



MULTI-TOOL INDEXING DRILLING MACHINE FOR INTEGRATED MACHINING OPERATIONS

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Abstract : The increasing demand for high productivity, reduced operational costs, and efficient space utilization in small-scale industries and maintenance workshops necessitates the development of multifunctional machinery. This paper presents the design and development of a multi-tool indexing drilling machine capable of performing multiple machining operations—such as drilling, sawing, shaping, and selected lathe operations—simultaneously at different working centers. Unlike conventional setups where each operation requires a separate machine, the proposed system integrates these functions into a single unit with indexing capability for precision and versatility. This design not only reduces the need for multiple machines and associated capital investment but also significantly minimizes processing time and labor costs. The machine is particularly beneficial for small-scale industries and automobile maintenance workshops, offering a cost-effective solution without compromising on quality or efficiency. The proposed system emphasizes productivity enhancement while maintaining low production and inventory costs, aligning with the modern industrial goal of achieving high output at minimal expenditure.

IndexTerms – Multiple operations, productivity, less space, lathe, drilling, sawing, shaping.

I. INTRODUCTION

Industries are basically meant for production of useful goods and services at low production cost, machinery cost and low inventory cost. Today in this world every task has been made quicker and fast due to technology advancement but this advancement also demands huge investments and expenditure, every industry desires to make high productivity rate maintaining the quality and standard of the product at low average cost in an industry a considerable portion of investment is being made for machinery installation. So, in this paper we have a proposed a machine which can perform operations like drilling, sawing, shaping, some lathe operations at different working centers simultaneously which implies that industrialist have not to pay for machine performing above tasks individually for operating operation simultaneously. According to some economists, manufacturing is a wealth producing sector of an economy, whereas a service sector tends to be wealth consuming. Emerging technologies have provided some new growth in advanced manufacturing employment opportunities in the Manufacturing Belt in the United States. Manufacturing provides important material support for national Infrastructure and for national defense. A multi-tool indexing drilling machine is a versatile piece of equipment used in machining and manufacturing processes. Machines are equipped with multiple spindle heads that carry multiple tools for performing machining operations. Multi-tool indexing drilling machine combines the functionalities of several tools into one, typically including drilling, tapping, reaming, countersinking, and milling operations. This machine combines drilling capabilities with indexing functionality, allowing for precise and efficient drilling operations on various materials. Its ability to index enables the drilling of multiple holes at precise angles and positions, making it ideal for tasks requiring complex hole patterns or intricate machining.

II. LITERATURE SURVEY

In the year 2013, Lipin et al. used Taguchi method to determine the main effects, significant factors and optimum machining conditions to obtain better performance characteristics. It is a statistical methodology used for quality improvement in manufacturing processes. It aims to improve the quality of manufactured goods and processes by reducing variation and minimizing defects. The method emphasizes designing robust products and processes that are less sensitive to variation. [1]

In the year 2016, A Rupesh et al. Tool Indexing Multi Chuck Drilling Machine is designed with the hope that it is very much economical and help full to large scale industries, workshops, etc... Multiple operations can be done and can increase the productivity. [2]

In the year 2017, Tushar T. Bhaisare et al. main objective was to discuss about how to design a spur gear. Which is required to drive a multiple drilling head of drilling machine. It helps to drive the all-drilling head by connecting a single motor. [3]

In the year 2018, J. Dixon Jim Joseph et al. has designed the project to perform different task in a single machine. it is very much economical and help full to large scale industries, workshops, etc... Multiple operations can be done and can increase the productivity. [4]

In the year 2019, Kishan Shah et al. made the frame to be designed with minimal vibration and temperature sensing device to safeguard the machine at higher temperature and the several operations possible on this multi operation angle wise machine. It will increase the overall efficiency of various process done using the machine. [5]

In the year 2019, M. Ravi sankara Vara prasad et al. scope of this work includes, to design, to model the bevel gear, to select gear materials, to detailed factor safety in design and to analysis bevel gears.so various processes can be done more efficiently using the machine. materials of gear can be selected. [6]

In the year 2020, Vijay Khawale et al. main aim is fulfilled to locate, hold and support the work securely so that the drilling operations can be performed. In a multi-tool indexing drilling machine, work holding is a critical aspect to ensure accurate and efficient drilling operations. Some work holding devices are vice clamping, chucks etc. The primary goals of work holding in a multi-tool indexing drilling machine are to ensure stability, accuracy, and repeatability of the machining process. Proper work holding is essential for achieving consistent results and maximizing productivity in manufacturing operations. [7]

In the year 2021, Sairaj Sawant et al. The chain drives are mostly used for high torque transmission. For chain material stainless steel should be used for better yield strength and ultimate strength. Chain material is selected which can withstand high torque. [8]

III. DESCRIPTION OF EQUIPMENTS

3.1 Induction Motor:

An induction motor (or asynchronous motor) is a type of alternating current motor where power is supplied to the rotor by means of electromagnetic induction. An electric motor converts electrical power to mechanical power in its rotor (rotating part). There are several ways to supply power to the rotor. In a DC motor this power is supplied to the armature directly from a DC source, while in an induction motor this power is induced in the rotating device. An induction motor is sometimes called a rotating transformer because the stator (stationary part) is essentially the primary side of the transformer and the rotor (rotating part) is the secondary side. The primary side's current evokes a magnetic field which interacts with the secondary sides' emf to produce a resultant torque, henceforth serving the purpose of producing mechanical energy. Induction motors are widely used, especially polyphase induction motors, which are frequently used in industrial drives.

3.2 DC Motor:

The d.c generators and d.c motors have the same general construction. **MOTOR PRINCIPLE:** An electric motor is a machine which converts a electrical energy to mechanical energy. All D.C machines have five principal components viz (i) Field system (ii) armature core (iii) armature winding (iv) Commutator (v) brushes

(i) **Field system:** The function of the field system is to produce Uniform field within which the armature rotates.it consists of a number of salient poles (of course, even number) bolted to the inside of circular frame (generally called yoke). the yoke is usually made of solid cast steel whereas the pole piece is composed of stacked laminations. Field coils are mounted on the poles and carry the d.c exciting current. The field coils are connected in such a way that adjacent poles have opposite polarity. The m.m.f. developed by the coils produces a magnetic flux that passes through the pole pieces, the air gap, the armature and the frame. Practical d.c machines have air gaps ranging from 0.5mm to 1.5mm. since armature and field systems are composed of materials that have permeability, most of the m.m.f. of field coils is required to set up flux in the air gap. By reducing the length of air gap, we can reduce the size of field coils (number of turns).

(ii) **Armature core:** The armature core is keyed to the machine shaft and rotates between the field poles. It consists of slotted soft-iron laminations (about 0.4 to 0.6mm thick) that are stacked to form a cylindrical core. The laminations are individually coated with a thin insulating film so that they do not come in electrical contact with each other. The purpose of laminating the core is to reduce the eddy current loss. The laminations are slotted to accommodate and provide mechanical security to the armature winding and to give shorter air gap for the flux to cross between the pole face and the armature "teeth".

(iii) **Armature winding:** The slots of the armature core hold conductors that are connected in a suitable manner. This are known as armature winding. This is the winding in which "working" e.m.f. is induced. The armature conductors are connected in series-parallel: the conductors being connected in series so as to increase the voltage and in parallel paths so as to increase the current. The armature winding of a d.c machine is a closed-circuit winding: the conductors being connected in a symmetrical manner forming a closed loop or series of closed loops.

(iv) **commutator:** A commutator is a mechanical rectifier which converts the alternating voltage generated in the armature winding into direct voltage across the brushes. The commutator is made of copper segments insulated from each other by mica sheets and mounted on the shaft of the machine. The armature conductors are soldered to the commutator segments in a suitable manner to give rise to the armature winding. Depending upon the manner in which the armature conductors are connected to the commutator segments, there are two types of armature winding in a d.c. machine viz (a) lap winding (b) wave winding. Great care is taken in building the commutator because any eccentricity will cause the brushes to bounce, producing unacceptable sparking. the sparks may burn the brushes and overheat and carbonize the commutator.

(v) **Brushes:** The purpose of brushes is to ensure electrical connections between the rotating commutator and stationary external load circuit. The brushes are made of carbon and rest on the commutator; the brush pressure is adjusted by means of adjustable springs. if the brush pressure is very large, the friction produces heating of the commutator and the brushes. On the other hand, if it is too weak, the imperfect contact with the commutator may produce sparking.

3.3 Stator:

The stator is the stationary part of an electric generator or electric motor. The non-stationary part on an electric motor is the rotor. Depending on the configuration of a spinning electromotive device the stator may act as the field magnet, interacting with the armature to create motion, or it may act as the armature, receiving its influence from moving field coils on the rotor. The first DC generators (known as dynamos) and DC motors put the field coils on the stator, and the power generation or motive reaction coils are on the rotor. This was necessary because a continuously moving power switch known as the commutator is needed to keep the field correctly

aligned across the spinning rotor. The commutator must become larger and more robust as the current increases. The stator of these devices may be either a permanent magnet or an electromagnet. Where the stator is an electromagnet, the coil which energizes it is known as the field coil or field winding. The stator is the stationary part of an electric generator or electric motor. The non-stationary part on an electric motor is the rotor. Depending on the configuration of a spinning electromotive device the stator may act as the field magnet, interacting with the armature to create motion, or it may act as the armature, receiving its influence from moving field coils on the rotor. The first DC generators (known as dynamos) and DC motors put the field coils on the stator, and the power generation or motive reaction coils are on the rotor. This was necessary because a continuously moving power switch known as the commutator is needed to keep the field correctly aligned across the spinning rotor. The commutator must become larger and more robust as the current increases. The stator of these devices may be either a permanent magnet or an electromagnet. Where the stator is an electromagnet, the coil which energizes it is known as the field coil or field winding.

3.4. Rotor:

The rotor is the non-stationary part of a rotary electric motor or alternator, which rotates because the wires and magnetic field of the motor are arranged so that a torque is developed about the rotor's axis. In some designs, the rotor can act to serve as the motor's armature, across which the input voltage is supplied.

3.5. Electromagnetic Coil:

An electromagnetic coil is formed when a conductor solid copper wire is wound around a core or form to create an inductor or electromagnet. One loop of wire is usually referred to as a turn, and a coil consists of one or more turns. For use in an electronic circuit, electrical connection terminals called taps are often connected to a coil. Coils are often coated with varnish and/or wrapped with insulating tape to provide additional insulation and secure them in place. A completed coil assembly with taps etc. is often called a winding. A transformer is an electromagnetic device that has a primary winding and a secondary winding that transfer's energy from one electrical circuit to another by magnetic coupling without moving parts. The term tickler coil usually refers to a third coil placed in relation to a primary coil and secondary coil. A coil tap is a wiring feature found on some electrical transformers, inductors and coil pickups, all of which are sets of wire coils. As self-induction is larger for larger coil diameter the current in a thick wire tries to flow on the inside. The ideal use of copper is achieved by foils. Multilayer coils have the problem of interlayer capacitance, so when multiple layers are needed the shape needs to be radically changed to a short coil with many layers so that the voltage between consecutive layers is smaller.

3.6. Spur Gears:

Spur gears are simple, easily manufactured gears and are usually the first choice when exploring gear options. Transmitting power between parallel axes, the teeth project radially on the disc. The sole variance in their identity remains the rack, which is covered more in-depth in Engineering360's Rack and Pinion Specification Guide. Spur gears are regularly used for speed reduction or increase, torque multiplication, resolution and accuracy enhancement for positioning systems. The teeth run parallel to the gear axis and can only transfer motion between parallel-axis gear sets. Spur gears mate only one tooth at a time, resulting in high stress on the mating teeth and noisy operation. A gear is a rotating machine part having cut teeth, or cogs, which mesh with another toothed part in order to transmit torque. Two or more gears working in tandem are called a transmission and can produce a mechanical advantage through a gear ratio and thus may be considered a simple machine. Geared devices can change the speed, torque, and direction of a power source. The most common situation is for a gear to mesh with another gear; however, a gear can also mesh a non-rotating toothed part, called a rack, thereby producing translation instead of rotation. The gears in a transmission are analogous to the wheels in a pulley. An advantage of gears is that the teeth of a gear prevent slipping. When two gears of unequal number of teeth are combined a mechanical advantage is produced, with both the rotational speeds and the torques of the two gears differing in a simple relationship. In transmissions which offer multiple gear ratios, such as bicycles and cars, the term gear, as in first gear, refers to a gear ratio rather than an actual physical gear. The term is used to describe similar devices even when gear ratio is continuous rather than discrete, or when the device does not actually contain any gears, as in a continuously variable transmission. The earliest known reference to gears was circa A.D. 50 by Hero of Alexandria, but they can be traced back to the Greek mechanics of the Alexandrian school in the 3rd century B.C. and were greatly developed by the Greek polymath Archimedes (287–212 B.C.). The Antikythera mechanism is an example of a very early and intricate geared device, designed to calculate astronomical positions. Its time of construction is now estimated between 150 and 100 BC.

The definite velocity ratio which results from having teeth gives gears an advantage over other drives (such as traction drives and V-belts) in precision machines such as watches that depend upon an exact velocity ratio. In cases where driver and follower are in close proximity gears also have an advantage over other drives in the reduced number of parts required; the downside is that gears are more expensive to manufacture and their lubrication requirements may impose a higher operating cost. The automobile transmission allows selection between gears to give various mechanical advantages. An external gear is one with the teeth formed on the outer surface of a cylinder or cone. Conversely, an internal gear is one with the teeth formed on the inner surface of a cylinder or cone. For bevel gears, an internal gear is one with the pitch angle exceeding 90 degrees. Internal gears do not cause direction reversal. Spur gears or straight-cut gears are the simplest type of gear. They consist of a cylinder or disk with the teeth projecting radially, and although they are not straight-sided in form, the edge of each tooth is straight and aligned parallel to the axis of rotation. These gears can be meshed together correctly only if they are fitted to parallel shafts.

3.7. Bearing:

A bearing is a device to permit constrained relative motion between two parts, typically rotation or linear movement. Bearings may be classified broadly according to the motions they allow and according to their principle of operation. Low friction bearings are often important for efficiency, to reduce wear and to facilitate high speeds. Essentially, a bearing can reduce friction by virtue of its shape, by its material, or by introducing and containing a fluid between surfaces. By shape, gains advantage usually by using spheres or rollers. By material, exploits the nature of the bearing material used. Sliding bearings, usually called bushes bushings journal bearings sleeve bearings rifle bearings or plain bearings. rolling-element bearings such as ball bearings and roller bearings. Jewel bearings, in which the load is carried by rolling the axle slightly off-center. fluid bearings, in which the load is carried by a gas or liquid magnetic bearings, in which the load is carried by a magnetic field. Flexure bearings, in which the motion is supported by a

load element which bends. Bearings vary greatly over the forces and speeds that they can support. Forces can be radial, axial (thrust bearings) or moments perpendicular to the main axis. Bearings very typically involve some degree of relative movement between surfaces, and different types have limits as to the maximum relative surface speeds they can motor, and this can be specified as a speed in ft/s or m/s. The moving parts there is considerable overlap between capabilities, but plain bearings can generally motor the lowest speeds while rolling element bearings are faster, hydrostatic bearings faster still, followed by gas bearings and finally magnetic bearings which have no known upper speed limit.

3.8. Bevel Gear:

Bevel gears are gears where the axes of the two shafts intersect and the tooth-bearing faces of the gears themselves are conically shaped. Bevel gears are most often mounted on shafts that are 90 degrees apart, but can be designed to work at other angles as well. The pitch surface of bevel gears is a cone.

3.8.1. Straight Bevel Gear:

Straight bevel gears are used for transmitting power between intersecting shafts. They can operate under high speeds and high loads. Their precision rating is fair to good. They are suitable for 1:1 and higher velocity ratios and for right-angle meshes to any other angles. Their good choice is for right angle drive of particularly low ratios. However, complicated both form and fabrication limits achievement of precision. They should be located at one of the less critical meshes of the train. Wide applications of the straight bevel drives are in automotive differentials, right angle drives of blenders and conveyors.

3.8.2. Spiral Bevel Gear:

Spiral bevel gears are also used for transmitting power between intersecting shafts. Because of the spiral tooth, the contact length is more and contact ratio is more. They operate smoother than straight bevel gears and have higher load capacity. But, their efficiency is slightly lower than straight bevel gear.

3.8.3. Hypoidal Bevel Gear:

These gears are also used for right angle drive in which the axes do not intersect. This permits the lowering of the pinion axis which is an added advantage in automobile in avoiding hump inside the automobile drive line power transmission. However, the non-intersection introduces a considerable amount of sliding and the drive requires good lubrication to reduce the friction and wear. Their efficiency is lower than other two types of bevel gears. These gears are widely used in current day automobile drive line power transmission.

IV. DESIGN OF EQUIPMENT AND CALCULATION:

4.1 Drawing for Fabrication of Multi Tool Concurrent Drilling Machine:

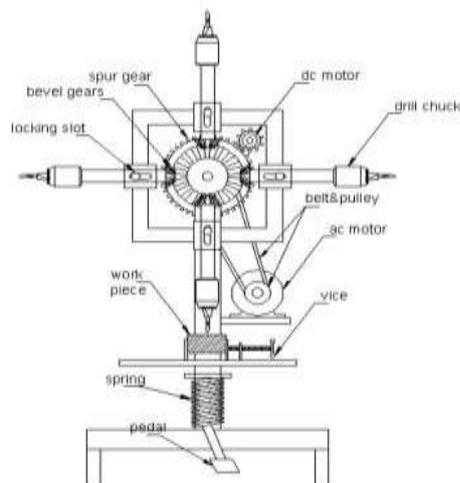


Fig 1: Multi tool concurrent drilling machine

- i. Spur gear: Spur gears are simple, easily manufactured gears and are usually the first choice when exploring gear options. Transmitting power between parallel axes, the teeth project radially on the disc. Spur gears are regularly used for speed reduction or increase, torque multiplication, resolution and accuracy enhancement for positioning systems. The teeth run parallel to the gear axis and can only transfer motion between parallel-axis gear sets.
- ii. Bevel gear: Bevel gears are gears where the axes of the two shafts intersect and the tooth-bearing faces of the gears themselves are conically shaped. Bevel gears are most often mounted on shafts that are 90 degrees apart, but can be designed to work at other angles as well. The pitch surface of bevel gears is a cone.
- iii. DC motor: A DC (direct current) motor is a type of electric motor that converts electrical energy into mechanical energy through the use of magnetic fields. DC motors consist of a stator (stationary part) and a rotor (rotating part). The stator typically contains permanent magnets or electromagnets arranged to produce a magnetic field. The rotor, usually made of coils of wire, is connected to a shaft and placed within the magnetic field.

Specifications dc motor used: Power =200W, Speed =100rpm

- iv. Drill chuck: A drill chuck is a specialized clamp used to hold drill bits or other rotary tools securely in place during drilling or milling operations. It's typically attached to the spindle of a drill press, hand drill, milling machine, or similar equipment.
- v. Belt and Pulley: Belts and pulleys are components of a mechanical power transmission system used to transmit motion and power between shafts that are at a distance from each other.
- vi. AC motor: An AC (alternating current) motor is an electric motor that operates using alternating current as its power source. These motors are widely used in various applications, ranging from industrial machinery to household appliances. AC motors work based on the principle of electromagnetic induction, where a rotating magnetic field is created within the motor to produce mechanical motion.
Specifications ac motor used: Power=0.25hp Speed=1450rpm
- vii. Locking slot: A locking slot is a feature commonly found in mechanical systems, particularly in conjunction with rotating components or parts. It's designed to prevent unintended movement or rotation of an object once it's in place. Locking slots are often used in combination with locking mechanisms such as pins, bolts, or clips to secure components firmly in position.
- viii. Vice: It is a mechanical device used to hold a workpiece securely in place while it is being worked on, typically during machining, woodworking, metalworking, or other fabrication processes. Vices come in various designs and sizes, each tailored to specific applications and workpiece sizes.
- ix. Spring: The spring is likely used to provide tension or force to either the drilling mechanism or the indexing mechanism of the machine. In drilling machines, springs are commonly used to apply downward pressure on the drill bit, ensuring consistent drilling depth and preventing the bit from bouncing or skidding on the workpiece surface.
- x. Pedal: The pedal is a foot-operated control mechanism that the operator uses to activate or deactivate the drilling operation. Pressing the pedal likely engages the drilling mechanism, causing the drill bit to move downwards and begin drilling into the workpiece. Releasing the pedal could then deactivate the drilling mechanism, allowing the operator to reposition the workpiece or perform other tasks.

4.2 CAD Design:

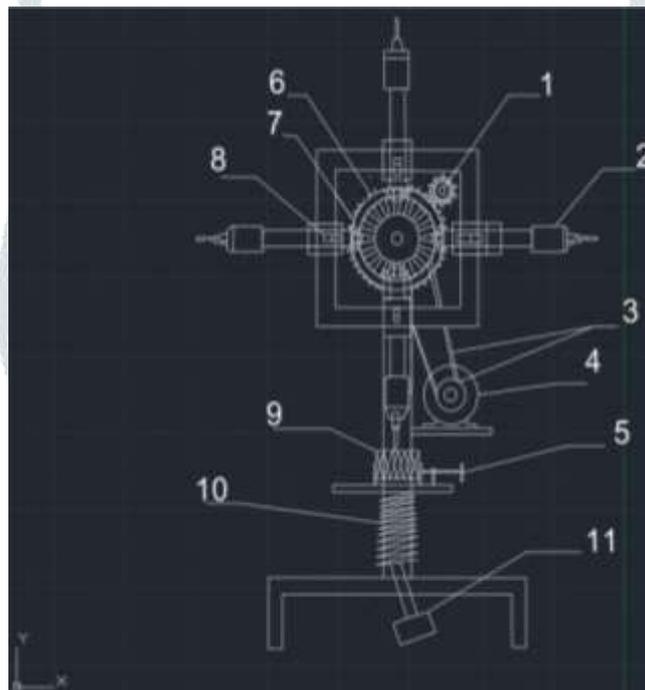


Fig 2: CAD Design

Table 1: Part Names

PART NUMBER	PART NAME
1.	DC Motor
2.	Drilling Chuck
3.	Belt & Pulley
4.	AC Motor
5.	Vise
6.	Spur Gear
7.	Bevel Gear
8.	Locking Slot
9.	Workpiece
10.	Spring
11.	Pedal

4.3 Final Model:



Fig 3: Final Model

4.4 Calculations:

i. Spur gear calculation:

Material of spur gear: Cast iron

Motor power =186W, N=1450rpm

Shaft diameter= $10 \times 10^{-3} \text{m}$

Pitch diameter= 93

To find module: from Lewis equation,

$$F_r = \pi \sigma_d C_v b y m \quad (1)$$

$$F_t = (1000 \text{PCs}) / v \quad (2)$$

$$v = \pi D N / 60 = (\pi * 10 * 10^{-3} * 1450) / 60 = 0.759 \text{m} \quad (3)$$

$$F_t = (\pi * 186) / 0.759 = 769.87 \quad (4)$$

$C_s = 1$

$\sigma_d = 200 \text{Mpa}$

Face width, $b = 10 \text{m}$

$$C_v = 6.1 / (6.1 + 760) = 0.00796 \quad (5)$$

$$y = 0.154 - (0.912 / (95 \text{m})) \quad (6)$$

We get,

Module, $m = 2.06$, $m \approx 2$

$Z = (d/m) = (93/2) = 46.5$, $z \approx 46$ teeth

Number of teeth in spur gear is 46 teeth

ii. Bevel gear calculations:

Material of bevel gear: Cast iron

Motor power =200W, N=100rpm

Shaft diameter= $10 \times 10^{-3} \text{m}$

Pitch diameter= 46

To find module: from Lewis eqn

$$F_t = \sigma_d C_v b Y_m ((L-b)/L) \quad (7)$$

$$F_t = (1000 * P) / v \quad (8)$$

$$v = \pi DN / 60 = (\pi * 10 * 10^{-3} * 100) / 60 = 0.052 \text{ m} \quad (3)$$

$$F_t = (1000 * 0.2) / 0.052 = 769.87 \quad (9)$$

$\sigma_d = 200 \text{ Mpa}$

Face width, $b = 10 \text{ m}$

$$C_v = 6.1 / (6.1 + 0.052) = 0.991 \quad (10)$$

$$Y = \pi * y = \pi * 0.125 = 0.392 \quad (11)$$

$$L = 0.5 * 1.2 / \sqrt{(d_1^2 + d_2^2)} = 25.71 \quad (12)$$

We get,

Module, $m = 2.3$

$Z = (d/m) = (46/2.3) = 20$ teeth

Number of teeth in bevel gear is 20 teeth

V. WORKING PRINCIPLE:

Project consists of DC motor, spur gear, bevel gear, drilling chuck and handle. The spindle motor is fixed in the machine column and it is coupled with the driving bevel gear. The chuck with spindle shaft is coupled with the driven gears which are fixed in the driving gear. The four types of operation tool are fixed in the chuck. The turrets containing the spindles are mounted on a spur gear which is coupled with a DC motor for index the tool head what diameter we want. When the spindle motor is switched ON, the motor rotates the bevel gear arrangement. Due to this the spindle rotates and the operation is carried out. If we need to change the operation means switch on the turret motor. It indexing the spindle arrangement and the required operation is done.

VI. RESULT AND CONCLUSION:

The project carried out by us made an impressive task in the field of small-scale industries and automobile maintenance shops. It is very useful for the workers work in the lath and smallscale industries. This project will reduce the cost involved in the concern. Project has been designed to perform the entire requirement task at the shortest time available. Industries are basically meant for Production of useful goods and services at low production cost, machinery cost and low inventory cost. Today in this world every task has been made quicker and fast due to technology advancement but this advancement also demands huge investments and expenditure, every industry desires to make high productivity rate maintaining the quality and standard of the product at low average cost in an industry a consider able portion of investment is being made for machinery installation. So, in this paper we have a proposed a machine which can perform operations like drilling, sawing, shaping, some lathe operations at different working centers simultaneously which implies that industrialist have not to pay for machine performing above tasks individually for operating operation simultaneously.

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