

Comparison between simulation and experimental results for drilling process in robot drilling and normal drilling machine

Akhil A A¹, and M R Stalin John²

¹PG Student, Department of Mechanical Engineering, SRM Institute of Science and Technology, Kattankulathur

²Department of Mechanical Engineering, SRM Institute of Science and Technology, Kattankulathur

Corresponding author: akhil_anilkumar@srmuniv.edu.in,
stalinjohn.m@ktr.srmuniv.ac.in

Abstract. Recently Robot is widely used in the drilling process for better flexibility and ease machining in assembly lines. In this study strain, rpm, surface roughness and circularity are analyzed in robot drilling process. Comparative experimental analysis between industrial manipulator [ABB IRB 1410] and pillar drilling machine are carried out by varying thickness of material [Aluminium 6061]. In this paper, Strain measurement can be measured with the LAB-View software by using load cells. Rpm can be analyzed with the arduino software by using IR Sensor. The optimization of drilling parameter is found out for both ABB IRB 1410 Robot and Pillar drilling machine. The results of the simulation indicate the machining parameters on feed rate, machining time, material removal rate. Strain, rpm, surface roughness and circularity of the robot drilling and normal drilling are measured and compared. This result also certifies the adequate result of the drilling process.

Keywords. Robot drilling, Pillar drilling, Strain, Rpm, Surface roughness, Circularity

1. Introduction

The robot drilling system provides a better alternate method when compared with normal drilling. They reduce costs of labour to improve the speed of production. It can produce dust and particles in air during some application. These can be removed from the harmful environment for robot drilling. Material, Robot reach, Pressure sensitivity one of the important factors of choosing the perfect robot. The control system of robot enables fast and precise work operations in ease of drilling system and a high safety level, lower installation and operation costs. Robot drill is to improve accuracy of product and certain robot has low noise and maintenance level is long. For Metal drilling Twist drill bit type have a maximum capacity 13mm. Different operation is carried out for drilling machine like Reaming, Boring etc. This paper proposes a comparison between simulation and experimental results for drilling process in robot drilling machine and normal drilling machine. The experiment is conducted using an industrial manipulator ABB IRB-1410.

Ozden Isbilira., [1] The study involves mainly it is to find out the cutting force, torque and stress with respect to drilling parameter. In this simulation process are carried out by Finite Element Analysis software to evaluate feed rate, estimate the force and efficiency is to be performed in it. J Antonio



Briones., [2] The study involves positioning and force control in drilling task. By using a load cell to easily force feedback can be carried out. Software was developed in LAB-View. They are tested by using wood material. The hybrid system in which serial, parallel is acceptable when penetration rate is low. Thiren G Poker., [3] The study is concerned with the drilling parameter by using Taguchi method. These designs the drilling parameter such as feed rate and cutting speed and responses are torque, force and machining time. It is to optimized multi responded Control parameter by using this method and find out accurate feed rate and spindle speed. Gullu Akkas., [4] Design and Kinematic Analysis of drilling robot effort to provide the internal control of the robot arm design process. It is to be carried out by Computer Aided Control. Assembly lines carried out by computer controlled way has less error and less period of time. Hyeonjun Park., [5] The study describe experimental and mechanism result of robotic finger by using a strain gauge load cell to evaluate the performance of violin robot. It is to apply force in the spring using a 3 axis integrated load cell easily analyse force can be applied into the violin playing robot can be easily carried out. Control force transmission and performance of the robot. It has 12 degrees of freedom, the number of joints 16 and 1 dependent join in each finger. Half bridge circuit arrangement for 2 strain gauges and output values can be found out by using an amplifier. They are applying different force and analyse these forces. Simulations has to be carried out by a force of 1N of different direction such as top, bottom, back front and right left. A R Srinivas., [6] This paper discusses the experimental strain measurement and force transducer it has to be designed. Simulation process is carried out in FEA software and it has to find unknown loads by using a force transducer. Stress and Strain can easily measured. The Wheatstone bridge arrangement principle applied find this unknown resistance. By using load Vs strain, voltage is plotted for cantilever beam of different load for this result it has to develop a force transducer. Muhammad Rosli Abdullah., [7] The study is concerned with improvement for patients in the rehabilitation process. For Gait Analysis can reduce the problem of health care systems overcharge. It has to combine gyro and acceleration to find complementary filter. The future works of system, particularly helpful for the exercise's beginning and end of smartphone application. It has to calculate tilt angle from accelerometer data and integrated tilt angle from gyro data over a certain amount of time. For locomotive Rehabilitation system, it has to find out compressive force, acceleration and angular velocity. Y.Ito., [8] This project presents the impact force measure which load cell is to build and find out the performance. The external force can be easily determined through analysis by using strain gauge load cells and shock absorbing material purpose, cell sponge and organism of soft tissue is in agreement has to be easily be carried out. Josephine Selavarani Ruth D., [9] This project involve design a shape memory alloy for force sensor. The principle is to execute load cell for the measurement system. Accurate measurement for static and dynamic. To evaluate sensing abilities for serving motor the active sensor prototype is used and to measure principle of sensor and sensor calibration, validity and reliability of sensor. It is to design and testing the principles. Prof Kamlesh H. Thakkar., [10] The study based on the performance and determine strain be concerned strain and deflection in a ring shaped force to gauge based load cell to better accuracy.

The main factors have to be concerned with accuracy of load cell from other factors such as various side load, impact load, temperature as well as control system. It also affects the performance of weighing and physical load has to be carried out amount of loading and other disturbing factors. Humberto Rodriguez Fuentes., [11] The study concerned with design and calibrate of circular ring type. Its maximum capacity is 60KN of load and factors such as factor of safety, momentum a displacement and normal strain to measured and calibrate test show high significance between load and strain can be measured by strain indicator. Diego Gabriel Gomes Rose., [12] The study concerned with test and analysis of force control operation for drilling in a robotic manipulator. It is to be applicable for industrial, medical applications and drilling in aircraft fuel. It demonstrates a good method to avoid failure in drilling process to implement force control. Irfan Ucin., [13] The study concerned with finite element method, drilling processes, the thrust force were analyzed with the experiment thrust force. It occur in the drilling process the results showed between experimental and numerical results. Aravind Russel., [14] The study based on load cells are tested loading the experimental results on a graph of output voltage[mV], applied load[kg] and the linear best fit is plotted. The experiment study is carried

out for rectangular and elliptical gauge areas with EN24 material and results are compared with each other. Awadhesh Kumar., [15] It is to be concerned with the world product are going to digitized for the purpose of benefits and friendliness of the customers. The digital fuel indicator showed the quantity of the fuel in the fuel tank in the form of digit with more accuracy. Due to this it will easy to know that how long distance can be covered by the remaining fuel in the fuel tank. Madhuban Prasad., [16] The force sensor has been studied using FEA analysis and to find the stress strain relation to be plot for deflection to be formed and are present in the form of stress- strain and deflection plot and it is form sensor to use them in square ring shaped force. P.Marimuthu., [17] The experiments designed to L27 orthogonal to find out spindle speed, feed rate of the micro drilling process. The experiments conduct drilling machine and micro holes are produced with help of micro drill jig. Diego Gomes Rosa., [18] The study concerned with drilling in aircraft purposes and in like a surgeries are better to precise control strategy force feedback to be controlled. It has developed for normal machining and extended to drilling process. Castro., [19] The study deals with instrument of equipment testing is used to optimize deliever a result beside minimizing error associated with manual measurements. Humberto Rodriguez Fuentes., [20] The study deals with the calibrating of load and strain to be measured by strain indicator. The above literature reviews reveals the strain measurement can be found out by using load cell and Robot drill is to improve accuracy of product, low noise, ease of machining and better flexibility. The experiments are carried out with pillar and robot drilling. The workpiece used in Aluminium 6061 after machining is tested for surface roughness and circularity. The results are compared.

2. Experimental strategy

2.1 Materials

The material used for friction stir welding process in Aluminium AA6061 plates 2mm, 3mm, 4mm in thickness. Aluminium AA6061 is very widely used alloy in 6000 series. It has the standard structure of the alloy, the composition, and also heat treatable alloy. It is widely used in manufacturing industries, aerospace, railways, shipping, automobiles and all types of large scale industries. It has very good corrosion resistance property which is very important in manufacturing companies. Aluminium alloy also gives the good finishing characteristics which are very important in the manufacturing sector.

2.2 Methodology

In order to define a robot that could carry out the drilling operations, a design methodology is followed to make the process figure. 1, suitable for strain and rpm measurement.

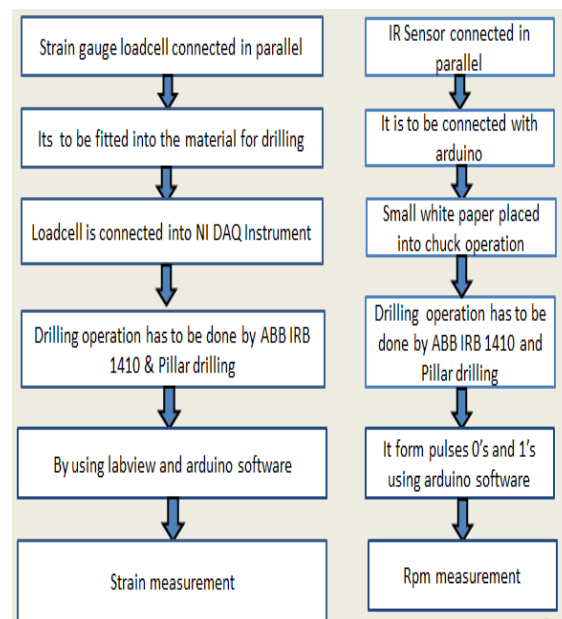


Figure 1. Methodology for drilling process

2.3 Drilling process

2.3.1 Robot Drilling

Robot Drilling was carried out in a ABB IRB 1410 Robot with three different thickness of Aluminium plate as a experimental setup . Primary step In case of this robot by using compressor the drill bit is to rotate for drilling process so primary step is to find out rpm measurement by using IR-Sensor[Infrared sensor]figure. 2 .To determine rpm on drill bit ,use an equation to convert pulse second to revolution per minute. $RPM = [PPS \div \text{Number of steps per minute}] \times 60$. The 60 is used as a multiplier because there 60 seconds in a minute.

2.3.2 ABB IRB 1410-industrial Robot

- 6-axis articulated robot(dexterous)
- Work volume-1.44 meter
- Pay load -5kg

2.3.3 Drive

- Pneumatic drive
- Max rotational speed-4500 rpm
- Weight-0.9kg
- Max pressure-9 bar

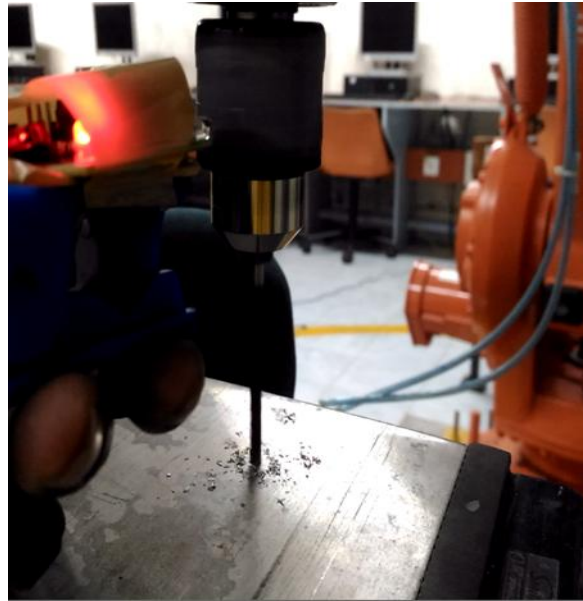


Figure 2. Robot drilling rpm measurement by using IR Sensor

Table 1. Drill diameter feed

Drill Diameter Recommended	Feed, fr [in.] [in./rev]
1/8 " to 1/4"	0.002 to 0.004
1/4" to 1/2"	0.004 to 0.008
1/2 " to 1 "	0.008 to 0.012
1" to over	0.012 to 0.020

2.3.4 Drilling formula

- $RPM = \frac{VC \times 12}{3.14 \times D}$
- Cutting Speed $[VC] = \frac{RPM \times 3.14 \times D}{12}$
- Material removal rate $[MRR] = Vf \times AT$
- Feed rate $[Vf] = IPR \times RPM$
- Cross section area of hole $[AT] = 3.14 \times R^2$
- Machining time = $\frac{L \times H}{Vf}$

L = depth of hole

R = radius of hole

D= drill bit diameter

H = Distance of work piece before feeding

Strain gauge is a sensor for strain measurement , the force being sensed. It consists of four gauges arrangement is there in Wheatstone bridge configuration .In figure 3.loadcell connection with Ni-Daq

shown below. Secondary step is to find out strain measurement by using loadcell for both robot drilling and normal drilling machine. Speed variation of robot, load factor, environmental factors like shock loading, vibration. Hence it is needed to optimize the drilling forces for both industrial manipulator and pillar drilling machine.

Table 2 . Experiment for drilling in Al-6061 plate

Thickness [mm]	Rpm	Drill bit Size [mm]	Cutting speed [m/min]	Feed rate [feed/rev]	MRR [cc/min]	Machining Time [s]
2	2500	3	23.56	12.5	88.3	8.7
		4	31.41	17.5	220	6.8
		5	39.26	20	392	6
4	2500	3	23.56	12.5	88.3	17.1
		4	31.41	17.5	220	14
		5	39.26	20	392	11
6	2500	3	23.56	12.5	88.3	29
		4	31.41	17.5	220	24
		5	39.26	20	392	18

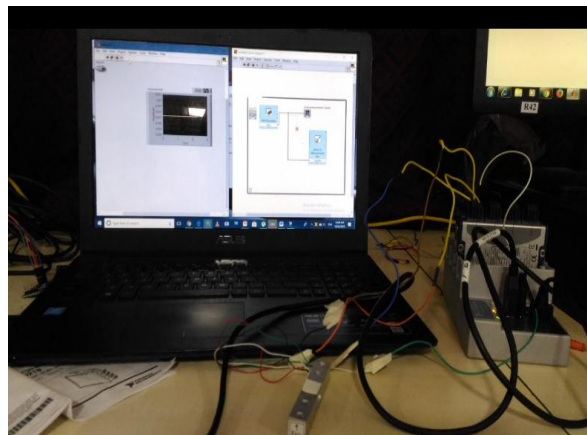


Figure 3 . Load Cell Connection with NI –Daq 9219

2.3.5 Pillar Drilling

Pillar drilling machines drill feed and work piece movement are done manually. It is having tubular columns and are grouted on the floor, generally used as a light drilling as shown in figure 4.



Figure 4. Pillar drilling machine

3. Load cell Test

Load cell testing was done on all 2 samples on the Aluminium material, strain measurement is measured for both the plate and Figure 5, compare the result of both the robotic and normal drilling machine. Workpiece is placed into the load cell sensor to measured strain value by Ni-Daq instrument connected with Lab-View Software.

3.1 Loadcell

- Voltage Range – 2.6 – 5.5 V
- Power Supply - $1\mu\text{A}$
- Operating Temperature – 20 degree to +85 degree

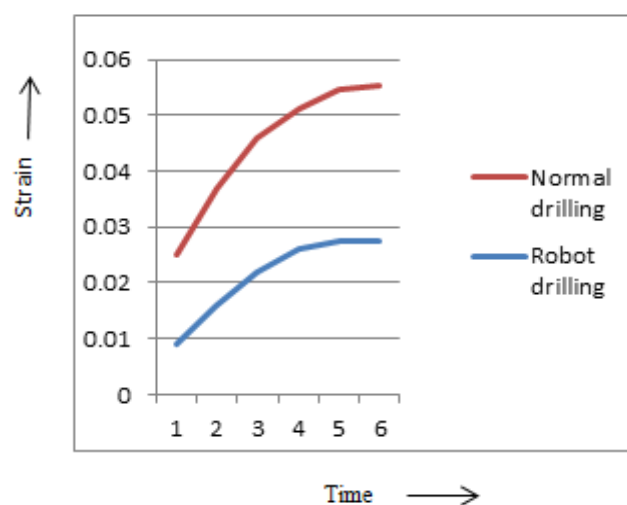


Figure 5. Strain Measurement for drilling process

Table 3. Strain Measurement for drilling

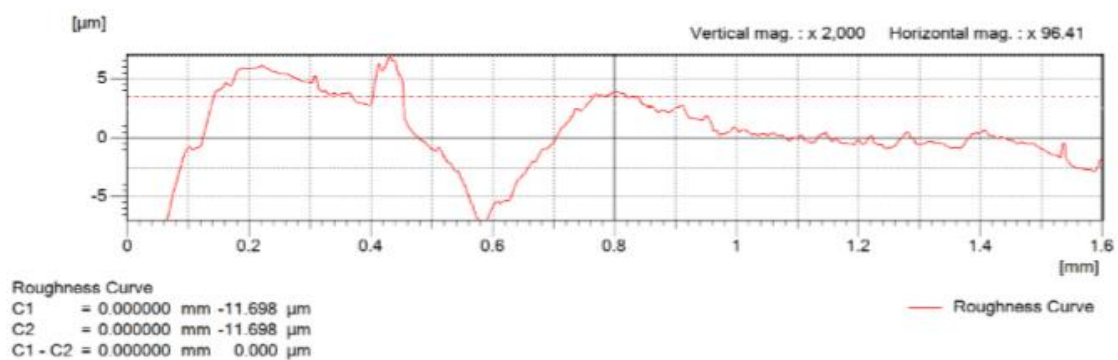
Time[s]	Robot drilling Strain measurement	Normal drilling Strain measurement	Difference
1	0.009	0.016	0.007
2	0.016	0.021	0.005
3	0.022	0.024	0.002
4	0.026	0.025	0.001
5	0.0275	0.027	0.0005
6	0.0275	0.0277	0.0008

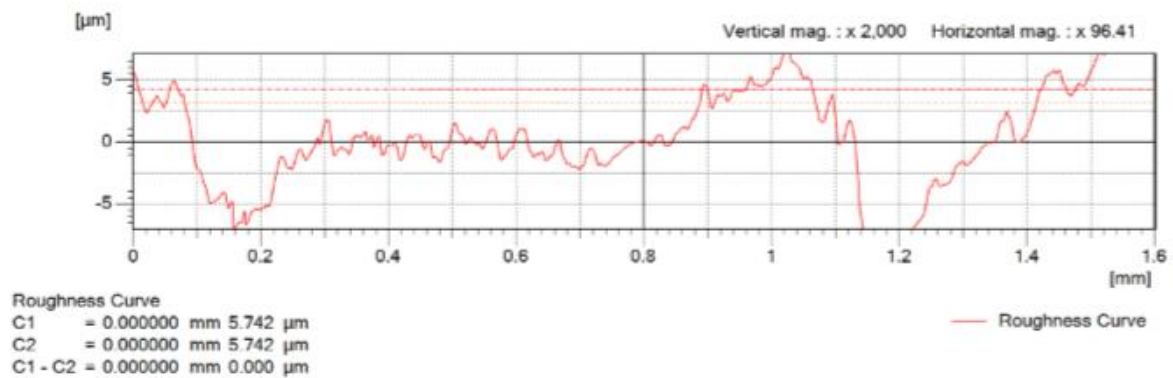
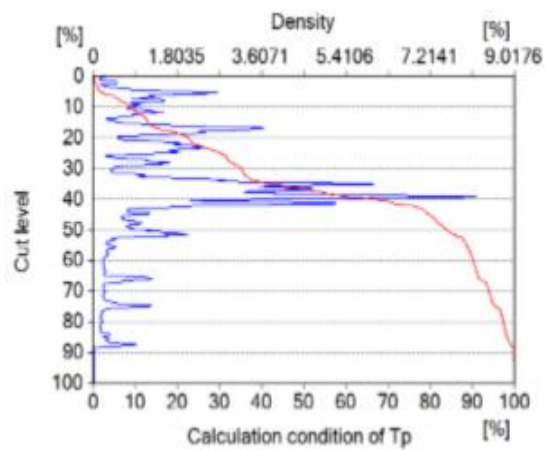
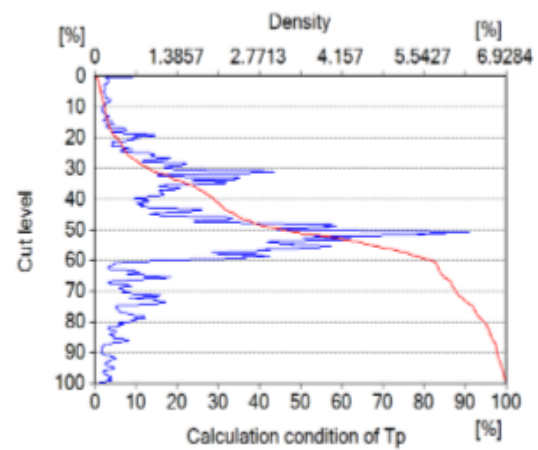
4. Surface Roughness Test

Testing was done on all 2 sample of Al6061 plates having 1.6mm thickness ,Surface roughness is measured by using Surfcom 1400G instrument to find the surface texture and deviation take place in normal vector. If the deviations are large then it is to be high otherwise surface roughness to be low Figure 6 and 7, compare the result of both normal and robotic drilling.

4.1 Surform 1400G

- Travel Range - $\pm 400\mu\text{m}$
- Sensing Method – Differential transducer
- Drive speed- 0.15 to 1.5 mm/s
- Stylus- 60 cone
- Measuring force-0.75mN

**Figure 6.** Robot Drilling Roughness Curve

**Figure 7.**Normal Drilling Roughness Curve**Figure 8.** Robotic Drilling roughness Curve with respect to density**Figure 9.**Normal Drilling roughness Curve with respect to density**Table 4.** Surface Roughness measurement for drilling process

Drilling process	Roughness Average [Ra] μm	RMS Roughness [Rq] μm	Average Maximum Height of the Profile [Rz] μm
Robotic Drilling	2.5232	3.0435	12.7252
Pillar Drilling	3.0946	3.9631	18.1058
Error	0.5714	0.9196	5.3806

5. Circularity Test

Circularity testing was done on all 2 sample of Aluminium plates having 1.6 mm thickness, measured by Optiv lite vision measuring machine . Reduction in the dimensionality is due to the fact that at entry the forces are higher at the too-work piece interaction. Compare the result of both robotic drilling and pillar drilling circularity.

5.1 Optiv lite vision measuring machine

- Least count - $1\mu\text{m}$
- Accuracy – $3+L/150\mu\text{m}$
- Camera- 1/3" colour CCD Camera
- Workpiece maximum load weight- 10kg
- Measuring Range - $300 \times 200 \times 200\text{mm}$

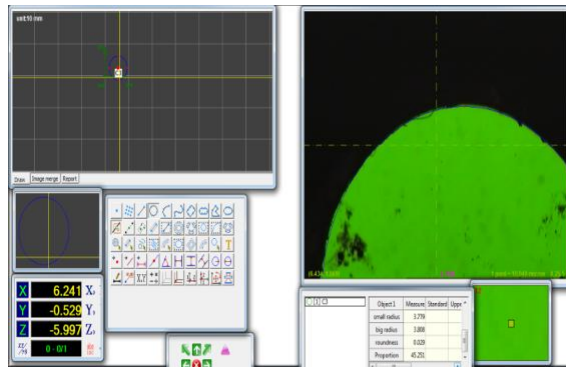


Figure 10. Robot Drilling Circularity

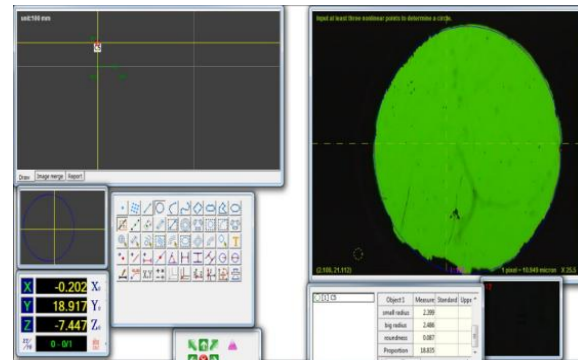


Figure 11. Normal Drilling Circularity

Table 5. Circularity measurement for drilling

Drilling process	Roundness	Proportion
Robotic Drilling	0.029	45.251
Pillar Drilling	0.087	18.835
Error	0.058	26.416

6. Results and Discussion

From the results it is inferred that the robotic drilling is good when the feed is moderate and surface quality is high. Delay in robotic drilling is given to reduce vibrations at end-effector end when compared with normal drilling process .circularity for robot drilling is 4times less than that of normal

drilling.feedrate findout the drilling quality .Strain value is morethan twice in terms of normal drilling compared to robotic drilling. Surface finish is good in case of robot and vibration to be less, surface roughness is minimum for robotic drilling.

7. Conclusion

The aim of this project is to design a load cell sensor and IR sensor detail analysis strain, rpm calculations for the drilling operation. The aim of the project has been formed and strain gauge for measuring strain for an manipulator type robot. Thickness of chip material and strain measurement from ABB IRB 1410 robot and pillar drilling machine. IR sensor for measuring rpm for drilling robot. The experimental analysis and the simulation for both robotic and normal drilling plots concludes that to reduce vibration, strain, surface roughness, circularity value, for the application of drilling process robot is feasible to operate and to get good surface finish and more productivity in less time. While comparing the result of both the drilling process, robot drilling have easy machining and better flexibility when compared with normal drilling process.

Acknowledgment

We wish to acknowledge our project coordinate Dr. Stalin John M. R , the head of our department Dr. Prabhu. S ,and Mr.Vasanth Kumar thank them for their deep interest they have shown in this project and for motivating us to do our best.

8. References

- [1] Ozden Isbilira and Elaheh Ghassemieha 2011 *Finite Element Analysis of Drilling of Titanium Alloy* **52** 2110-20
- [2] J Antonio Briones and Eduardo Castillo 2015 *Position and Force Control of the CAPAMAN 2 bis Parallel Robot for Drilling Tasks* **88** 599-607
- [3] Thiren G Pokar 2013 *Optimization and Modeling of Micro drilling Process Parameters* **89** 607-645
- [4] Gullu Akkas 2011 *Design and Kinematics Analysis of a Drilling Robot* **13** 1350-60
- [5] Hyeonjun Park and Wonse Jo 2010 *Development of Robotic Finger Using 3-Axis Load Cell for Violin Playing Robot* **11** 135-140
- [6] Bipin D Patel and A R Srinivas 2011 *Validation of Experimental Strain Measurement Technique and Development of Force Transducer* **13** 125-129
- [7] Muhammad Rosli Abdullah 2012 *The study is concerned with improvement for patients in the rehabilitation process* **45** 1410 - 1430
- [8] Y Ito and T Nemoto 2011 *Measurement by load cells of impact force which a human body receives by external force* **55** 340-350
- [9] Josephine Selvarani and K Dhanalakshmi 2015 *Shape memory alloy wire for force sensing* **45** 349-355
- [10] Kamlesh Performance 2013 *Evaluation of Strain Gauge Based Load Cell to Improve Weighing Accuracy* **55** 450-452
- [11] Rodríguez Fuentes 2015 *The study concerned with design and calibrate of circular ring type load cell* **13** 456-460
- [12] Diego Gabriel Gomes 2012 *Robotic system with force control for drilling operations* **15** 345-356
- [13] Irfan Uzun 2011 *3D finite element modelling of drilling process of Al7075-T6 alloy and experimental validation* **11** 556- 560

- [14] Aravind Russel 2014 *Simulation and Experimental Study for Selection of Gauge Area CrossSection of S Type Load Cell* **12** 650-654
- [15] Awadhesh Kumar and Sandip Kumar Singh 2008 *Digital Fuel Indicator in Two Wheelers* **32** 57-60
- [16] Madhuban Prasad and Nabi Hasan 2010 *Design studies of a square ring shaped force sensor* **34** 45-66
- [17] P.Marimuthu 2013 *Experimental Investigation and Design Optimization of Micro Drilling Process Parameters of Austenitic Stainless Steel* **45** 56-67
- [18] Diego Gabriel Gomes 2011 *Robotic system with force control for drilling operations* **11** 67-70
- [19] R M Castro and M Pereira 2010 *Optimization of method a load cell calibration for the measurement of coefficient of friction* **55** 110-113
- [20] Humberto Rodríguez Fuentes 2012 *Design manufacturing and calibration of a circular ring type monolithic load cell addressed to drawbar pull testing of the farm tractor* **23** 123-130