Design, Fabrication and Automation of Indexing Drill Jig

Raghavendra H and Shanti kiran M and Sunitha M S

Abstract --An automatic indexing drill jig has been designed and fabricated and installed in a drilling machine. It is a supporting device which holds the work, guides the tool and also locating work piece in its position during machining/drilling process. The main purpose of indexing drill jig is to eliminate the process of marking on the work piece according to the dimensions provided before machining the component and thus the high accuracy is achieved. Drill jig can also perform operations like ream and tap at a sufficient speed and with required accuracy as compared to the process of creating holes conventionally by hand. The role of operator to maintain the accuracy in the process is replaced by the drill jig because of its capability for guiding, clamping and locating of tool and work piece respectively according to the need. The automation in the drill jig is incorporated to make the work easy and accurate. By automation process the advantages like reduction in human errors and idle time is reduced, which increases the production rate.

Index Terms—Indexing, Drilling machine, Drill jig, Automation, Productivity, Steel, Lead time.

1 INTRODUCTION

There are different types of jigs and each one is made for a specific job. Many jigs are created because there is an imperative to do so by the tradesperson some are made to increase productivity through consistency, to do repetitive task or to do a job more precisely [1]. Jigs are made for frequent use or may be improvised from scrap for a particular project depending on the task [2]. The drill jigs eliminate frequent checking, individual marking and positioning. This increases productivity and reduces operation time. Jigs are made from a variety of materials, some of which can be hardened to resist wear. The materials often used in jigs are steel, iron, nylon, fiber and bronze [3].
The automation of indexing drill jig is done to, increase the production rate and labour productivity, improve the worker safety, improve the product quality and reduce the manufacturing lead time [4].

2 METHODOLOGY

The drill jig has been designed and fabricated for a drilling machine and the steps involved in carrying out the proposed work are described below.

2.1 Indexing Jig

This tool is needed to make sure that the production line is going smoother and easier for the operators doing their job in manufacturing process. Processing or in operation, jig helps operator by holding the work piece. Production rate can be achieved by using jigs, which increases the productivity by minimizing the production time.

2.2 Material selection

The material used for the manufacturing of the indexing jig is mild steel which approximately consists of 0.05% to 0.26% carbon content and up to 0.4% manganese content. Mild steel is low cost material compared to other materials and is also easy for machining and through carburizing surface hardness can be increased.

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2.*3* Design of parts of indexing jig and creating 2D drawings

By using the standard dimensions the 2D drawings are done by using the solid edge software for future processes [5].

2.3.1 Selection of bush*:* Fixed bush with hole range diameter = 6 mm Bush selected is fixed type. The diameter to be drilled on the work piece is 6 mm, the tolerance provided for the inner diameter of the bush is D_1. In the proposed work, dimensions of bush are as follows

$D_1 = 6.2\ mm, D_2 = 20\ mm$ and $D_3 = 28\ mm$, $L_1 = 25\ mm, L_2 = 5\ mm$

2.3.2 Selection of locator*:* Pin locator is used for side location and is fabricated to the work piece. Locator diameter is 20 mm which is equal to inner diameter of the work piece. The locator height is 66.5mm.

2.3.3 Design of screw of M12*:* Size of the screw = M12, Pitch = 1.75 (from pg course series table) [6]
The tensile force calculated and is f_1 = 430.07N/mm^2 and shear force is 203.45N/mm^2
Tensile force > shear force, since 430.07 >203.45.

2.3.4 Selection of jig body: Thickness of the frame t= 20mm
Base length = 3× length of the work piece= 3×40 = 120mm. Working height of the jig, h_2 = 2× outer diameter of the work piece= 2× 26 = 52mm
Total height of the jig, h = 2t+h_2
= 2×20+52 = 92mm

2.3.5 Design of screw rod: Size of the screw rod is = M6, Pitch = 1mm (from the ISO standard)
The tensile stress and shear stress has been calculated and are

430.06 N/mm^2 and 426.37 N/mm^2 respectively.
Since the Tensile stress > shear stress, hence the design is safe.

2.4. Analysis of jig

To validate the design and to confirm the component will be safe after manufacturing, analysis is done with respect to their properties

2.4.1 Calculation for analysis*:* The standard formulae for the various forces associated with the operation of jigs are explained below:

Torque, M=K$\times A \times f \times 0.8 \times d \times 1.8$ (1)

Thrust,

T =2$\times K \times B \times f \times 0.8 \times d \times 0.8 + K \times E \times d \times 2$ (2)

Where, d = Diameter of the drill and A, B, E and K are constants

Also, thrust/drilling force

= 1.16$\times K \times d \times (100 \times s)^{0.85}$ (3)

Where, K = Material factor, d = diameter of the drill in mm and s = feed mm/rev

The force acting in each of the lips $p_{1=(k_1 \times d \times s)/4}$ (4)

The torque, M also calculated as $p_1 \times d)/20$ (5)

Clamping force, Q is given as

Torque (M) $X\ safety\ factor$ (6) (6)

For the adequate strength and rigidity mild steel with 4 mm in diameter was chosen for the design of jig.

From equation (3)

Thrust/drilling force = 1.16$\times k \times d(100 \times s)^{0.85}$

But k is material factor and k for mild steel = 1.5

d is the diameter of the drill = 4 mm and

s is the feed rate = 0.17mm/rev.

Substituting,

Thrust/ drilling force = 77.353kgf

Therefore, thrust/ drilling force = 758.88 N

From equation (4)

Force acting on each of the lips, $p_1$is calculated as = 42.5 kgf = 416.92 N

From equation (5) the torque M = 83.38 N-mm

From equation (6) Clamping force (Q) = 83.38$\times$3 = 250.15N

2.5 Manufacturing of individual components

Each and every component is manufactured by adopting the required machining process [7]. Standard dimensions are maintained with the specified tolerances. Figure 1a to 8b shows the 2D drawing and 3D model of different components of indexing drill jig.

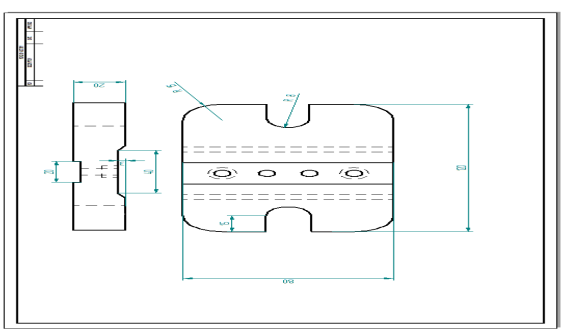

Fig. 1a 2D drawing of Bottom plate

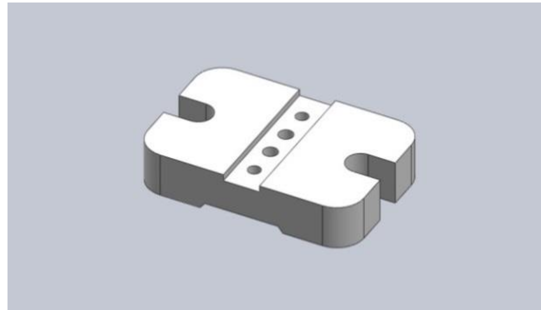

Fig. 1b 3D Model of Bottom plate

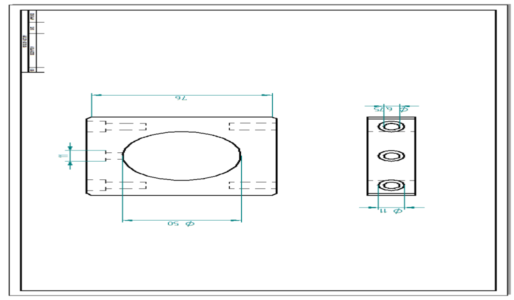

Fig. 2a 2D Drawing of supporting plate

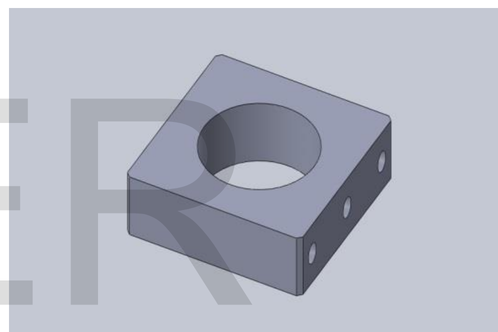

Fig. 2b 3D Model of Supporting plate

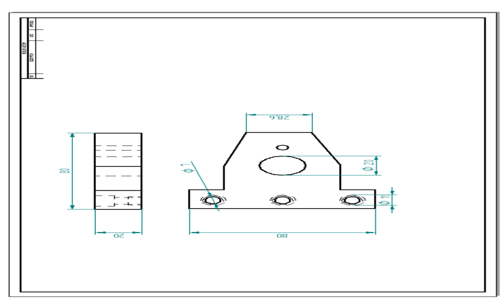

Fig. 3a 2D drawing of Top plate

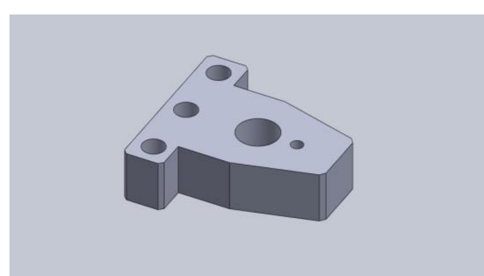

Fig. 3b 3D Model of Top plate

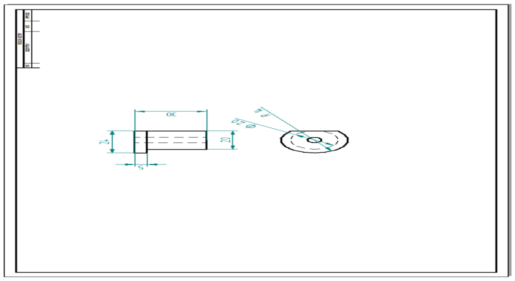

Fig. 4a 2D drawing of Drill guide bush

Fig. 4b 3D Model of Drill guide bush

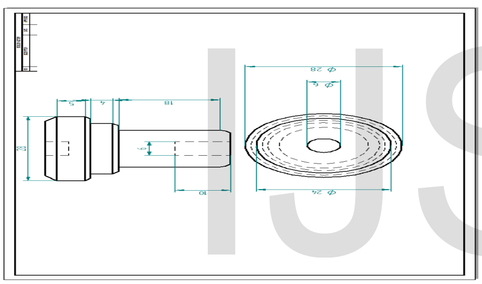

Fig. 5a 2D drawing of Locking Plate

Fig. 5b 3D Model of Locking plate

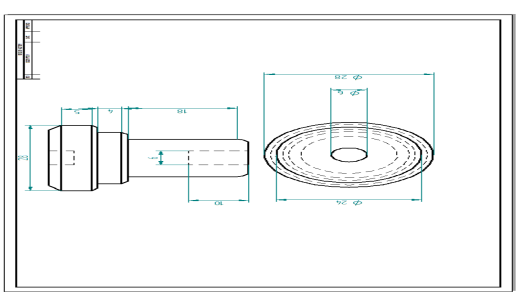

Fig. 6a 2D drawing of Locking Pin

Fig. 6b 3D Model of Locking pin

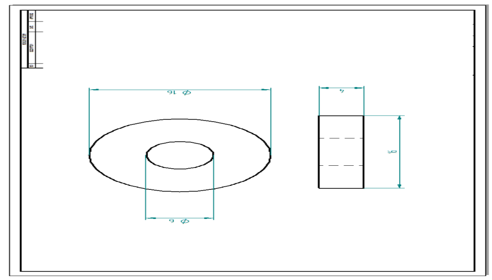

Fig. 7a 3D Model of Washer

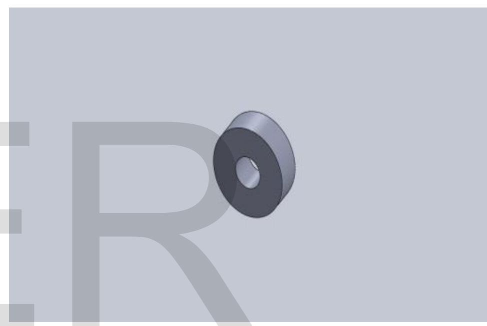

Fig.7b 3D Model of Washer

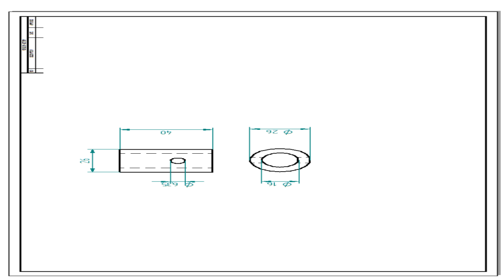

Fig. 8a 2D Model of Component (Job)

Fig. 8b 3D Model of Component (Job)

2. 6 Assembly and automation

After manufacturing all the components of indexing jig, the assembly process is carried out and also the automation is done by using sensors, microcontroller, limiting switches and motors.

2.7 Preparation of 3D model

The 3D model of indexing jig was done in solid edge software is shown in figure 9 and the exploded view is shown to the particular position of each component.

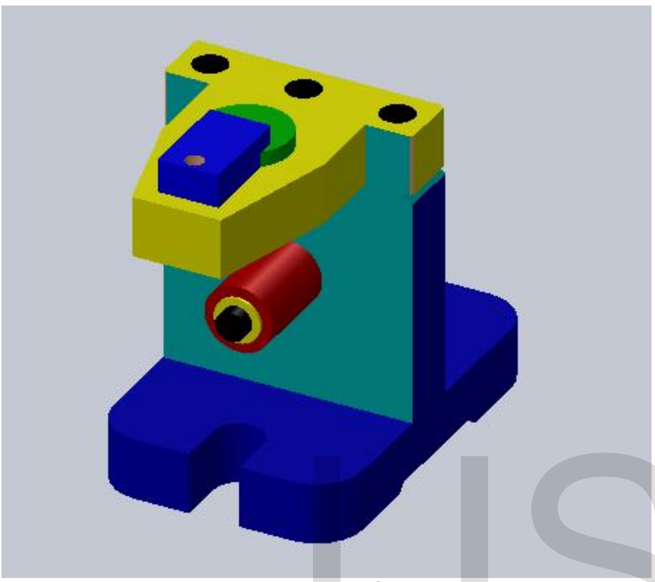

Fig. 9 D Model of Indexing drill jig

2.8 Components used for Automation

2.8.1 DC Servo motor: First we have to understand the basic servo mechanism, before going to the working principle of dc servo motor (shown in figure 10). Basically servo mechanism consists following 3 components:

Output sensor, Controlled device and Feedback system.

Fig.10 DC Servo motor

Technical specification:
DC servo motor 1.3kg/cm^2, 0.6 seconds for 1degree at full load 12v 500ma.

2.8.2 Power supply unit: The required amount of power for the particular operation will be supplied by power supply unit. It consists of transformer, relay, diode, capacitor and resistor.

2.8.3 Printed circuit board (PCB): A printed circuit board (PCB) is shown in figure 2.11 is the board base for physically supporting and wiring the surface-mounted and socket components in most electronics devices.

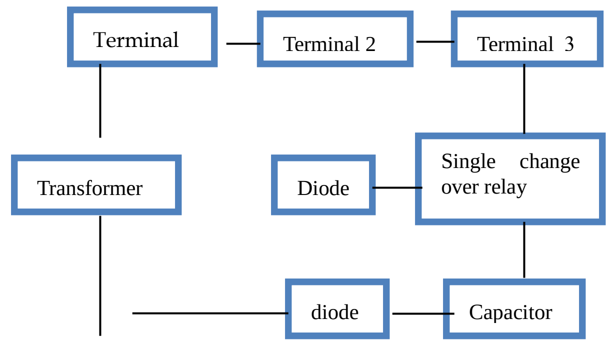

Fig.11 Printed circuit board (PCB)

Technical specification of PCB is as follows:
Capacitor 50v 1000uf, Power driller 230v, 2.8a 650w 1250 rpm max 10mm, 1c relay 220v 5a,
2c relay 5a, PBC board for soldering, 230/12v transformer, 1 rectifier bridge, connecting wires.

4). Microcontroller unit: Microcontroller (Figure 12) 320 AT mega is used with 220V and 50Hz AC power supply is reduced to 12V AC power using step down transformer circuit or step down circuit. A rectifier 7805 IC (integrated circuit) and a capacitor is connected to output of the step down circuit. Rectifier converts an AC power supply into DC power source and capacitor acts as a filter to remove the residual harmonics (that is a small amount of power source which is not converted into DC) from the DC source. The function of the 7805 IC is to produce 12V power source to 5V supply. The main power supply is reduced to 5V supply because the microcontroller used in this work is in the range of 0-5V supply.
The IC (7805 IC) consists of three connections in which one is connected to the 12V input, the second is connected to 5V output and the last one is grounded. 5V output from the IC is connected to the 14TH pin of microcontroller.

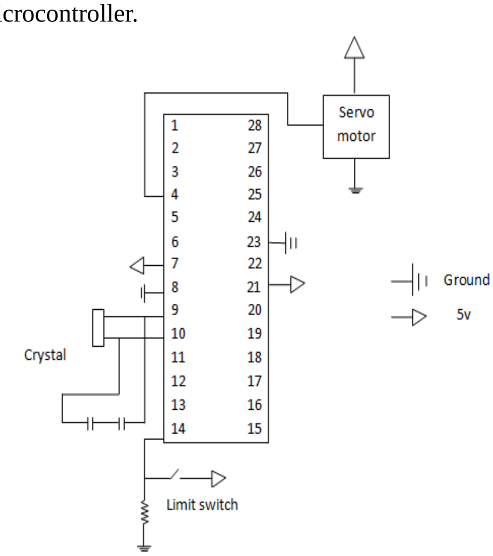

Fig. 12 Micro Controller

Technical specification of micro controller is as follows:

8bit microcontroller 32kb flash Atmel make, 7805 voltage regulator ic,1k, 2k, 10k resisters, 12v 500ma adapter for supply, 16 MHz crystal,18pf capacitor 2 numbers and PBT 220v 1a 10 numbers

3 EXPERIMENTATAL WORK

The drilling set up for conducting the machining operation is shown in figure 13.

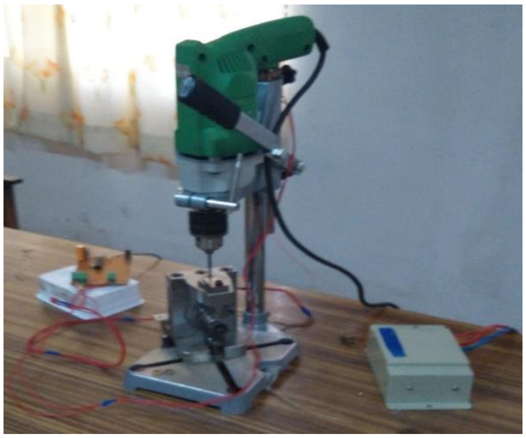

Fig.13 Automated Indexing Drill Jig

A step down transformer reduces mains supply voltage of 220V to 12V alternating current and then it is converted into 12V direct current through the rectifier bridge. A 7805 IC is used to convert 12V direct current into 5V through the polarised capacitor and is given to microcontroller in which limiting switch is connected to the 14^{th} pin of the microcontroller that waits for the signal from microcontroller. Power provided for the microcontroller is then supplied to the DC servo motor within three seconds. The 4^{th} pin of the microcontroller is connected to the pulse wide modulator that modulates speed and position. The program is generated to instruct the jig which gets indexed to $20°$ in three seconds. The crystal present plays an important role in the function of microcontroller; the purpose of connecting crystal oscillator to microcontroller is that it requires clock pulses for its functionality. For each instruction fetching, decoding, executing, and storing, processor require clock pulses.

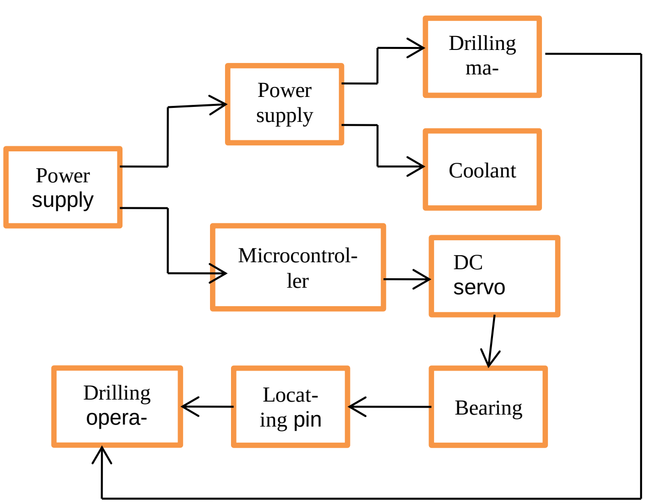

Fig.14 Block Diagram of Working Principle

4 RESULTS AND DISCUSSION

For four different materials experiment was carried out and time required for the drilling operation is noted down and tabulated as shown in table 1. man – machine utilization is shown in table 2.

TABLE 1
Total Time Required for Fiber Material

Material required	Angle of indexing in degrees	Diameter of drill bit in mm	Setup time in sec	Time required in sec	Average time in sec
Fiber	20	4	14	12	26
	60	4	14	12	
	100	4	14	12	
	140	4	14	12	
	180	4	14	12	

TABLE 2
Utilisation of Man and Machine

	Man	**Machine**
Idle time in sec	12	14
Working time in sec	14	12
Total cycle time in sec	26	26
Percentage utilization	$\frac{14}{26} \times 100$ $= 53.84\%$	$\frac{12}{26} \times 100$ $= 46.16\%$

Similarly machining time and man – machine utilisation for other materials were determined by the same procedure and are tabulated in table 3

TABLE 3
Utilisation of Man and Machine for Aluminium , Mild Steel and Cast Iron Material

Material used	**Average time taken in Secs**	**%age utilisation of man**	**%age utilisation of Machine**
Aluminium	28	50	50
Mild Steel	34	41.8	58.2
Cast iron	38	36.86	63.14

Above Table 3 shows that the test conducted for cast iron material and comparison is made for man and machine operation as shown in Table 4 which indicates that automated system reduces the % of utilization time 26.29% than the existing machine

TABLE IV
Comparison Between Earlier and Automated System for Different Material

Material type	%age utilisation of earlier system		%age utilisation of automated system	
	Man	Machine	Man	Machine
Fiber	90.9	9.09	53.89	46.15
Aluminium	89.74	10.25	50	50
Mild steel	85.88	14.41	48.17	58.8
Cast iron	84.84	15.17	36.86	63.14

4.1 Programming for Indexing

```
#ifndef Servo_h
#define Servo_h
#include <inttypes.h>
// Say which 16 bit timers can be used and in what order
#if defined(__AVR_ATmega1280__) || defined(__AVR_ATmega2560__)
#define _useTimer5
#define _useTimer1
#define _useTimer3
#define _useTimer4
typedef enum { _timer5, _timer1, _timer3, _timer4, _Nbr_16timers } timer16_Sequence_t ;
#elif defined(__AVR_ATmega32U4__)
#define _useTimer1
typedef enum { _timer1, _Nbr_16timers } timer16_Sequence_t ;
#elif defined(__AVR_AT90USB646__) || defined(__AVR_AT90USB1286__)
#define _useTimer3
#define _useTimer1
typedef enum { _timer3, _timer1, _Nbr_16timers } timer16_Sequence_t ;
#elif defined(__AVR_ATmega128__) ||defined(__AVR_ATmega1281__)||defined(__AVR_ATmega2561__)
#define _useTimer3
#define _useTimer1
typedef enum { _timer3, _timer1, _Nbr_16timers } timer16_Sequence_t ;
#else  // everything else
#define _useTimer1
typedef enum { _timer1, _Nbr_16timers } timer16_Sequence_t ;
#endif
#define Servo_VERSION           2      // software version of this library
#define MIN_PULSE_WIDTH       544     // the shortest pulse sent to a servo
#define MAX_PULSE_WIDTH      2400     // the longest pulse sent to a servo
#define DEFAULT_PULSE_WIDTH  1500     // default pulse width when servo is attached
#define REFRESH_INTERVAL    20000     // minumim time to refresh servos in microseconds
#define SERVOS_PER_TIMER       12     // the maximum number of servos controlled by one timer
#define MAX_SERVOS   (_Nbr_16timers  * SERVOS_PER_TIMER)
#define INVALID_SERVO         255     // flag indicating an invalid servo index
typedef struct  {
 uint8_t nbr        :6 ;             // a pin number from 0 to 63
 uint8_t isActive   :1 ;             // true if this channel is enabled, pin not pulsed if false
} ServoPin_t   ;
typedef struct {
 ServoPin_t Pin;
 unsigned int ticks;
  } servo_t;
class Servo
{
public:
 Servo();
 uint8_t attach(int pin);           // attach the given pin to the next free channel, sets pinMode,      returns channel number or 0 if failure
  uint8_t attach(int pin, int min, int max); // as above but also sets min and max values for         writes.
 void detach();
 void write(int value);             // if value is < 200 its treated as an angle, otherwise as pulse    width in microseconds
  void writeMicroseconds(int value); // Write pulse width in microseconds
  int read();                        // returns current pulse width as an angle between 0 and 180 degrees
  int readMicroseconds();            // returns current pulse width in microseconds for this servo   (was read_us() in first release)
  bool attached();                   // return true if this servo is attached, otherwise false private:
 uint8_t servoIndex;                // index into the channel data for this servo
 int8_t min;                        // minimum is this value times 4 added to MIN_PULSE_WIDTH
 int8_t max;                        // maximum is this value times 4 added to MAX_PULSE_WIDTH
 };
int pin = 2;
int r;
int flag=0;
#include <Servo.h>
Servo myservo;
int pos = 0;
void setup()
{
 pinMode(pin,INPUT);
 myservo.attach(9);
 void loop()
 {
  delay(3000);
  r=digitalRead(pin);
  if (r==HIGH)
  {
   myservo.write(pos);
   pos=pos+20      ;
  flag=1;
  while(flag==1)
 {
  r=digitalRead(pin);
  if (r==LOW)
```

```
  {
  flag=0;
//break();
  }}
if(pos>180)
{
pos=0;
}
```

5 CONCLUSIONS

The following conclusions are drawn from proposed work:

1. Design and fabrication of the automated indexing drill jig has been devised.
2. Drilling operation was carried out for different materials and machining time for each material is found out and compared with conventional machining time.
3. The machining time for fiber, aluminium, mild steel and cast iron are found to be 26 sec, 28 sec, 34 sec & 38 sec respectively.

Finally it is concluded that high accuracy and less consumptions of time is achieved in automated indexing drill jig as compared to the conventional machining

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