10.1007/978-1-349-81735-1_17. [8]

There are several types of band saws made for different work. The largest is the band mill, which is used in sawmills for cutting logs into planks. This saw has wheels up to 7′ in diameter and blades up to 16″ wide. The band resaw is somewhat smaller and is used in mills and lumber yards for resawing thick lumber into thinner material. The type of saw used in small industrial shops, schools and home workshops is the band scroll saw. This is a smaller, general-purpose saw used for cutting curved and straight work, and is simply referred to as a band saw. This is the type of saw we will describe here.

Edmiston, W. & Harrison, H. & Morris, H. (1971). [9]

Metal drilling with portable hand drills. Study of metal drilling solves problems of excessive burring, oversized holes, and out-of-round holes. Recommendations deal with using the proper chemical coolants, applying the coolants effectively, employing cutting oils, and dissipating the heat caused by drilling.

3. PROBLEM STATEMENT

Replacing a conventional handheld saw machine with an external attachment, in terms of saving manual labour and cost. To convert rotational motion of the shaft to reciprocating motion of the runner.

4. METHODOLOGY

- Analysis of Problem Statement.

- Literature survey.
- Study of the mechanism.
- Selection of material and components readily available in market.
- CAD / SolidWorks Design
- Thermal Analysis
- Prototype of the mechanism.
- Required calculations.
- Actual Experimental setup.
- Testing and Simulation of mechanism on working parameter.

5. OBJECTIVE

- Converting Rotational motion to reciprocating linear motion
- Making the product compact.
- Reducing weight for mobility/portability of the product.
- Faster dissipation of heat at mating part.
- Damping vibrations.
- Comparing SolidWorks simulation with manufactured product.
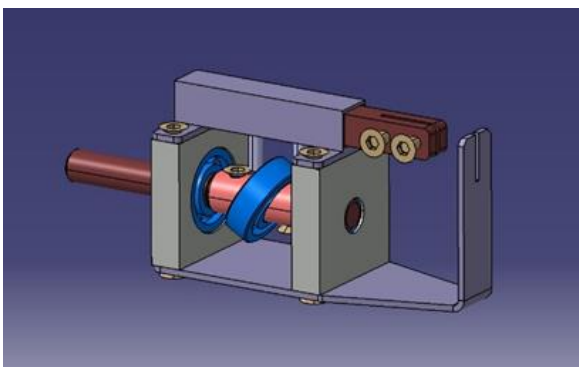- Material selection for cost reduction.

6. EXPERIMENTAL LAYOUT

Figure 1. CAD Model

7. COMPONENTS

Components	Material	Dimension	Qty
Block Bearing	Aluminium	40 X 40	2
Base plate	Aluminium	160 X 40	1
Shaft	Mild Steel	10 X 100	1
Retainers	Mild Steel	15 X 10	2
Runner Case	Stainless Steel	12 X 12	1
Follower Rod	Mild Steel	10 X 10	1
Follower Guide	Hard Steel	M4 Allan	2
M4 Allen Bolts	Hardened	-	12

Table 1. Components List

Note: All dimensions are in millimetre

7.1 Block Bearing

Figure 2. Block Bearing

The block bearing consists of a ball bearing press fitted inside a block. There are 2 block bearings installed in this product. Each block is tapped with counter threads at four points which helps in assembly of the product. Material used for the block is Aluminium of dimensions 40 X 40 X 10 mm and standard SS ball bearing of 6200-2Z/C3 which is of 10 mm ID X 30 mm OD X 9 mm Width.

7.2 Base plate

Figure 3. Base Plate

The base plate is made of 2mm aluminium sheet metal. This plate acts as a base for other components to mount. There are four holes on the base plate. On the other side of the plate is a 90° bend to achieve the required shape of the plate. A small opening is made for the hacksaw blade to reciprocate in between.

7.3 Shaft

Figure 4. Shaft

The shaft is the most important component of the product. One end of the shaft is supposed to be attached to the chuck of the Power Drill in use. The shaft rotates

along its own axis providing the rotational motion required on the inclined ball bearing assembled on the shaft. Two 15° slots are made opposite to each other on the shaft for the bearing to sit inclined on it. Two slots for circlips also provided. Two counter threaded holes are provided for Retainers. A lathe machine was used to turn the shaft according to the required shape and size [Dimensions 10 mm Diameter X 100 mm length].

7.4 Retainers

Figure 5. Retainers

Retainers holds the ball bearing at its inclined position at high rpm's. In order to do this, the retainers are cut diagonally and clamped onto the shaft with the help of M4 bolts. Retainers are made of Stainless-steel hollow shaft 12mm diameter with holes.

7.5 CAM Bearing

Figure 6. CAM Bearing

A standard ball bearing of 6200-2Z/C3 series which is of 30 mm X 10 mm X 9 mm is used as the CAM. These bearing sits inclined on the shaft between the retainers tightly so that it is attached to the shaft firmly, such providing an infinity type of pattern for the follower.

7.6 Follower Rod

Figure 7. Follower Rod

A Square metal rod of Mild steel having dimension of 10 mm X 85 mm is used for Follower/ Runner. The follower

moves in a linear reciprocating motion. There are two probes screwed on it, probes are made of threaded bolts cut to required length. A slot for the hacksaw blade is provided with two bolts clamping the blade on the square rod.

7.7 Runner case

Figure 8. Runner Case

A square hollow shaft of Stainless-steel having dimension 12 mm X 60 mm is used for the Follower to reciprocate in a linear motion inside it. This case is welded to two metal plates which sits on the block. A linear path is cut out from below for the follower probes to move inside it.

7.8 Bolts

Figure 9. Bolts

Standard ISO M4 bolts are used. There are in total 12 bolts required for the whole assembly of the product. Different lengths of bolts are used on different parts as per the requirement.

8. PROCEDURE

a) Firstly, market survey of drill saw attachment was done where we found out similar machines are there for the soul purpose of jig saw cutting which was expensive as well as bulky. So, we decided to make solution for this which should be inexpensive and compact in size

b) Most engineers, households, manufacturers have hand drill machine available so we decided to make an attachment, whose purpose will be to convert the hand drills rotary motion into linear motion which can act as saw machine.

c) Hence, we started modelling many products on computer based on 3D software where many models were made, but we chose the best and compact model which is used in this project.

d) After the selection of model, materials were chosen for each part. While choosing the materials things like frictional forces, stresses, weight, size, shape, machining, and cost were kept in mind. Materials like aluminium, Stainless steel, Mild steel. Are used in this project to keep the product light weight, durable as well as cost efficient at the same time. Some standard materials like Bearings, Bolts, etc. which cannot be made were purchased from the hardware

e) After the selection of the material, analysis was done by Ansys 16 Workbench software where analysis like thermal stresses, frictional forces, bending stresses, etc. were calculated and as per the results remodification of dimensions and material was done on the 3D model till the required results were matched

f) After the Ansys results, we started making the parts one by one, starting with the base of the product which is of aluminium sheet of 2 mm. Firstly, base was cut on a CNC laser cutting machine as per the drawing, then it was bend on a CNC Press brake machine then 4 countersunk holes were made at the 4 corners of the base and thus Base plate was ready.

g) After the base plate, we made 2 block bearings which was made out of 2 aluminium square blocks of 40 X 10 mm. For this block was mounted on lathe on 4 jaw chuck, a bore of 12 mm diameter throughout was made at the centre of the block then step turned of diameter 30 mm and 9 mm deep. Each block bearing was tapped with M4 on top and bottom opposite corners. Such 2-block bearing were made.

h) Two Ball bearing of 6200 2Z/C3 was press fitted on each block bearing. And these block bearing were mounted on the base plate.

i) On the top runner and guide were made where runner used is square rod of 10mm mild steel and guide made of square pipe of 10mm X 12mm Stainless steel. Guide is welded on two metal strips horizontally and mounted on the top of the assembly.

j) Where runner is tapped with 2 holes on the bottom for the guide pin to get in contact with the cam

k) Through the block bearing 10 mm shaft is passed in which a fixed bearing acting as a cam which is inclined at 30 degrees on to the shaft and retainers are provided on each side of the inclined bearing to keep the bearing sturdy and fix at high rpms

l) Before inserting the runner into the guide, some grease is applied on the runner so that there will be minimal friction and thermal dissipation.

m) After the whole assembly of product, product was run on a safe environment where we cut few samples like plastic, wood, 10 mm steel pipe, etc. and as a result the product was working fine.

n) After running the product, we took the readings of the cutting speed on every sample, also hand drill machine was checked thoroughly for damages, then we compared the calculated and empirical results of stress strain, thermal stresses etc.

o) After some minor adjustment and tightening, vibration damping was done in order to reduce noise , vibration and for smooth functioning.

9. CALCULATION

I. Calculation for Runner

Square bar of Mild steel having:

Force applied (F)= *22 KN = 22000 N*

Yield strength ($\sigma_{allowable}$)= *225 N/mm²*

Max stress ($\sigma_{maximum}$)= *420 N/mm²*

Young's Modulus (E) *= 210 GPa = 21X10⁴ N/mm²*

• For Area

$$\sigma_{allowable} = \frac{F}{A}$$

$$225 = \frac{22000}{A}$$

$$A = \frac{22000}{225}$$

$$\boldsymbol{A = 97.77 \ mm^2 \approx 100 \ mm^2}$$

$$since, our \ runner \ is \ of \ Square \ bar$$

$$A = s^2$$

$$100 = s^2$$

$$s = \sqrt{100}$$

$$\boxed{\boldsymbol{s = 10 \ mm}}$$

$$\therefore Square \ bar \ of \ 10X10mm \ is \ used.$$

• **For factor of safety**

$$F.O.S. = \frac{\sigma_{max}}{\sigma_{allowable}}$$

$$F.O.S. = \frac{420}{225}$$

$$\boxed{\boldsymbol{F.O.S. = 1.866}}$$

• **For Strain**

$$E = \frac{\sigma_{allowable}}{\varepsilon}$$

$$21 \times 10^4 = \frac{225}{\varepsilon}$$

$$\varepsilon = \frac{225}{21 \times 10^4}$$

$$\boxed{\boldsymbol{\varepsilon = 1.0714 \times 10^{-3}}}$$

II. Calculation for Shaft

Circular bar of Mild Steel having:

Yield Strength (σ_{max})= *200 MPa*

= 200 N/mm²·

Force Applied (F) = *2.8 KN/mm²*

Allowable Stress (σ_{max}) = *38 N/mm²*

Young's Modulus (E) = *180 GPa*

= 180000 N/mm²

• **For Area**

$$\sigma_{allowable} = \frac{F}{A}$$

$$A = \frac{2800}{38}$$

$$\boldsymbol{A = 73.68 \ mm^2}$$

$$Since, our \ Shaft \ is \ cicular$$

$$A = \pi r^2$$

$$73.68 = \pi r^2$$

$$r^2 = \frac{73.68}{\pi}$$

$$r = \sqrt{23.45}$$

$$r = 4.84 \ mm$$

$$D = 2r$$

$$D = 2 \times 4.84$$

$$\boxed{\boldsymbol{D = 9.68 \ mm \ \approx 10 \ mm}}$$

$$\therefore Circular \ shaft \ of \ diameter \ 10 \ mm \ is \ used.$$

• **For Factor of Safety**

$$F.O.S. = \frac{\sigma_{max}}{\sigma_{allowable}}$$

$$F.O.S. = \frac{200}{38}$$

$$\boxed{\boldsymbol{F.O.S. = 5.26}}$$

• **For Strain**

$$E = \frac{\sigma_{allowable}}{\varepsilon}$$

$$\varepsilon = \frac{38}{18 \times 10^4}$$

$$\boxed{\boldsymbol{\varepsilon = 2.111 \times 10^{-4}}}$$

III. Bending Stress for Runner

$$\sigma_b = \frac{Mc}{I}$$
$$our \ runner \ is \ having \ 200 \ N \ point \ load$$
$$load \ is \ acting \ on \ a \ cantilever \ bar \ of \ 40mm$$

$$F_{reaction} = 0.2 \ KN \times 0.04m$$
$$F_{reaction} = 8 \times 10^{-3} KN$$
$$M = \frac{1}{2} \times l \times F_{reaction}$$
$$M = \frac{1}{2} \times 0.04 \times 8 \times 10^{-3}$$
$$M = 1.6 \times 10^{-4} \ KN \ldots\ldots\ldots\ldots (1)$$

$$I = a^4$$

$$a = cross \ section \ of \ Square \ bar \ in \ meter$$

$$I = 0.01^4$$
$$I = 8.33 \times 10^{-10} \ m^4 \ldots\ldots\ldots\ldots (2)$$
$$c = distance \ from \ neutral \ axis$$
$$c = 0.005 \ m \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

$$\sigma_b = \frac{Mc}{I}$$
$$\sigma_b = \frac{(1.6 \times 10^{-4}) \times (0.005)}{8.33 \times 10^{-10}} \ldots\ldots\ldots From \ (1), (2) \ \& \ (3)$$

$$\sigma_b = 960.38 \, KN/m^2$$

IV. Axial Stress on Runner

$$\sigma_{axial} = \frac{F_{axial}}{A}$$

$0.225 = \frac{F_{axial}}{0.1}$...............(from $\sigma_{allowable}$)

$$F_{axial} = 0.0225 \, KN/m^2$$

V. Cutting Speed

1 revolution of shaft provides 15 mm of forward linear stroke and 15 mm of backward linear stroke

1 rev = 30 mm of linear motion

On an average drill machine runs at 2000 Rpm.

∴ 2000 rpm = 2000 strokes/min

Maximum a human can give 180 to 220 hacksaw strokes in a minute. Which is 10 times less than Drill saw attachment

Hence, Productivity/cutting speed is increased by 10 times.

Note: If the drill machine speed is increased, cutting speed also increases.

10. RESULT

After the design, possible failures were calculated with the help of Ansys 16 Workbench software.
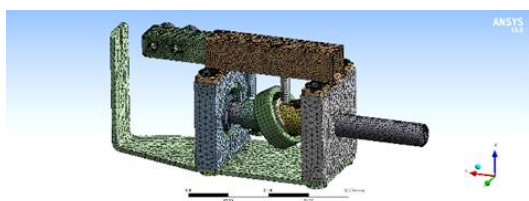
Figure 10. Meshing

The above figure shows the type of mesh done on the 3D model in order to have accurate Ansys results. Mesh done here is normal without any method, relevance used is 40 with 0 refinement also relevance centre and smoothing were kept at medium, transition was kept slow. Total number of nodes are 376836 and Elements are 204319
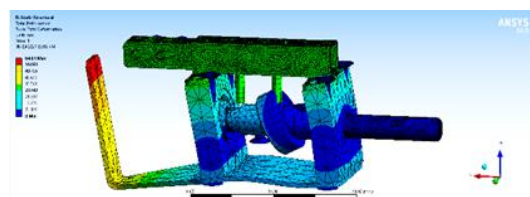

Figure 11. Rear Deformation

The above image shows failure due to deformation stresses at the base guide while working.
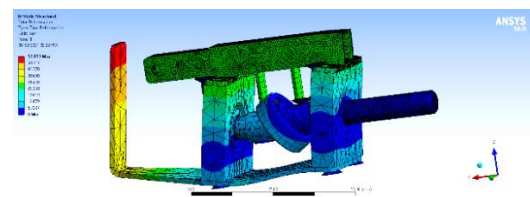

Figure 12. Front Deformation

The above image shows failure due to front collateral while working. The force assumed here is 200 N and the deformation occurred is of 55-60 mm.
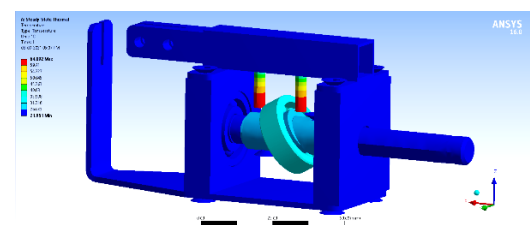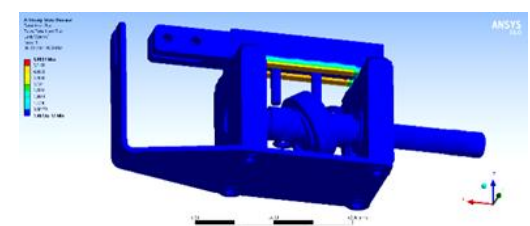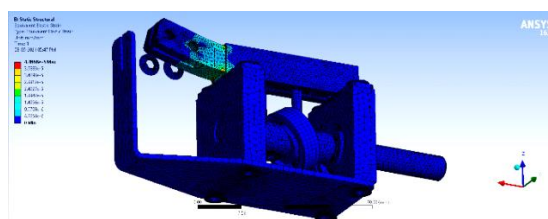

Figure 13. Thermal Stresses

The above Fig 5 & 6 shows thermal stresses build up due to friction at the mating parts which is at the bottom of the runner and guide and secondly at the cam and follower. Here heat flow is assumed 0.02 Watt/mm2 which results in temperature rise up to 55 to 60 ℃. Which is considered safe.
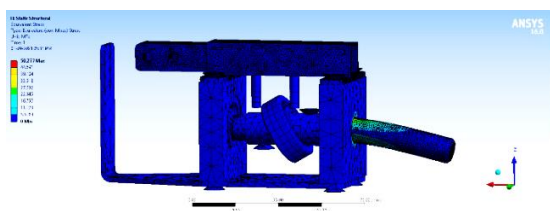
Figure 14. Bending Stresses

The above figure 7 & 8 shows the location of bending failure at the respective parts. Types of stresses used are elastic stress and Equivalent Stress respectively. In both cases force applied are 300 N directed towards the failure resulting in Maximum Equivalent stress of 50 Mpa.

The product is also tested physically on safe environment, cut few materials using Jig saw blade and the results are:

a) Plastic pipe (PVC) of 50 mm diameter took 5 min to cut.

b) Wooden block of 20mm X 20 mm cross sectional took 6 min to cut.

c) Mild steel pipe of 30 mm diameter took 10 min to cut.

d) MDF board of 20mm X 200 mm took 10 min to cut.

Cutting rates of metals with a reciprocating saw are dependent upon several process parameters, such as the applied pressure on the saw, the reciprocating speed of the saw blade, and the geometry of the cutting edges.

Comparing Ansys results and calculated results vary according to the material specification and its properties. After calculating and comparing all the results, we have observed that the product is too far from any failure as per the Ansys results, the load conditions given were exceptional and cannot be applied by any humans.

Figure 15. Experimental Layout

11. APPLICATION

  i.   It is used for cutting tubing, wood, plastics, and are also used for cutting beneath walls or wood joints because the blade can cut nails as well as wood.
 ii.   It is used for cutting circular shapes.
iii.   It can cut intricate shapes.
 iv.   Angle sawing is also possible with this product.
  v.   It can be used for basic DIY projects.
 vi.   Can be used in fabrication shops for cutting bars and square pipe
vii.   For plumbing use to cut PVC pipes, elbows, joints, etc.

12. FUTURE SCOPE

i. Drill Saw can be modified to be used as power shear cutting tool.

ii. Rubber washer/packing at joints can be provided for vibration damping and noise proof.

iii. Bigger Cam bearing can be used for larger stroke length

iv. Room for a handle for better grip on the product.

v. Replacing standard SS ball bearings with self-lubricating bearings for smoother and silent working.

vi. A safety cover can be attached to avoid any finger injury.

vii. Injection moulded casing for the product can be added for light weight.

viii. Small Gearbox can be provided to increase cutting speed.

13. CONCLUSIONS

This paper's purpose is to manufacture a device or more like an attachment to a drill machine which can convert it into a jig saw machine instead of buying heavy and expensive machine whose sole purpose is cutting, where this attachment device is light in weight, compact in size, also cost effective, and can be used easily in every household work or fabrication industries,

This paper shows the conversion of rotary motion into linear reciprocating motion having effective way to convert a drill machine's rotary motion into jig saw reciprocating motion. Many materials were researched during this paper and selection of material was according to the durability and cost efficient. The project is cost effective as well as compact in size, so it can be carried along with the drill machine. Many calculations and studies are done on this paper. Ansys results were compared and studied during this project, it is observed that the failure rate is nearly zero if used safely and efficiently.

It is proved that it saves time, money and efforts for cutting. Some parts like bearings, shafts, square bar and rods used in this project are readily available in the market, some fabrication work is needed to these parts to manufacture this project.

14. ACKNOWLEDGMENT

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