Design of a Universal Micro Radial Drilling Machine

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Abstract

In the present growing world of emerging technology, the micro machining process has demanding operation in various sectors like aerospace, oil, defence, automobile, biomedical science and many industries at micro and nano levels of manufacturing and designing. In various different types of micro machining, micro drilling is one of the tool based micro machining operation. Generally micro drilling is used to fabricate micro holes in micro products. Main emphasis is drilling speed (R.P.M) and the feed rate of the spindle. In this study, the cutting speed and feed rate will be taken as process parameters. We tried to increase the accuracy by giving feed to drill spindle through lead screw instead of direct feed. Here are some aspects which are considered in the design of universal micro radial drilling machine.

Keywords: Micro, RPM, Feed rate, Universal, Torque, Radial

I. INTRODUCTION

Micro-drilling processes have been widely used to produce micro holes such as micro dies and molds, fuel injection nozzles, watches, bearings and printed circuit boards etc. And it has more attention in a wide spectrum of precision production industries. Experiments are conducted to investigate the effectiveness of drilling processes by measuring the hole quality after micro-machining. Two aspects, location error and oversize of the hole, of drilling quality are measured. Depending on the type of drills and drilling processes, it may occur that the drill walks on the surface of the work piece before entering the part. Whirling of the drill edge at the time of penetration into the work piece degrades hole quality as well. In order to avoid whirling of drill bit on the surface of work piece, we require the high R.P.M machine. This high R.P.M will lead to drill hole easily in a sheet of nearly 4mm. in order to attain high R.P.M generally two systems are used and they are pulley system or gear ratio system. But here also required R.P.M are not obtained so we can use embedded systems for getting desired R.P.M. In this machine the arm acts similar to a robotic arm but in a manual way. There is a cross slide which gives the linear movement to the drilling machine which takes care of the depth of the hole required and a stroke length of 125mm can be achieved using the slide. Since the machine is manually set, the accuracy of the hole or point at which the hole can be drilled depends on the accuracy with which the machinist sets the end drill bit to the point. Once the drill bit is made to touch the pointer-marked on the work piece, then the machine is to be started, set to the required speed and the depth is given using the slide, which gives a linear motion to the drilling machine. The flexibility achieved using this machine is an added advantage to the machine. With multiple axes available we aim to achieve drilling at any position known to us or required in the given design. The measuring and accuracy in order to maintain perpendicularity of the drill is obtained using angular measuring instruments like spirit levels, protractors etc. The linear measurements are done using linear scales.

Due to the modernization and globalization, the energy resources are depleting very rapidly and very vastly of this world. Thus the price of these precious resources going very high on the international market. So the need to use energy more efficiently has become a necessity. The recovery of waste heat from exhaust gases has become essential due to declining energy resources and production cost. A major result of the energy conversion drive is the development of process recovery aimed at reducing the amount of waste heat discharged to the environment thus increases the overall efficiency of various processes and systems. Heat recovery conserves energy, reduces the overall operating costs and thereby reduces peak loads.

A. Drilling Process

1) Basic Purposes Of Use Of Drilling Machines

Drilling machines are generally or mainly used to originate through or blind straight cylindrical holes in solid rigid bodies and/or enlarge (coaxially) existing (pre machined) holes.

- Of different diameter ranging from about 1 mm to 40 mm.
- Of varying length depending upon the requirement and the diameter of the drill.
- In different materials excepting very hard or very soft materials like rubber, polythene etc.

2) Classification Of Drilling Machines

a) General Purpose Drilling Machines Of Common Use:

- Table top small sensitive drilling machine:
  These small capacity (≤ 0.5 kW) upright (vertical) single spindle drilling machines are mounted (bolted) on rigid table and manually operated using usually small size (φ≤ 10 mm) drills. Fig. 1.1 typically shows one such machine.
- Column Drilling Machine:
  These box shaped column type drilling machines as shown in Fig. 1.2 are much more strong, rigid and powerful than the pillar drills. In column drills the feed gear box enables automatic and power feed of the rotating drill at different feed rates as desired. Blanks of various size and shape are rigidly clamped on the bed or table or in the vice fitted on that. Such drilling machines are most widely used and over wide range (light to heavy) work.
- Radial Drilling Machine:
  This usually large drilling machine possesses a radial arm which along with the drilling head can swing and move vertically up and down as can be seen in Fig. 1.3 The radial, vertical and swing movement of the drilling head enables locating the drill spindle at any point within a very large space required by large and odd shaped jobs. There are some more versatile radial drilling machines where the drill spindle can be additionally swiveled and / or tilted.

b) General purpose Drilling Machines with more specific use:

- Hand Dills:
  Unlike the grouted stationary drilling machines, the hand drill is a portable drilling device which is mostly held in hand and used at the locations where holes have to be drilled as shown in Fig. 1.4 the small and reasonably light hand drills are run by a high speed electric motor. In fire hazardous areas the drill is often rotated by compressed air.
- Gang Drilling Machines:
  In this almost single purpose and more productive machine a number (2 to 6) of spindles with drills (of same or different size) in a row are made to produce number of holes progressively or simultaneously through the jig.
- Multi spindle Drilling Machine:
  In these high production machine tools a large number of drills work simultaneously on a blank through a jig specially made for the particular job. The entire drilling head works repeatedly using the same jig for batch or lot production of a particular job. The rotation of the drills are derived from the main spindle and the central gear through a number of planetary gears in mesh with the central gear) and the corresponding flexible shafts. The positions of those parallel shafts holding the drills are adjusted depending upon the locations of the holes to be made on the job. Each shaft possesses a telescopic part and two universal joints at its ends to allow its change in length and orientation respectively for adjustment of location of the drills of varying size and length. In some heavy duty multi spindle drilling machines, the work-table is raised to give feed motion instead of moving the heavy drilling head.
- Micro/Mini Drilling Machine:
  This type of tiny drilling machine of height within around 200 mm is placed or clamped on a table, as shown in Fig1.5 and operated manually for drilling small holes of around 1 to 3 mm diameter in small work pieces.

3) Drilling Machine Operations

a) Reaming:

It is a finishing operation of a predrilled hole using a reamer, which has multi longitudinal straight flutes. To obtain a smoothly finished accurate size hole, a slightly under size hole will be drilled first. It is then finished with a reamer. In such a case the amount of material to be removed should not exceed 0.125mm.

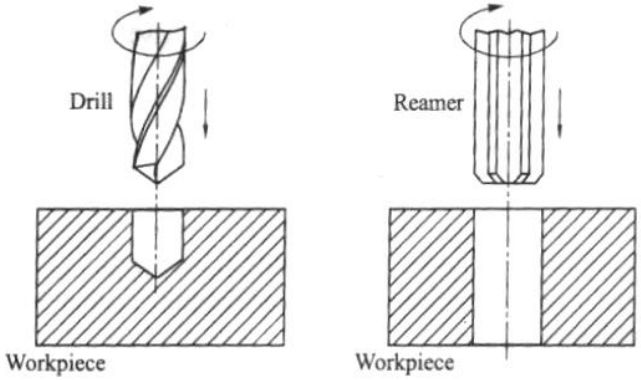


Fig. 1: Reaming

b) Boring:

It is an enlarging operation of a pre-drilled hole using a boring tool, which has a single cutting point. In order to produce a non-standard size hole the nearest size hole is drilled first using the standard drill. Later it can be enlarged using a boring tool.

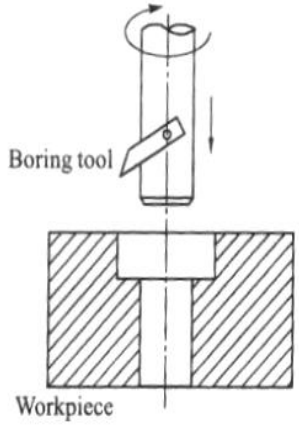


Fig. 2: boring

c) Counter-Sinking:

It is an operation to produce a conical surface at the end of a predrilled hole, using a counter sink. A conical shaped cutting tool. The angle size of the hole depends on the angle size of the screw thread, whichever is to be seated in it. A countersink hole avoids unwanted projection over the top surface of the work piece, e.g. furniture, joints in doors, windows etc.

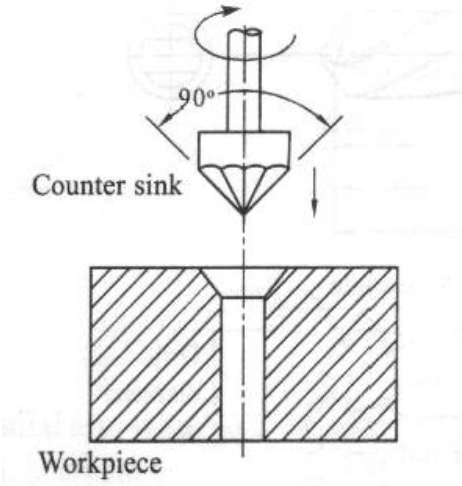


Fig. 3: Counter-sinking

d) Counter-Boring:

It is an operation to enlarge one end of the pre drilled hole concentrically to the required depth, using a counter bore tool, to form a square shoulder. The counter bore is used to drive in the socket head screw, bolts, bolts, and pins etc. the pilot of the tool helps to maintain concentricity with the original hole. It is replaceable depending on the required size.

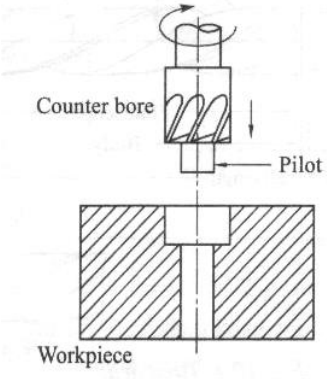


Fig. 4: Counter- boring

e) Spot-Facing:

It is an operation to produce a smooth flat seating at the top of the hole surface for bolt heads, washers, nuts etc. it may be done using counter bores or special spot facing tools.

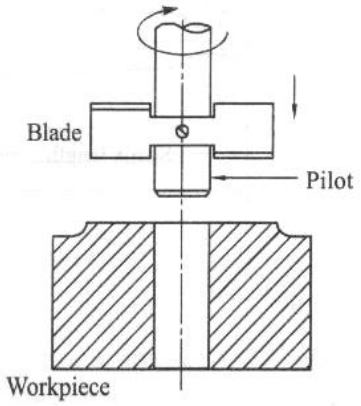


Fig. 5: spot facing

f) Tapping:

It is an internal thread generating operation in a predrilled hole, using a set of 3 taps, used one after the in succession. To generate a specific size thread, a nearest drill size is calculated and drilled first. Then using standard size taps, slowly and gradually the threads are generated.

4) Advantages of Drilling Machine

- Price will be much cheaper as compared to other available in market, the presently available smallest radial drilling machine will cost approximately 1.5 lakes but this machine costs only 40000 rupees.
- While drilling, complex drills can be achieved with high accuracy.
- It is a multifunctional portable machine.
- The sixth degree of freedom is an added advantage of using this machine.
- Helping the needy small scale industries had been our mail goal and we have succeeded in providing a simple solution which has a huge scope to be improvised in the near future.
- The machine design with furthermore up gradation is a new step towards evolution of drilling machine, and would compete the presently available model.
- The flexibility of machining is also one of the main features of our machine.

5) Disadvantages of Drilling Machine

- Drilling manually, which is time consuming process and is a hectic job.
- Drilling machine available in market is costly and small scale companies cannot afford it.
- In a radial arm drilling machine can only rotate up to 270 deg. about its base.
- Work part should always be smaller than its work table form it perform the drilling operation.
- It is less portable because of being very heavy.
- Cost of machine is high.
- Maintenance of machine is also high.
- Difficult for the small scale companies to afford the costlier machines.
- Angular drilling cannot be done on the work piece.

B. Background Of Study

Ever since mankind has made machine or tools to minimize his work he has been in a continuous mission to identify simpler alternatives hence led the invention of many machines like milling machine, drilling machine, lathe, etc. Drilling is a machining process in which a hole is produced or enlarged by the use of a specific type of end cutting tool called the drill. It is usually the most economical and effective method of producing holes in solid materials. The invention of 1st Electric drill is credited to be Arthur James Arnot & William Blanch Brain in 1889.The 1st Portable drilling machine was created in the year 1895 in Melbourne and then came the other types of drilling machines. In the increasing growth of competition environment, production technology is the key to industrial prosperity. Hence there was a need of innovation and implementing new and better designs in almost every possible field in every possible way. However not many changes were made in the geometrical shape of a drill point. It is only in recent years that significant development has taken place to generate more efficient drill designs, productive methods of manufacturing drills, newer tool materials and better methods of sharpening drill points. As the name itself explains that it is a manually controlled machine which has been designed with multiple axis so as to achieve the required drilling action in many complex degrees which were difficult to achieve initially.

II. OBJECTIVES OF THE WORK

Design and fabrication of universal micro radial drilling machine with high r.p.m using spindle arm and precise spindle feed with the help of lead screw.

III. PROBLEM STATEMENT

Drilling is basically done on heavy and larger objects manually but if holes are to be drilled or enlarged at certain angles, it is impossible to achieve accuracy by using hand drilling. Hence there has been a need for better and relevant equipment's in order to make human work simpler which has been the sole concern behind every invention that we see now a day in our day to day life. A similar effort to give rise to a new cost effective and simpler solution to the already present radial drilling machine is the main objective of our project. Our project is made keeping in mind of the needs of present-day small scale industry and provide them the ease of working which was previously benefited only by the large scale industries that had huge investment capital. Since it is a portable type of design, this machine also removes the problem of dismantling work pieces and then drilling it instead it can be used to directly mount on the large work piece or near to it.

IV. SOLUTION APPROACH

Solution for maximum micro radial drills is controlled and desired R.P.M along with precise feed rate in order to attain accuracy. Here in this project we have chosen a automatic spindle with R.P.M 10000 to 33000. A regulator is also fitted in order to vary R.P.M.

Many dedicated researchers have done their research projects on micro machining processes from various part of the world. The survey consists of some of the journal papers by them which are discussed below:

Yi Xin Yang et al [1] investigated upon Drilling force and temperature of tibia at the high speed drilling for improving the design of surgical drills are very important. In this paper we describe experiments using pig tibia bones, measuring the drilling force and temperature of a new design of drill bit and compare the results against a twist drill. The result shows that the drilling force and temperature are affected by the feed rate and drilling speed, which vary with the drilling depth into the bone. The new surgical drill with three top cutting edges can achieve lower temperature below 47oC and lower drilling force than with the stainless steel twist drill and carbide twist drill.

Tapas Kumar et al [2] investigated upon Small highly accurate holes are a common requirement across various industries and applications. In this paper, the investigation of micro drilling on copper coated printed circuit board (PCB) has been reported. Taguchi methodology has been used to plan the experiments and by using grey rational grades the optimum process parameters have been calculated. The process parameters considered in this case are spindle speed and feed rate. The torque, thrust force, time of machining and circularity has been measured. An attempt to calculate the influence of these parameters on the response variables has been made in order to plan an economically feasible machining operation.

Osamu Horiuchi et al [3] investigated upon theoretical analysis of bending deflection and anisotropic rigidity of drill, and the induced radial forces in micro drilling. The main results obtained are as follows. (1) There are two different modes of drilling which cause bending deflection of drill and induce radial forces. They are position error mode and run-out mode. (2) The radial forces induced behave quite differently between the two modes. (3) The radial forces increases as the depth of hole increases, because the rigidity of drill beam increases. (4) The position error mode induces a cyclic stress in the drill which may cause a fatigue breakage.

V. EXPERIMENTAL INVESTIGATION

Our aim is fabrication of universal micro radial drilling machine as shown in figure.

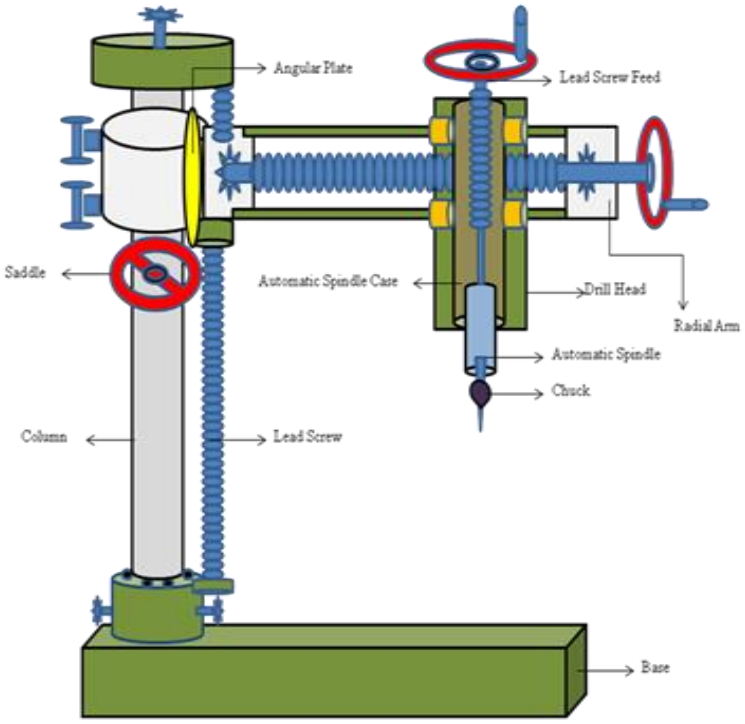


Fig. 6:

A. Calculations

1) Torque Calculation:

Power of motor = 0.18 hp = 135 watts

$P = 2 \pi N T / 60$ …….. (3.1)

$135 = 2 * 3.14 * 20000 * T / 60$

$T = 135*60 / 125663.7$

= 0.064 N-M

= 64.4 N-mm

Considering 25 % overload

Tmax = 80.5 N-mm.

2) Feed Rate:

$F = N * Fr$ ..... (3.2)

Where:

F = feed rate [in/min]

N = spindle speed [rpm]

Fr = feed per revolution [in/rev]

B. Design Specifications Of A Radial Micro Drilling Machine

1) Base Material

Base Material	*Cast Iron*
Base Length	*24 inch*
Base Width	*12 inch*
Base Height	*2 inch*
Base Thickness	*7-8 mm*

2) Column Material

Column Material	*Steel*
Column Length	*28 inch*
Inner Diameter	*12 inch*
Outer Diameter	*2 inch*
Type	*Hollow Column*

3) Automatic Spindle

Use	*Main Power Supply*
Type	*Spindle Arm*
Power	*0.18 hp*
Current	*0.5 - 0.6 amp*
Speed	*10000 – 33000 rpm*

4) Lead Screw

3 lead screw used:-

- For feed of spindle arm.
- For movement of drill head along radial arm.
- For movement of radial arm along the column.

5) Drill Specifications

Drill on non grade metals like:-

- Plastic
- Wood.
- Semiconductor devices.
- Mild steel.
- Aluminum sheets.
- Drill up to 4mm thickness.
- Drill hole of range 0.1mm to 3mm.

6) Feed Details

- Feed of spindle head will be 0.4 mm on rotating the feed hand wheel by 360 degree.
- Lead screw is used for feed control mechanism of spindle arm.
- Feed of column head will be of 1 inch on rotating feed hand wheel by360 degree.

C. Methodology Flow Chart

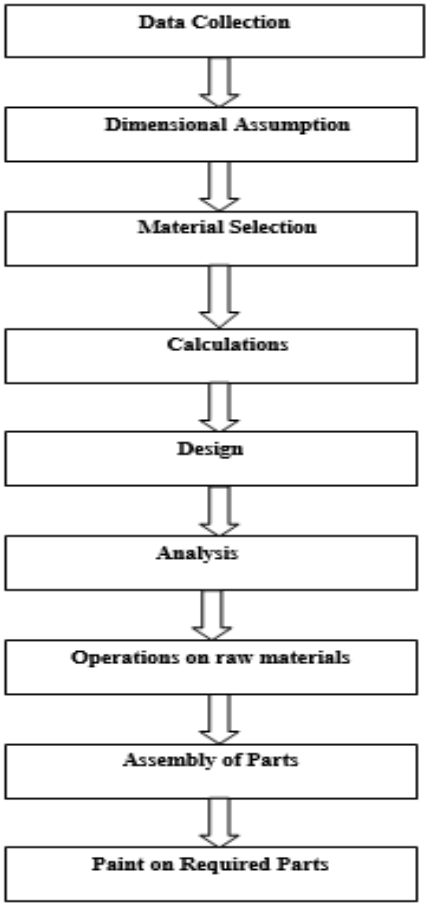


Fig. 7: Flow Chart

D. Uses Of Radial Drilling Machine

- Weight reduced to 40 kg.
- Motor and pulley system is not used which decreases the total weight of machine which will lead to less bit failure.
- High speed Spindle arm is used.
- High R.P.M. and high torque.
- Desired R.P.M. as per requirement.
- Universal micro radial drill (can drill at different angles also).
- Lead screw is used for feed system.

VI. RESULTS

A. Design Of Universal Micro Radial Drilling Machine On Pro-E

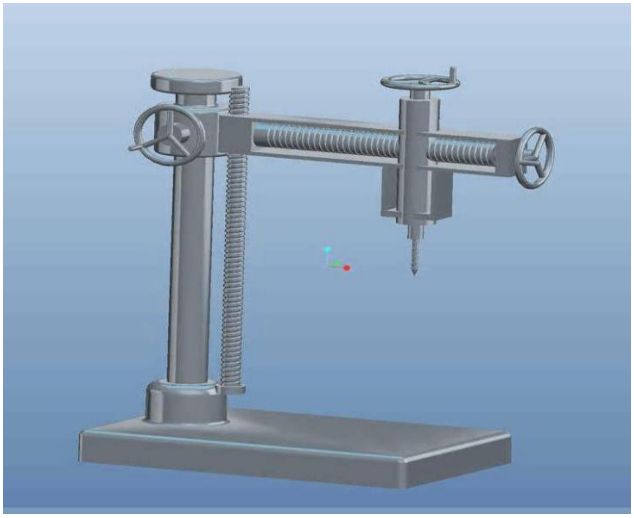


Fig. 8: Design of Universal Micro Radial Drilling Machine On Pro-E

B. Result Analysis For Micro Radial Drilling Machine

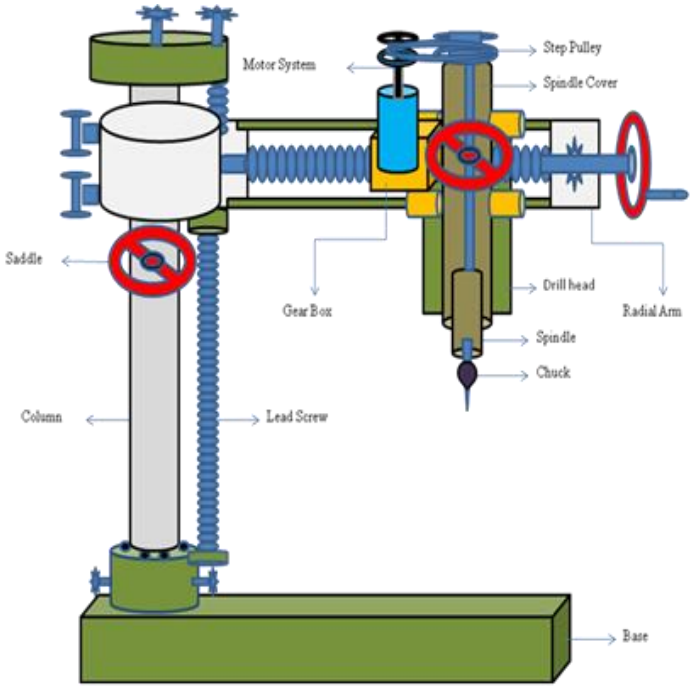


Fig. 9: Result Analysis For Micro Radial Drilling Machine

- Weight reduced to 105 kg.
- Motor and pulley system is used which increase the total weight of machine.

- Speed of Drill Spindle is according to gear ratio or pulley system.
- High torque.
- Desired R.P.M. can't be obtained as per requirement.
- Micro radial drill can't drill at different angles.
- Manual feed is given to drill spindle.

C. Result Analysis For Universal Micro Radial Drilling Machine

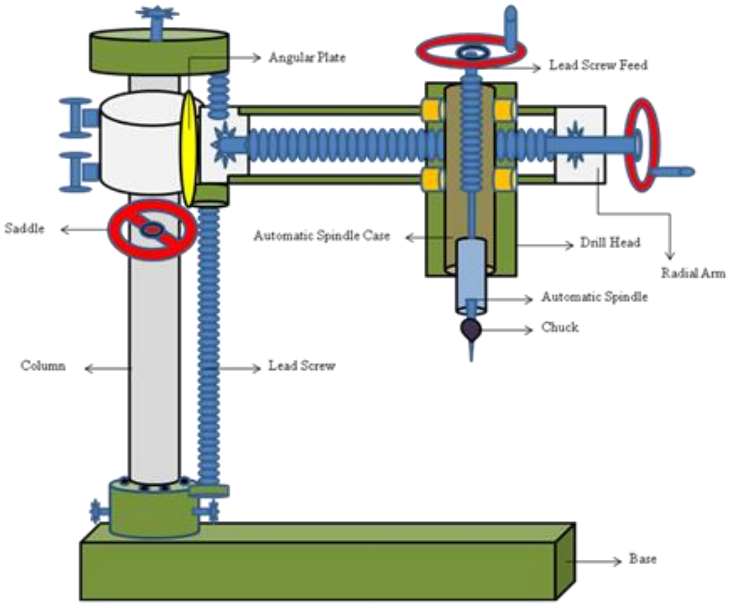
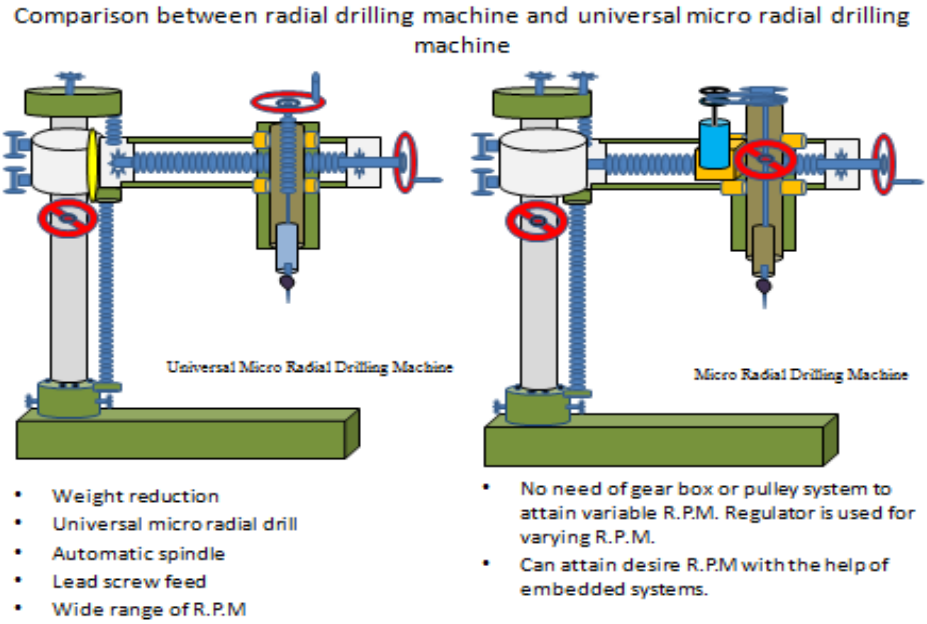


Fig. 10: Result Analysis For Universal Micro Radial Drilling Machine

- Weight reduced to 40 kg.
- Motor and pulley system is not used which decreases the total weight of machine which will lead to less bit failure.
- High speed Spindle arm is used.
- High R.P.M. and high torque.
- Desired R.P.M. as per requirement.
- Universal micro radial drill (can drill at different angles also).
- Lead screw is used for feed system.

D. Comparing Result



E. Limitations

- Manual feeding with feed wheel will take a lot of time.
- Desired R.P.M are not obtained exactly.
- Base plate is not magnetized.

VII. CONCLUSION

This project is a combined effort and the goal was to produce a cost effective drilling machine which would help the small scale industry. It would help to drill holes easily at any desired angle accurately. So this project stands in line to produce fully automated portable drilling machines in the upcoming years. There are plans to develop the project in the near future. This is just the beginning.

VIII. FUTURE WORK

- In future exact desired R.P.M. can be achieved with the help of embedded system (with the use of micro controller).
- Complete automation can be achieved.
- Base bottom plate can be magnetized for an environment where no clamping is possible.
- The machine can be automated by fixing motors at joints so as to rotate the base, arms and cross slide.
- The drilling head assembly with slide can be replaced by other equipments like toweling gun/ gas welding nozzle/ gas cutting equipment thus making it a multifunctional machine.

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