To Design, Develop and Test Strain Gauge Based Dynamometer for Measuring Cutting Forces in Turning

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DEDICATION

I dedicate this thesis to my beloved parents for their endless love, support and prayers to achieve this milestone and to my family members and friends for their encouragement and motivation.

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I am extremely thankful to Almighty Allah, the most merciful and the most beneficent. I offer my humblest regards from the deepest core of my heart to our Holy Prophet Hazrat Muhammad (S.A.W.W), *"who is the tower and torch of guidance and knowledge for humanity as a whole"*.

Words are insufficient to express my sincere gratitude to **Dr. Mushtaq Khan**, for his helpful guidance, perpetual encouragement, and understanding. His professional expertise, together with his valuable and tireless assistance, was major factor in the successful completion of this effort.

ABSTRACT

A great amount of engineering world uses processes like casting, molding and forming for manufacturing of products of distinct shapes and sizes to satisfy customer's needs. But to attain final and fine shape of the product offers several metal cutting processes before it is ready to use. In material cutting processes to obtain products with maximized quality and reduced cost demands some much needed factors like appropriate selection of tool material, parameters affecting cutting condition, tool structural features etc. Attempts made to achieve this goal got attention for research on computation and estimation of machining forces generated during any metal cutting process. Experimental and real-time acquiring of the cutting forces data has been indispensable because theoretically calculated results of cutting forces vary to a large extent when geometry of the tool is intricate, cutting conditions are fluctuating regularly and some uncounted factors or stresses are induced. For this purpose, development of dynamometers is very essential. Through this project an attempt is being made to design, develop, calibrate and experimentally test a dynamometer, with strain gauges as sensors mounted, for measuring cutting forces generated during turning of metallic parts. The constructed device is experimentally tested against experimental results acquired via highly reliable commercial dynamometer by comparing forces results for cutting of Aluminum 6061-T6. Obtained results proved the excellent characteristics of the designed device and its effectiveness for investigating advanced machining applications.

Key Words: *Cutting Forces, Strain Gauge, Dynamometer, Turning, Beam Type.*

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CHAPTER 1

INTRODUCTION

1.1 Introduction to Research

The benefits of estimation of the forces generated during turning have been of great consideration in tool machining industries [1-3]. The experimental data of machining force helps in evaluation of wear, fracture, roughness etc in tools as it includes the effect of heat dissipation during machining. Experimental and real-time acquiring of the cutting forces data has been indispensable because theoretically calculated results of cutting forces vary to a large extent when geometry of the tool is intricate, cutting conditions are fluctuating regularly and some uncounted factors or stresses are induced. To acquire this, development of dynamometers is very essential [4, 5]. So many researches regarding measuring the elastic strain due to induced stresses in materials by using various strain sensors have been carried out[6, 7]. Studies on various types o elastic elements like ring type, beam type, shank type etc have been presented to measure force components of machining with improved accuracy [8]. Through this project an attempt is being made to design, develop, calibrate and experimentally test a dynamometer, with strain gauges as sensors mounted, for measuring cutting forces generated during turning of metallic parts. Interfacing of DAQ system, strain gauges and PC have been carried out to notice and record real time values of force components for machining of Aluminium 6061-T6 at different cutting parameters like spindle speed, feed rate, etc.

1.2 Aims of Research

Aims of this research work include development of a dynamometer model using CAD software like CATIA, analysis of model using ANSYS software for determination of strength of designed structure and strain gauges installation locations, fabrication of dynamometer and strain gauges installation. Finally calibration and experimental testing of fabricated dynamometer by using Data Acquisition (DAQ) system and LabView Software.

1.3 Research Objectives

The objectives of this thesis include application of knowledge regarding dynamometers, machining forces in turning and parameters affecting them, selection of appropriate strain gauges and their determination of installation points on elastic element, realization of elastic element design considerations, modeling and drafting in CAD software like CATIA, analysis and simulations in software like ANSYS Workbench. Application of Design for Function (DFF), Design for Manufacturing (DFM) and Design for Assembly (DFA), Data Acquisitioning using DAQ System by its interfacing with dynamometer and LabVIEW software.

CHAPTER 2
LITERATURE REVIEW OF DYNAMOMETER

2.1 Dynamometer

It is a device used for measuring power, torque, or force of any mechanical system. It was first invented by George Graham, mentioned in the writings of John Desagulier (12 March 1683 – 29 February 1744. In this study machining forces measuring dynamometer is discussed.

2.2 Historical Background

In 2004, Suleyman Yaldız [9] carried out his research on dynamometers with strain sensing element of ring type. He used strain gauges as strain sensors for measuring static load and piezo-electrics to acquire data during dynamic loading. In his work appropriate orientation o rings was determined and strain sensitive points were located on the rings to attain maximum sensitivity with reduced cross sensitivity in results. In 2006, Mustafa Gunay [10] presented results on turning performed on workpiece of steel of grade AISI 1040 at various rake angles and strain sensing element of beam type. In 2007, Sedat Karabay [11] carried out research on elastic elements of dynamometers, to locate proper placement of strain sensors under the action of tension and compression stresses. In 2009, G. Totis [12] carried out study on a shank type elastic element containing dynamometer with piezo-electric sensors for measuring three components of machining forces simultaneously for milling or turning process. In 2010, G. Totis [13] illustrated the development a dynamometer for milling with strain sensors mounted on a rotating tool-holder. In 2015, Muhammad Rizal [15] also introduced a dynamometer with strain gauges as strain sensors mounted on a rotating tool-holder provided with a no wires environment to evaluate cutting force generated in milling and drilling processes.

It is of utmost importance for competing industries across the whole world to put their endless efforts in attaining products with minimal costs in a lesser lead-time and improved surface finish [16]. Due to this aspect for more than 100 years, a bulk of reaches have been carried out on phenomenon of metal removal by many scientists and engineering experts [17] so as to gain better understanding of the physics of cutting process [18] to present models for cutting forces with maximum reliability [19], for the material characterization, machinability tests and tool comparison [20], tool geometry optimization [21], cutting parameters optimization [22]. Also, cutting force measurements can be successfully applied for tool condition monitoring [23, 24] and detection of chatter vibrations [25] to produce products with reduced cost but improved quality. In an attempt to achieve this, a better understanding of the cutting forces is required.

2.3 Cutting Forces

The three main cutting or machining forces that occur during metal cutting processes are stated as:

a) *Cutting or Tangential Force (F_y)* that occurs tangent to workpiece.
b) *Feed Force (F_x),* it is induced parallel to the longitudinal axis of workpiece.
c) *Thrust or Radial Force (F_z),* it is generated along the longitudinal axis of cutting tool.

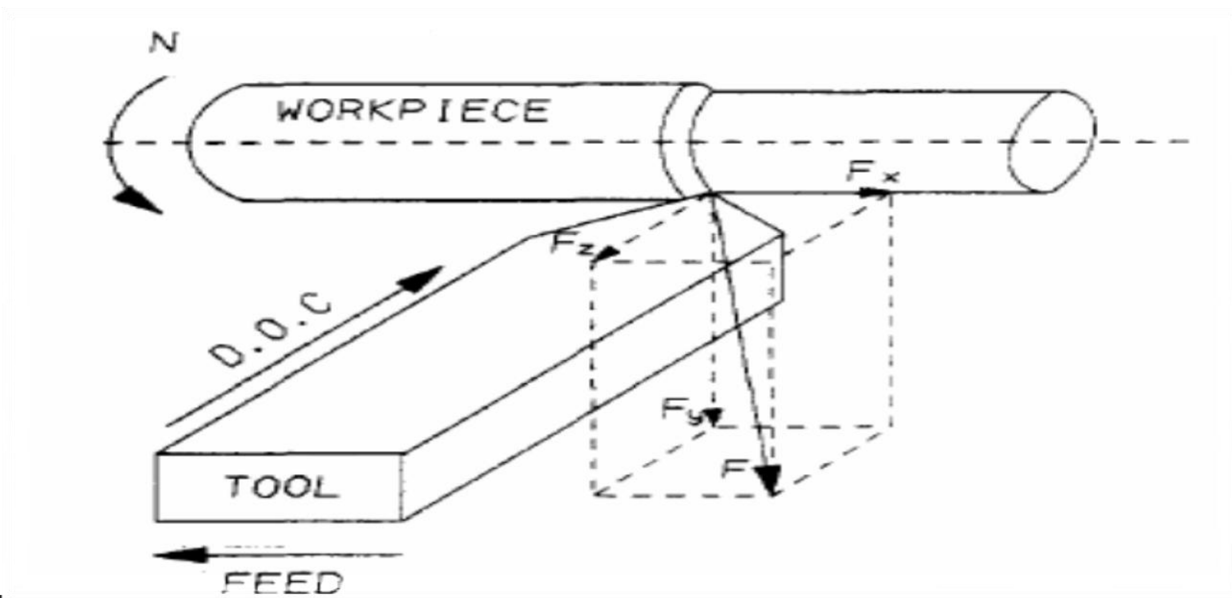


Fig.2.1 Cutting force components in turning operation

2.4 How to measure the Cutting Forces?

The cutting forces generated during machining can be measured:

- By *indirect method* i.e. from evaluated power consumption.
- By *direct method i.e.* by using *Dynamometer* during machining.

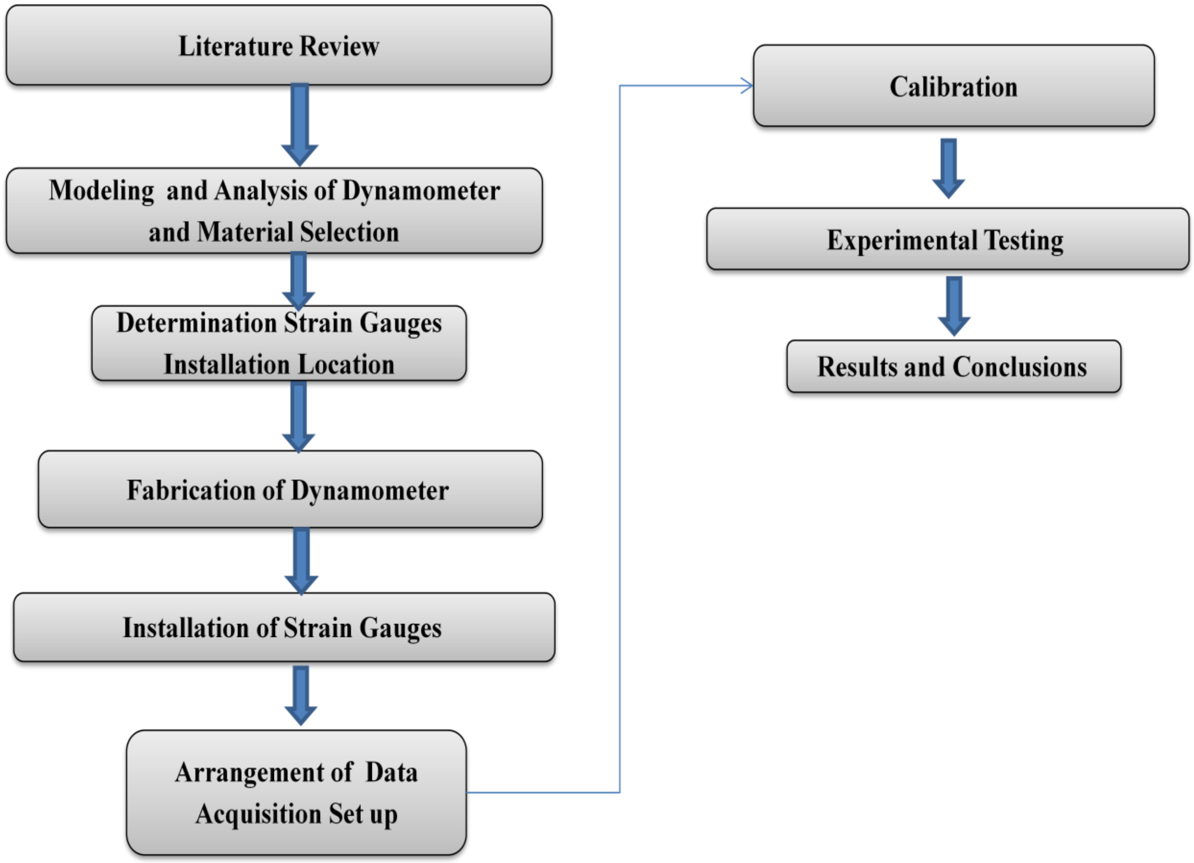
2.5 Why to use a Dynamometer?

Experimental and real-time acquiring of the cutting forces data has been indispensable because theoretically calculated results of cutting forces vary to a large extent when geometry of the tool is intricate, cutting conditions are fluctuating regularly and some uncounted factors or stresses are induced [10].

So in this research, strain gauges mounted mechanically decoupled beam-type static dynamometer for turning has been constructed and tested which is not considered in the research studies available in literature.

2.6 Research Methodology

The below mentioned methodology has been adopt to proceed this research work.


Literature Review
Modeling and Analysis of Dynamometer and Material Selection
Determination Strain Gauges Installation Location
Fabrication of Dynamometer
Installation of Strain Gauges
Arrangement of Data Acquisition Set up
Calibration
Experimental Testing
Results and Conclusions

CHAPTER 3

DESIGN AND CONSTRUCTION OF DYNAMOMETER

3.1 Design

Basically design is process that aims at innovation after a series of iteration based on decision making and formulation of process to come up with a product which fulfils customers or demander's requirements accommodating factors like reliability, functionality, safety, marketability etc.

3.2 Important Design Considerations

To obtain a valuable design of dynamometer the below mentioned steps are necessary to be carried out:

- Selection of dynamometer type
- Geometry and orientation on Turret
- Material selection
- Strength analysis and shape optimization
- Selection of strain gauges
- Determination of strain sensitive points
- Validation of model and drawings generation

3.3 Selection of Type of Dynamometer

There are many types of dynamometers on the basis of following classification:

a) Mechanical coupling
b) Elastic element
c) Sensors used
d) Machining process

a. Mechanical Coupling

Mechanical coupling in case of dynamometers is the ratio of δ_y to δ_x due to pure F_x. Where δ_y is the amount of strain induced in Y-axis, δ_x is the amount of strain induced in X-axis and F_x is the force acting in X-axis. [26] So on coupling basis dynamometers can classified as

- Mechanically coupled
- Mechanically decoupled

Mechanically coupled dynamometers are those in which δ_y / δ_x has a value greater than 0 whereas *mechanically decoupled* ones are those with δ_y / δ_y equals to 0.

b. Elastic element

Elastic element is the strain sensitive structure of dynamometer on which strain sensors are installed. Elastic element can be of following types:

- Shank Type
- Beam Type
- Ring Type
- Plate Type

Shank type includes those in which strain sensors are mounted directly on the shank of cutting tool. In *beam type* strain sensitive structures are of the beam type and strain sensitive points of beam structures are used for mounting strain sensors. In *ring type* dynamometers the strain sensitive part is like ring, either hexagonal, octagonal or any other ring structure. *Plate type* dynamometer is assembled between the job and machine bed [14].

c. Sensors used

Mostly two types of sensors are used for determining induced strain in elastic elements

- Piezo-electrics
- Strain gauges

d. Machining Process

Dynamometers can be of various types depending upon the type of machining process, like turning, milling, drilling etc.

In this study, mechanically decoupled beam type strain gauge based dynamometer for turning process has been discussed.

3.4 Geometry and Orientation on Turret

It is intended to model a structure that should be capable to fulfil following requirements;

- Can hold tool shank firmly of size 25 x 25 mm^2 cross section.
- Tool can be adjusted for various sizes of work pieces.
- Can be accommodated on the turret for a various size of work pieces.
- Can align elastic elements in the direction of desired cutting forces.
- Can be easily integrated and disintegrated from the turret.
- Cabling of data acquisitioning system can be accessed without any risk of damaging.

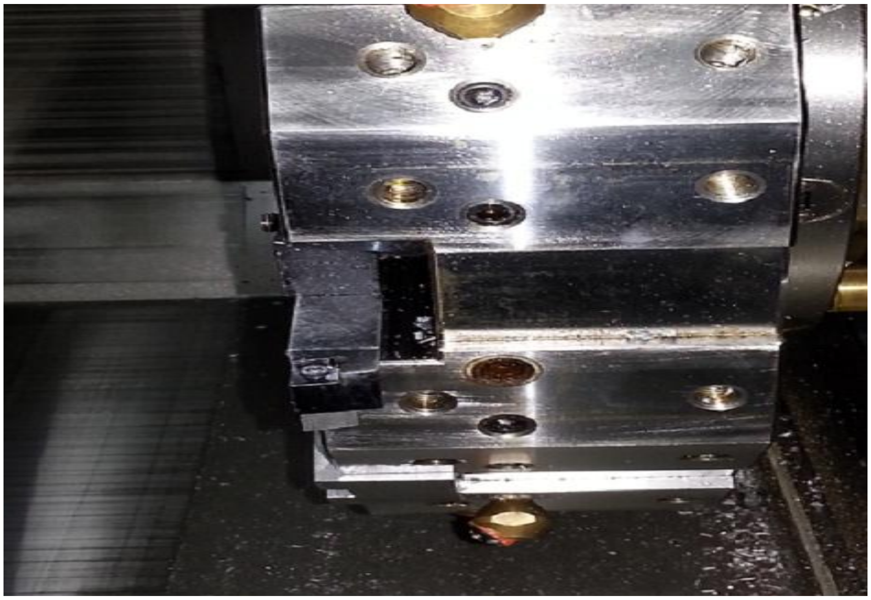


Fig 3.1 Dynamometer mounting feasibility on Turret

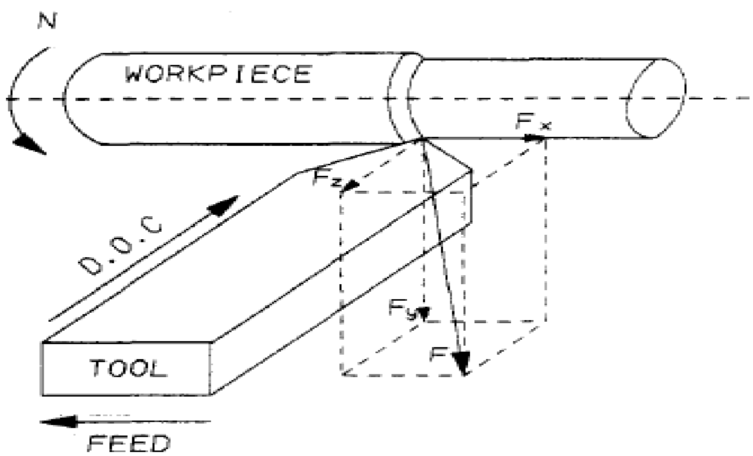


Fig 3.2 Cutting force components direction with respect to tool.

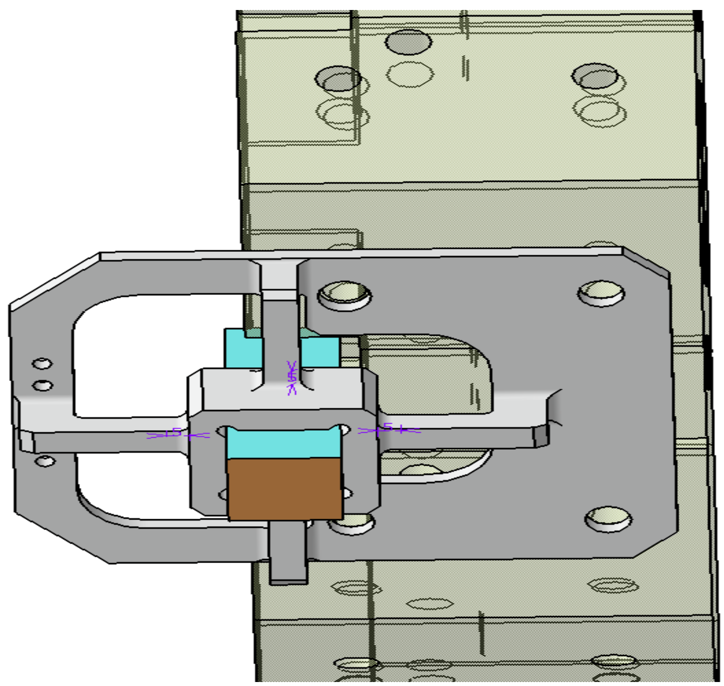


Fig 3.3 Model for Dynamometer mounting on Turret

3.5 <u>Material Selection</u>

Dynamometer structure should be rigid enough to withstand machining forces and vibration with a good factor of safety for fatigue life. So Stainless Steel of grade 304 has been selected as a material for tool holding and elastic elements of dynamometer to meet the desired specifications.

Composition of SS-304 includes:

Carbon, C	<= 0.080 %
Chromium, Cr	18 - 20 %
Iron, Fe	66.345 - 74 %
Manganese, Mn	<= 2.0 %
Nickel, Ni	8.0 - 10.5 %
Phosphorous, P	<= 0.045 %
Silicon, Si	<= 1.0 %
Sulphur, S	<= 0.030 %

Mechanical Properties of SS-304 are:

Density	8.00 g/cc
Hardness, Rockwell B	70
Tensile Strength, Ultimate	505 MPa
Tensile Strength, Yield	215 MPa
Elongation at Break	70 %
Modulus of Elasticity	193 GPa
Poisson’s Ratio	0.29
Shear Modulus	77.0 77.0 GPa

3.6 Strength Analysis and Shape Optimization

For strength analysis ANSYS software was used to determine maximum stress value applying load of 1000N in cutting force direction and 1000N load on feed force arm separately. From this simulation maximum determined stressed for 1000N is 44.7MPa while Tensile Yield Strength of SS 304 is 215 MPa i.e. factor of safety is “4”.

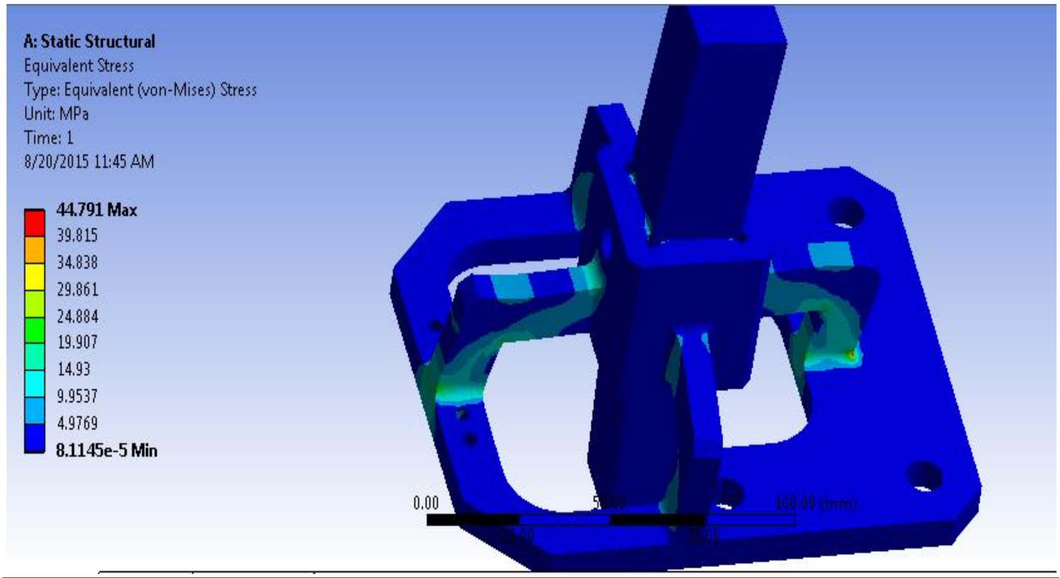


Fig.3.4 Strength Analysis results in ANSYS

For structure optimization following relation was used to select appropriate cross section for elastic beams

As

Flexural Stress = Mc / I

$I = bt^3 / 12$, $c = t/2$

Where,

t = thickness of section (for designed structure t = 13mm)

b = width of section (for designed structure b = 8mm)

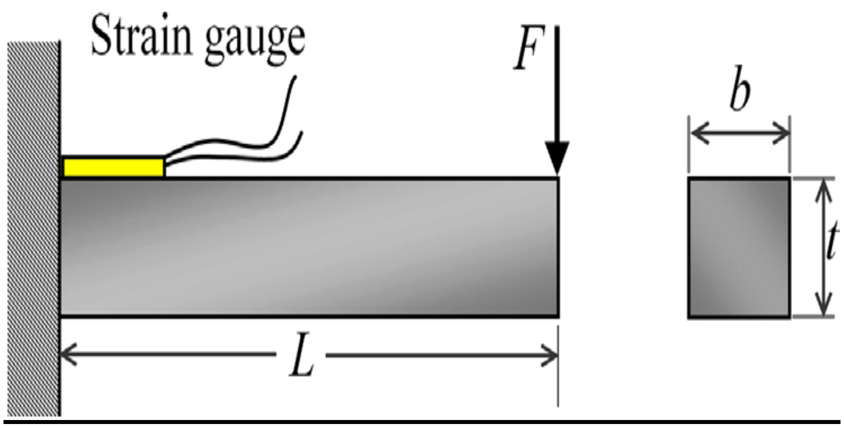


Fig 3.5 Elastic beam cross section.

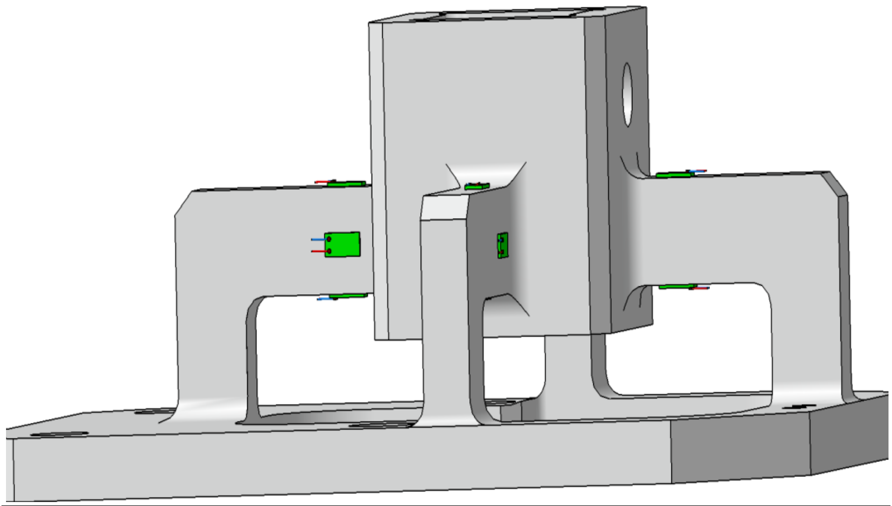


Fig 3.6 Elastic beams structure of modeled dynamometer.

3.7 Selection of Strain Gauges

"A strain gauge is a device used to measure strain on an object"- by Edward E. Simmons and Arthur C. Ruge in 1938.

Working Principle*: *Each metal has its characteristic property of specific electrical resistance. By applying an external tensile force or compressive force will increase or decrease this electrical resistance due to elongation or contraction produced in it.

Ks is a gauge factor, for accommodating strain gauge sensitivity.

ΔR is measured by using *Wheatstone bridge.*

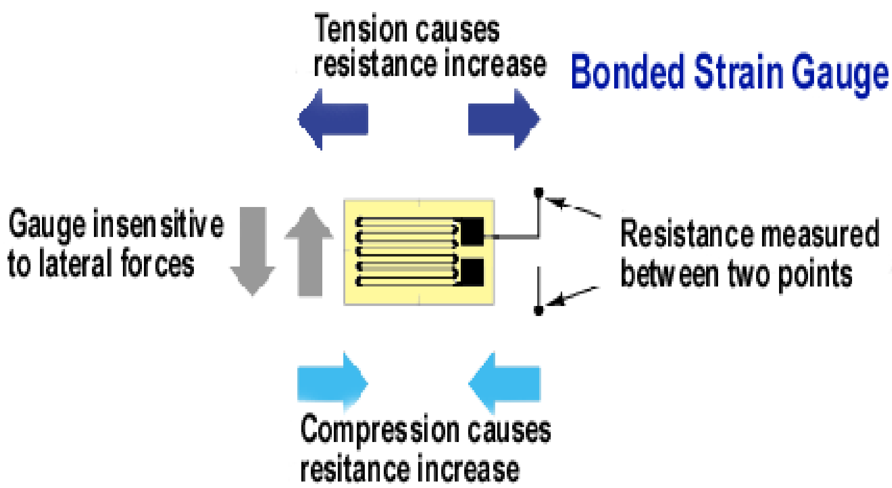


Fig 3.7 Strain gauge description

To select a strain gauge one has to go through many types of strain gauges:

- Optical Strain gauges
- Vibrating wire type gauges
- Pneumatic Strain gauges
- Electrical Resistance Strain gauge
    - Photoelectric gauges
    - Thin-film
    - Metallic foil-type

Also following factors are needed to be considered before choosing a strain gauge

- Operational Factors
- Temperature
- Nature of the strain to be detected
- Stability requirements
- Cost

Finally the slected strain gauge for this research work was Metallic Foil Type Linear Strain Gauge of specification ***ECH-350-6AA-(16)-O-SP.***

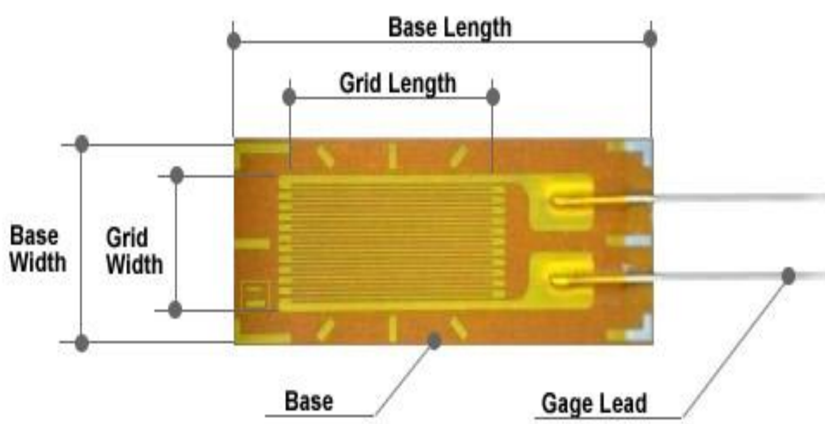


Fig 3.8 Foil type strain gauge

3.8 Determination of Strain Sensitive Points

As it is obvious from Young's Modulus of Elasticity that stress *is directly proportional to strain*. So the stress sensitive points are also the strain sensitive points for determination strain gauges installation locations.

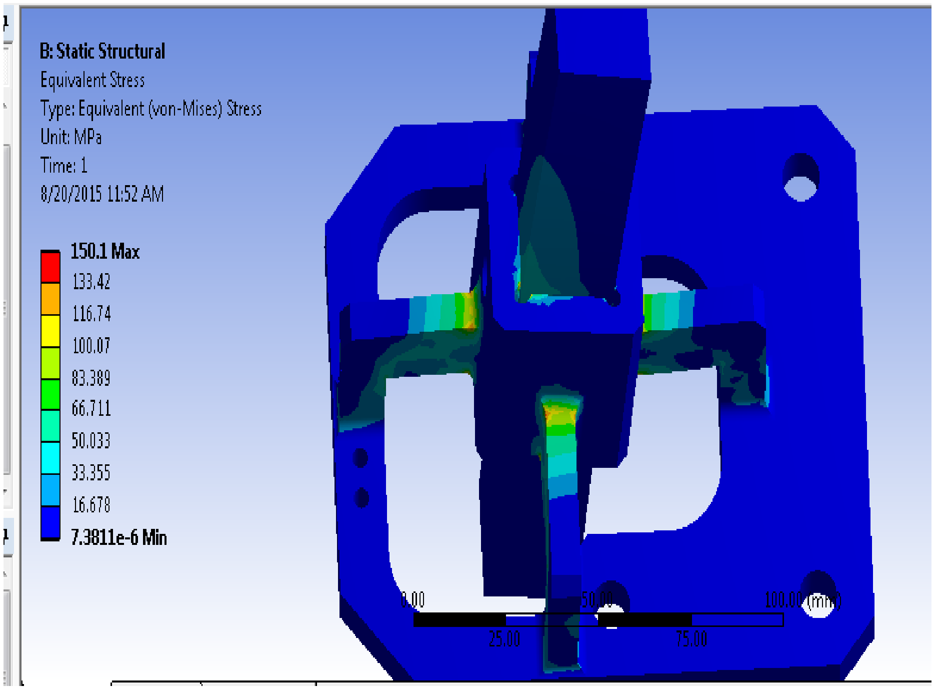


Fig.1.1 Analysis results in ANSYS for strain sensitive points.

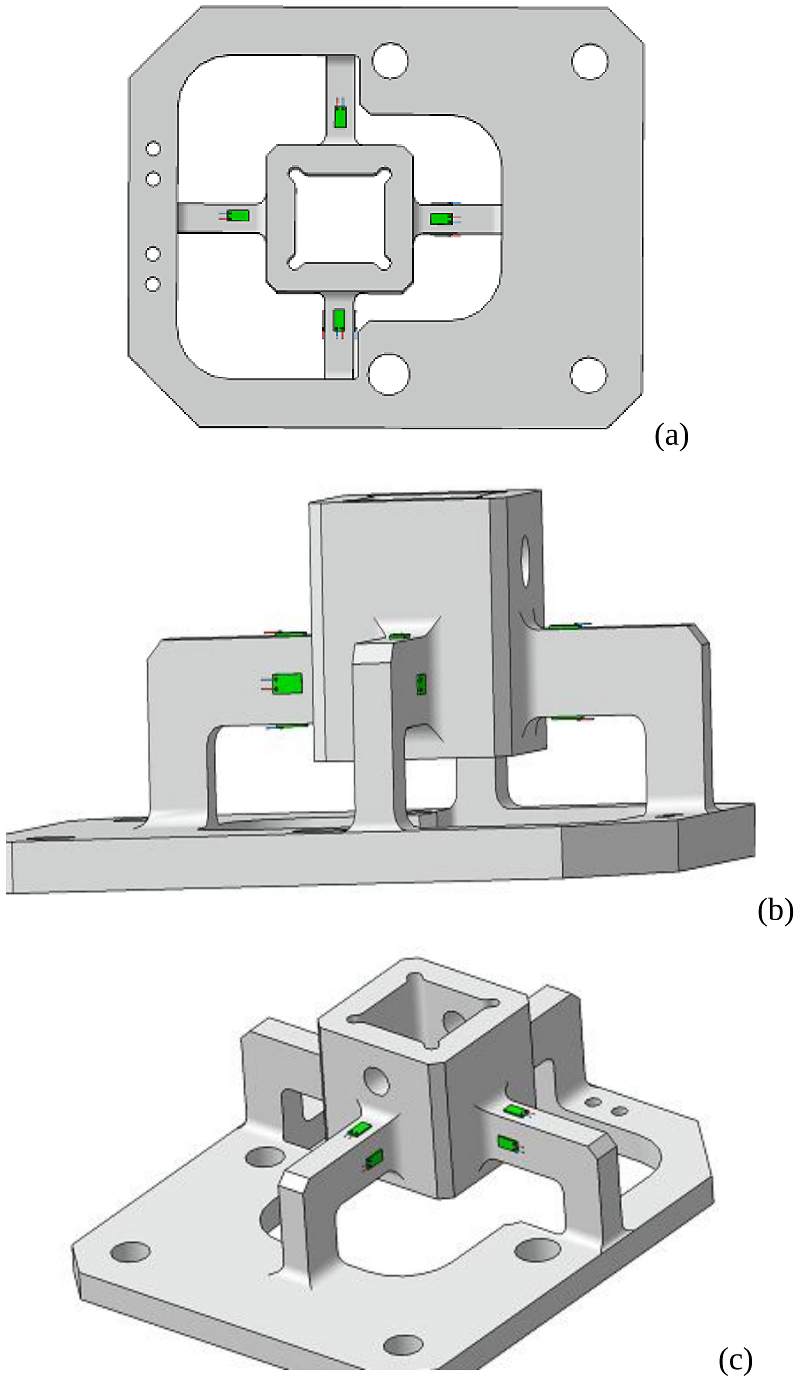


Fig 3.10 a, b and c model for strain gauge installation location

3.9 Validation of Model and Drawings Generation

The modeled dynamometer was then reviewed for manufacture-ability and assembly and then the drawings were generated.

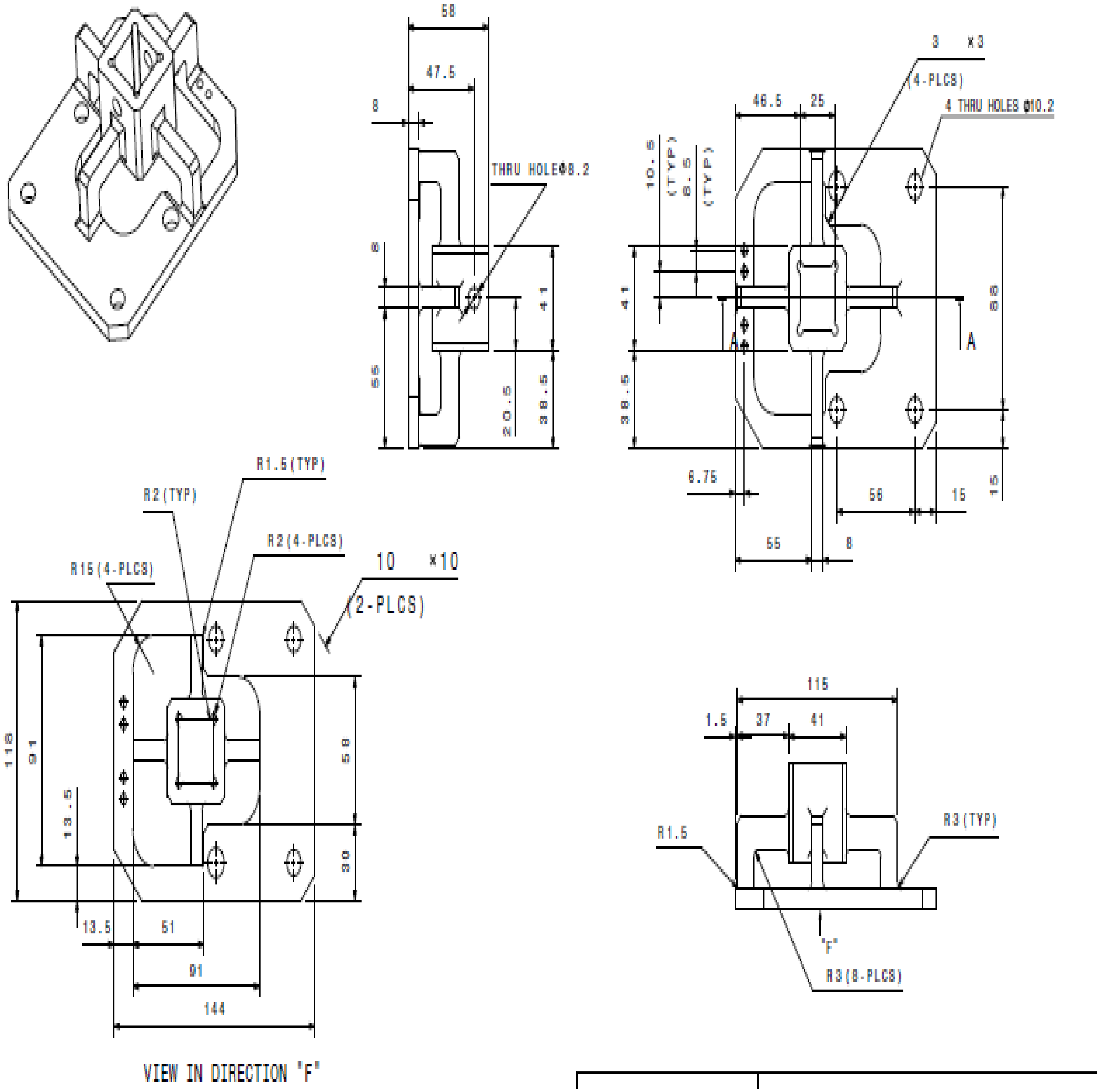


Fig 3.11 Drawing of modeled dynamometer for manufacturing

3.10 Construction of Dynamometer

During construction dynamometer has been processed various manufacturing processes which include:

- Milling
- Shaping
- Facing
- Drilling
- Boring
- Grinding
- Electric wire cutting

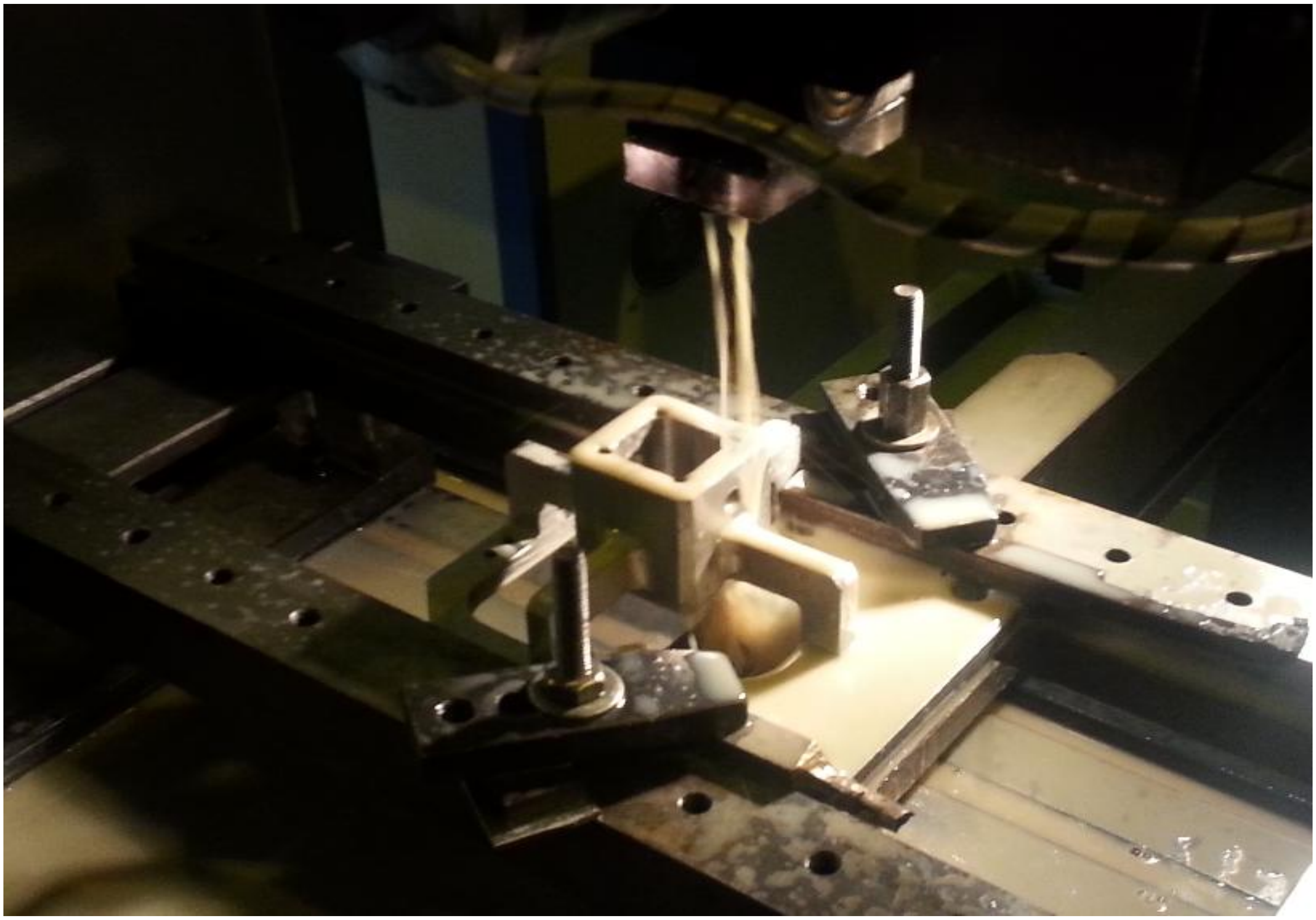


Fig 3.12 Electric wire cutting of dynamometer

3.11 **Installation of Strain Gauges**

Requirements for strain gauges installation are:

- Strain Gauges
- Elastic element (metal surface)
- Degreaser (GC-6 Isopropyl Alcohol)
- M-Prep Neutralizer 5A
- M-Prep Conditioner A
- M Bond-200
- Silicon-Carbide Paper
- Cotton Applicators
- Pressure Pads
- Gauze Sponges

Steps in strain gauges installation are:

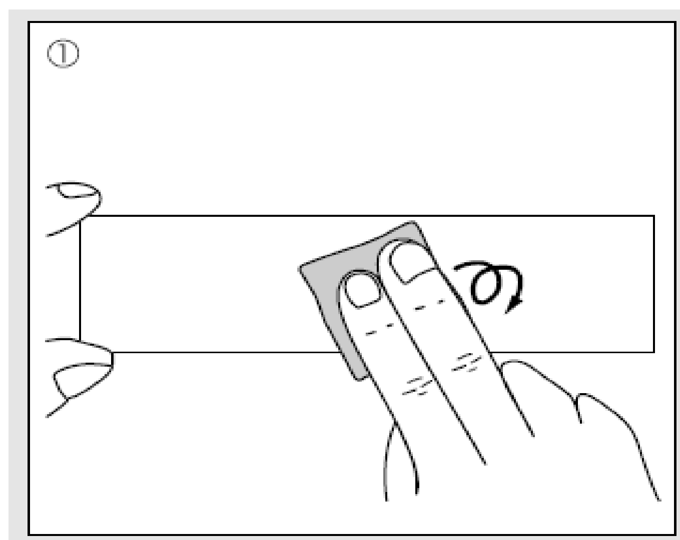


Fig.3.13 Degreasing metal surface

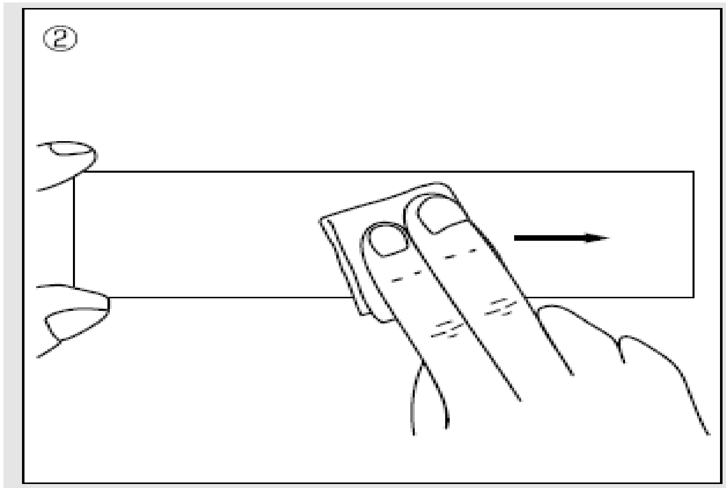


Fig.3.14 Cleaning metal surface

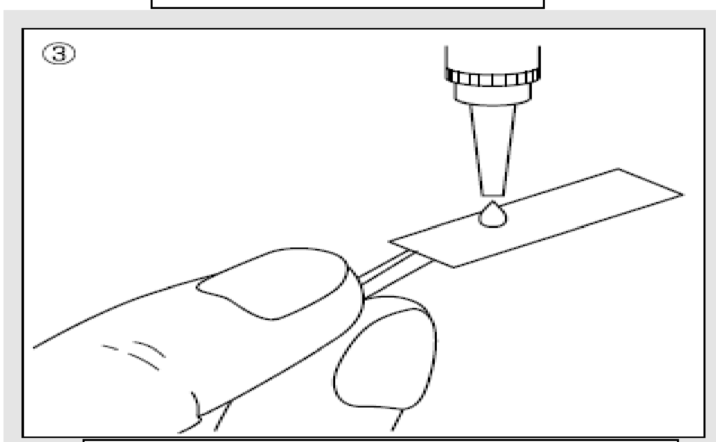


Fig 3.15 Applying adhesive on strain gauge

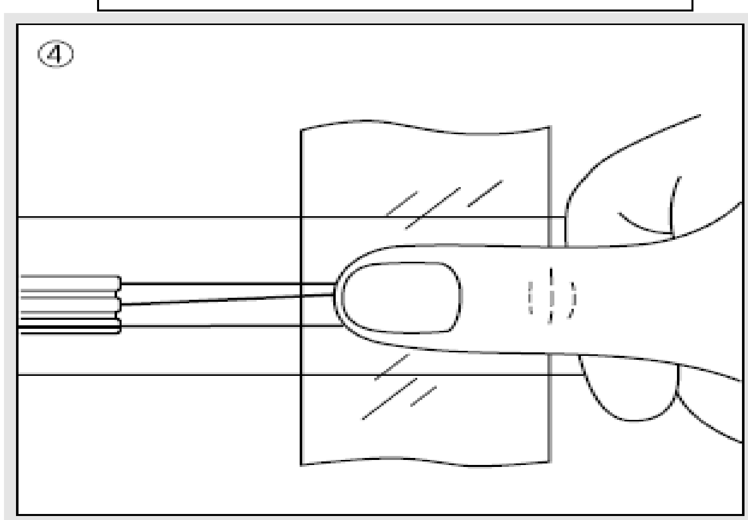


Fig 3.16 Bonding on metal surface

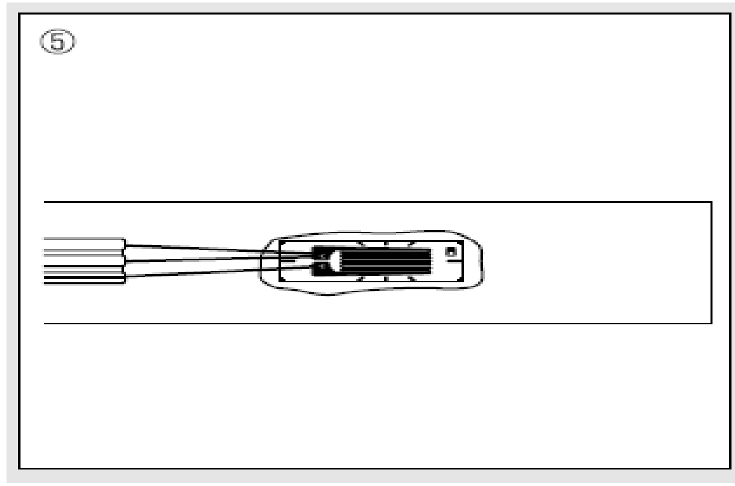


Fig 3.17 Curing

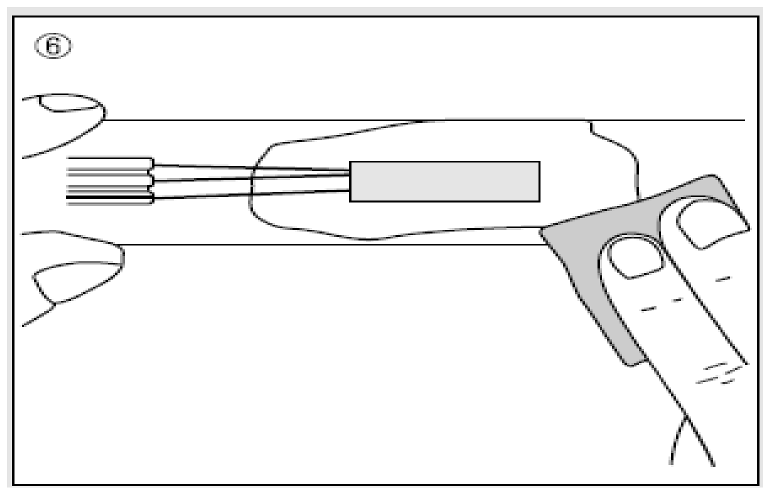


Fig.3.18 Removing protruding adhesive.

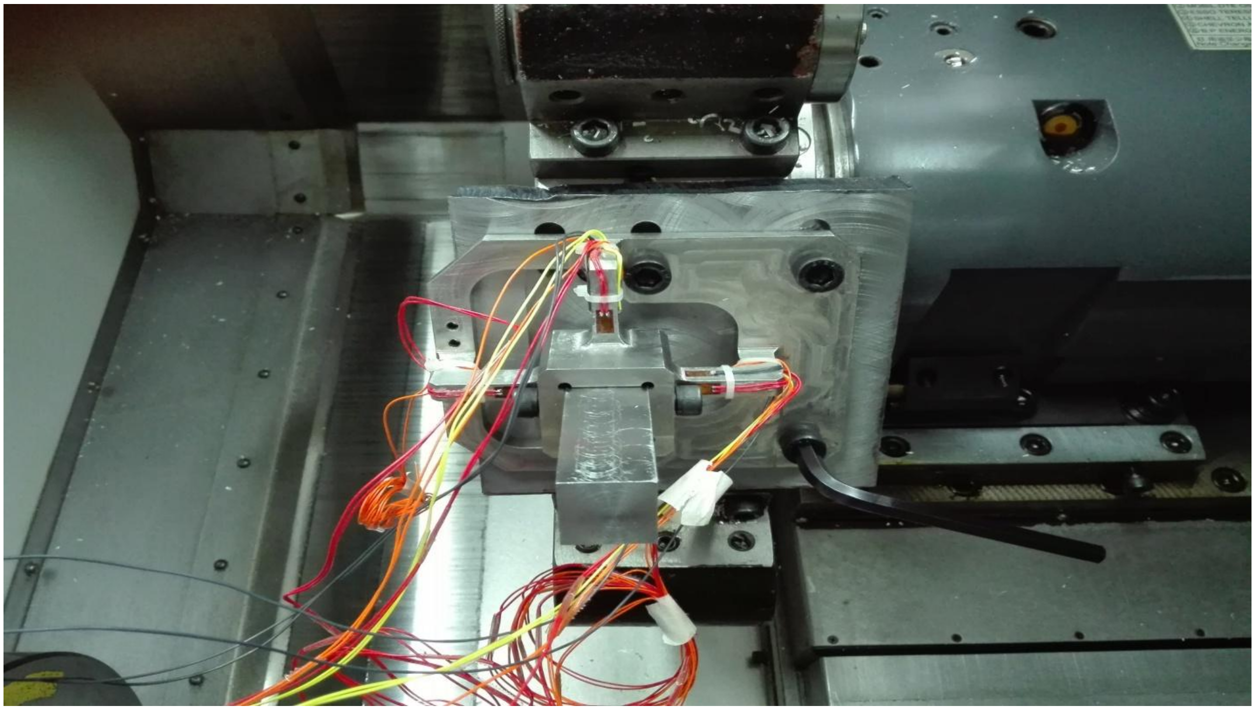


Fig 3.19Fabricated dynamometer with installed strain gauges

CHAPTER 4
DATA ACQUISITION AND CALIBRATION

In the previous chapter construction of dynamometer has been discussed now it is needed to interface it with data acquisitioning system.

4.1 Data Acquisitioning System

DAQ (Data Acquisition) system requirements are:

- DAQ Card (NI DAQ-9219)
- DAQ Chassis (NI cDAQ-9174)
- Power Cables
- Data Cable
- Laptop / PC
- LabView Software installed on Laptop / PC
- DAQ Drivers
- LabView Device drivers
- Flexible Teflon wires connected to strain gauges.

4.2 DAQ Set Up

NI-cDAQ-9174

It is a chassis whose purpose is to provide mixed data, formed by combining sensors input strain signal and voltage, through USB data cable to PC.

Fig 4.1 DAQ Chassis (NI cDAQ-9174)

NI DAQ-9219:

It is a 4-channel, 24-Bit, Universal Analogue Input Module. It acquires the strain variation form strain gauges and provides it to the chassis in the form of analogue signals.

Requirements:

Operating system:

Windows 7.

Drivers used:

NIDAQ1501f3Runtime

Readable software: Lab-View,

Fig 4.2 DAQ Card (NI DAQ-9219)

4.3 Determination of corresponding terminals:

The below mentioned DAQ card (NI DAQ-9219) consists of four channels each containing six spring terminals.

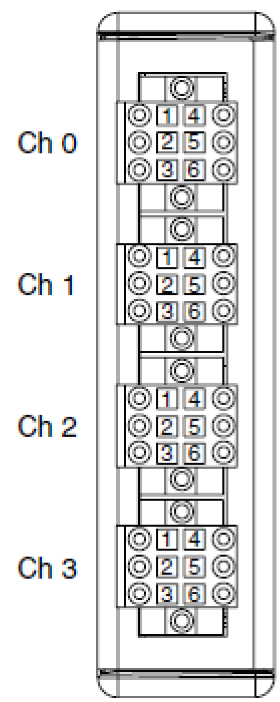


Fig 4.3 NI 9219 Channel and Terminal Assignments

Mode	Terminal					
	1	2	3	4	5	6
Half-Bridge	T+	T–	EX+	HI	EX-	-
Full-Bridge	T+	T–	EX+	HI	EX-	LO

Table 4.1 NI 9219 Terminal Assignments for bridge.

Wires connection making to the spring terminals of DAQ card:

This can be done by using a pin pointed like needle but not easily deformable or via screw driver from watch-maker box collection. Pin was inserted in square cavity and pressed so that the spring opens the round hole for wire. Then wire was inserted and pin was taken out as it automatically locks as soon as the pin is taken out.

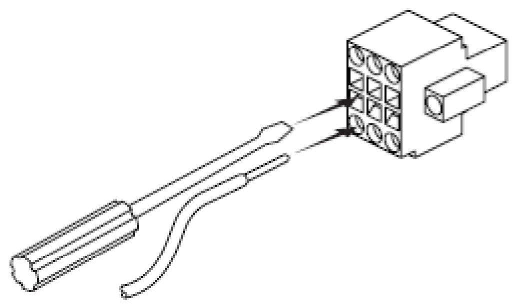


Fig 4.4 Wires connection making to the spring terminals of DAQ card

4.4 Making Full or Half Bridge

To make a Half or Full Bridge in DAQ card according to the Wheat Stone Bridge as can be seen in Fig. 4.5. Hidden line format shown in the Fig 4.5 will be used to make a half-bridge. To make the necessary bridge connection for the dynamometer for this research one has to go through the below described procedure.

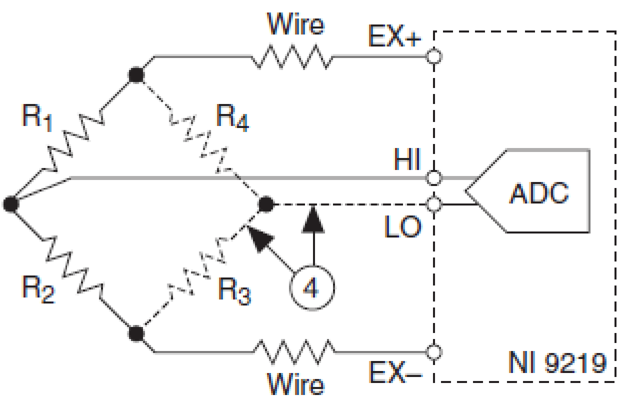


Fig 4.5 Wheat stone bridge connections

In this study, each strain gauge that is mounted on every single arm of dynamometer has two wires of unique colour soldered at its pads. For a single arm with four strain gauges have four colours of wires. A strain gauge with wires of red colour is R1 in above mentioned Full-Bridge, one with yellow colour wires is R4, R2 is one with orange colour wires and R3 is the strain gauge with black colour wires.

Now to make a Full-Bridge connection, a red wire is connected to a yellow wire and inserted in terminal 3 of channel 0 of NI DAQ-9219. Similarly, a red and orange wire connection is inserted at terminal 4, orange and black wire connection at terminal 5, finally a yellow and black wire connection at terminal 6.

4.5 Procedure for Interfacing DAQ

Firstly, LabVIEW 2011 software has been installed in PC. Afterwards, the DAQ card NI DAQ-9219 has been mounted on the DAQ chassis NI cDAQ-9174. Power was supplied through power cable to DAQ chassis and data cable was connected to PC. It was observed that PC was unable to recognize the device this is because the drivers NI-DAQmx were needed to interface the DAQ with PC. For NI cDA-9174 supporting drivers file "NIDAQ1501f3Runtime" was installed and PC detected the device. After this, NI MAX module of LabView has been opened to test the device. At the left top corner below "Data Neighborhood" option of "Devices and Interfaces" should appear but it was not so. The reason was "LabVIEW 2011 Device Drivers" to interface the LabVIEW with the DAQ chassis. So after installation of LabVIEW 2011 Device Drivers set up file, NI cDAQ-9174 and NI DAQ-92 in the Devices and Interfaces option. At this stage, device was tested by using option "self test" and it passed the self test.

4.6 Calibration Set Up

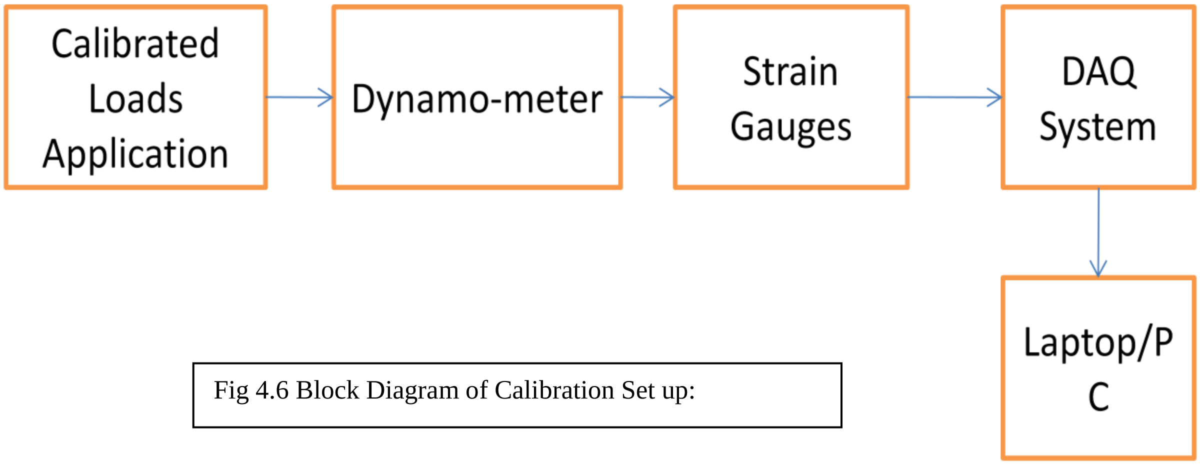


Fig 4.6 Block Diagram of Calibration Set up:

Before proceeding to calibrate the dynamometer, a calibration jig was needed to properly assemble the device and apply loads. For this purpose, a fixture plate and a dummy tool shank was designed and constructed. Fixture plate was mounted on the turret such that the dynamometer cutting force arm and feed force arm can be aligned parallel to force of gravity and then the weights of known value are placed in the pain and change in voltage was noticed on PC by LabVIEW.

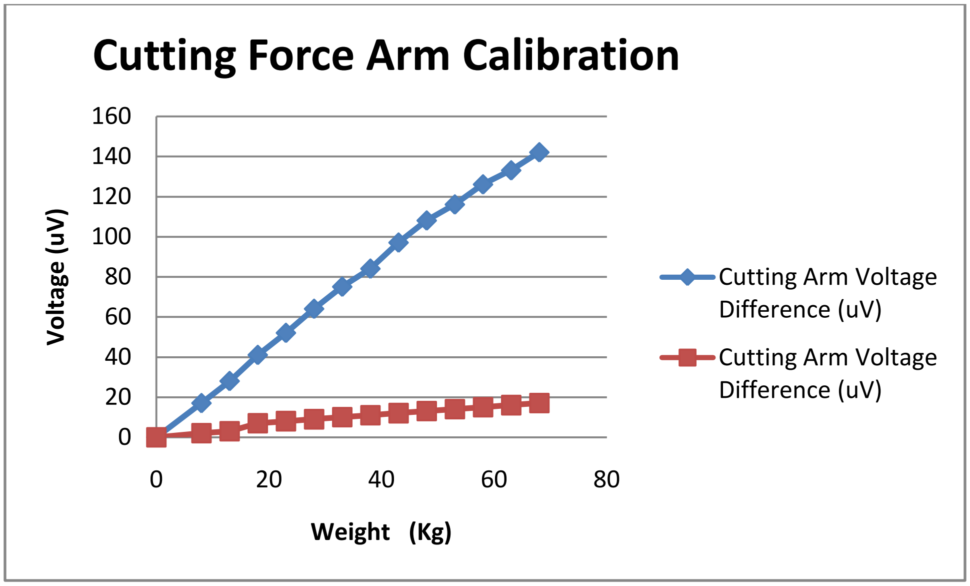


Fig 4.7 Cutting Force arm calibration graph

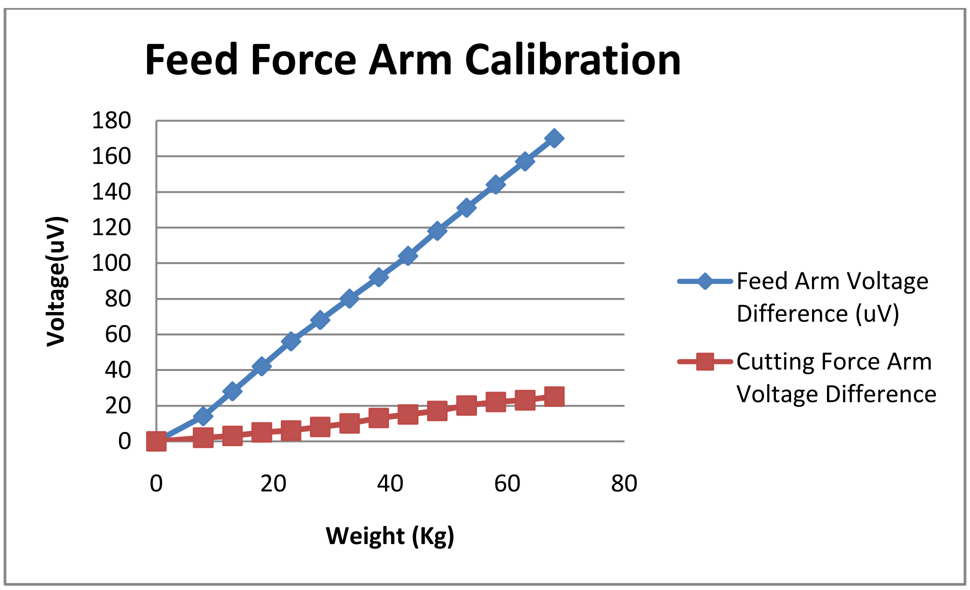


Fig 4.8 Feed Force arm calibration graph

Calibration Factor: From Figs 4.7 and 4.8, calibration factors were calculated which are as follows:

Calibration factor for *cutting force* is:

1uV = 4.5454N

Calibration factor for *feed force:*

1uV = 20N

CHAPTER 5
RESULTS AND CONCLUSIONS

5.1 Results

To perform experimentation DOE (Design of Experiments) was carried out for Aluminum 6061-T6 from which following parameters are obtained to plot cutting forces and analyze the results.

Trial #	Insert		OD	ID	Speed (meter/min)	Feed (millimeter/rev)	Spindle N (RPM)	Theoretical Time (Sec)
	#	Side						
1			113.2	105	300	0.06	843	3.6
2			113.2	105	300	0.09	843	2.4
3			113.2	105	300	0.12	843	3.0
4			113.2	105	300	0.15	843	2.4
5			113.2	105	500	0.06	1405	3.6
6			113.2	105	500	0.09	1405	3.3
7			113.2	105	500	0.12	1405	3.2
8			113.2	105.15	500	0.15	1405	3.1
9			113.2	105.15	700	0.06	1968	10.2
10			113.2	105.15	700	0.09	1968	6.8
11			113.2	105	700	0.12	1968	2.5
12			113.2	105	700	0.15	1968	2.0
13			113.2	105	900	0.06	2530	7.9
14			113.2	105	900	0.09	2530	5.3
15			113.2	105.05	900	0.12	2530	5.5
16			113.2	105.05	500	0.15	1405	8.0

Table 5.1 Parameters for Design of Experiments.

5.2 First Experiment

First experiment was performed for parameters mentioned against "**Trial 1**" of DOE table 5.1. The results obtained are discussed below.

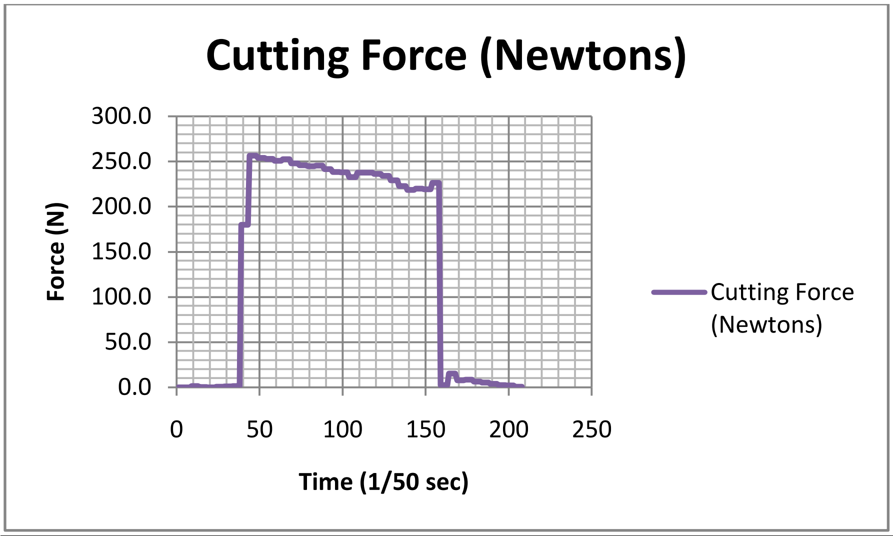


Fig 5.1 Cutting force for 1st experiment

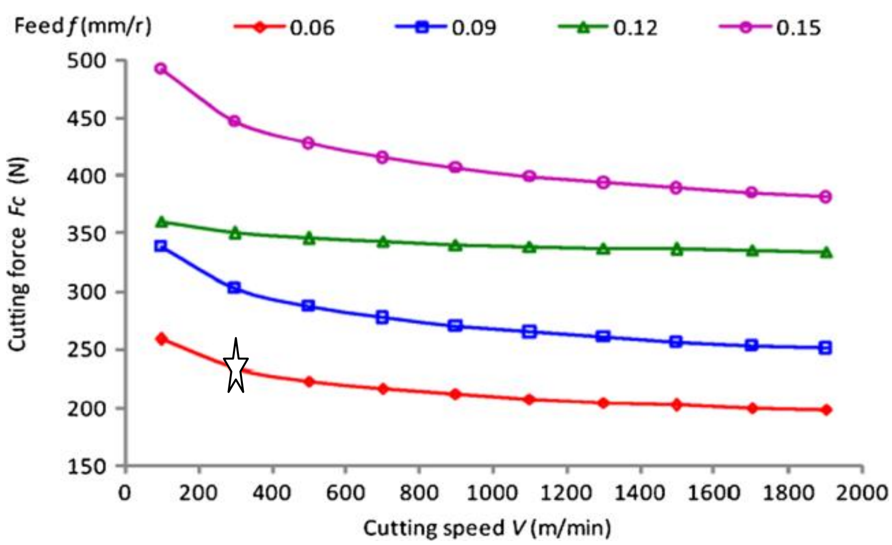


Fig 5.2 Cutting force from literature [27]

Comparison:

Mean Cutting force value obtained in this study = 230 N

Cutting force value from literature [27] = 235 N

Discussion: Difference between both values is around 5 N.

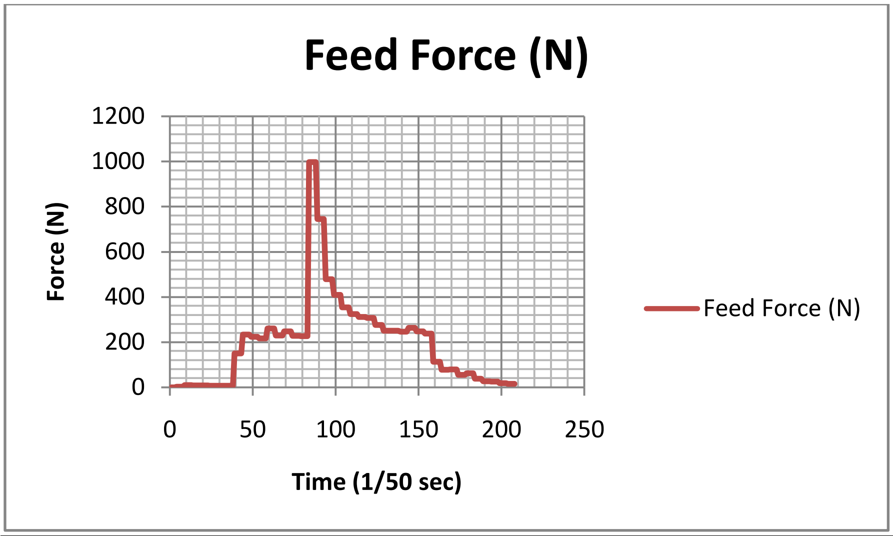


Fig 5.3 Feed force from 1st experiment

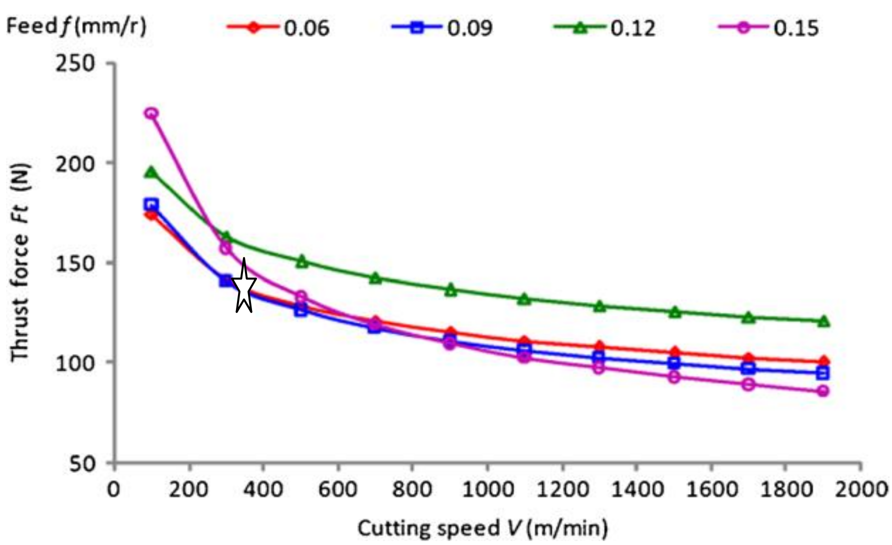


Fig 5.4 Feed force from literature [27]

Comparison:

Mean Feed force value obtained in this experiment = 202 N

Feed force value from literature [27] = 140 N

Discussion: Difference between both values is around 62 N. This huge difference is because of improper connection of a strain gauge so it was re-calibrated.

Second Experiment

Second experiment was performed for parameters mentioned against "**Trial 4**" of DOE table 5.1. The results obtained are discussed below.

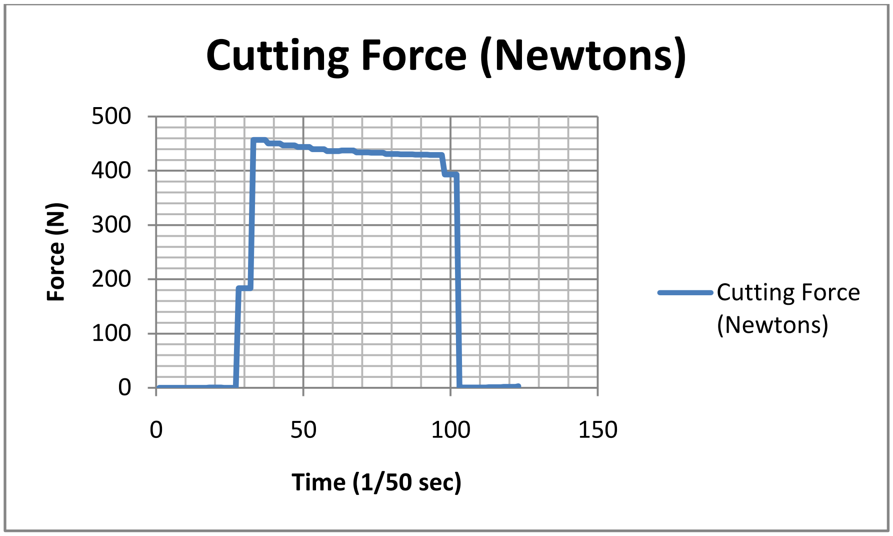


Fig 5.5 Cutting force for 2nd experiment

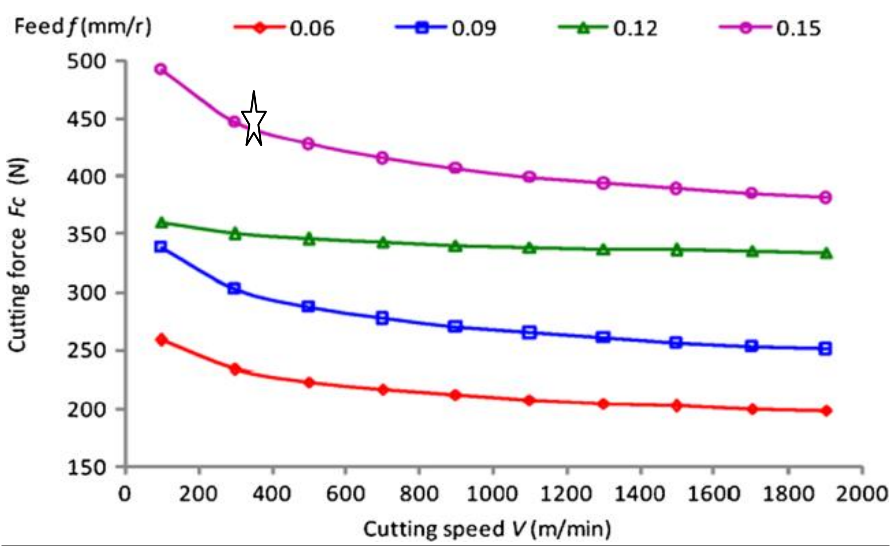


Fig 5.6 Cutting force from literature [27]

Comparison:

Mean Cutting force value obtained in this experiment = 440 N

Cutting force value from literature [27] = 430 N

Discussion: Difference between both values is around 10 N.

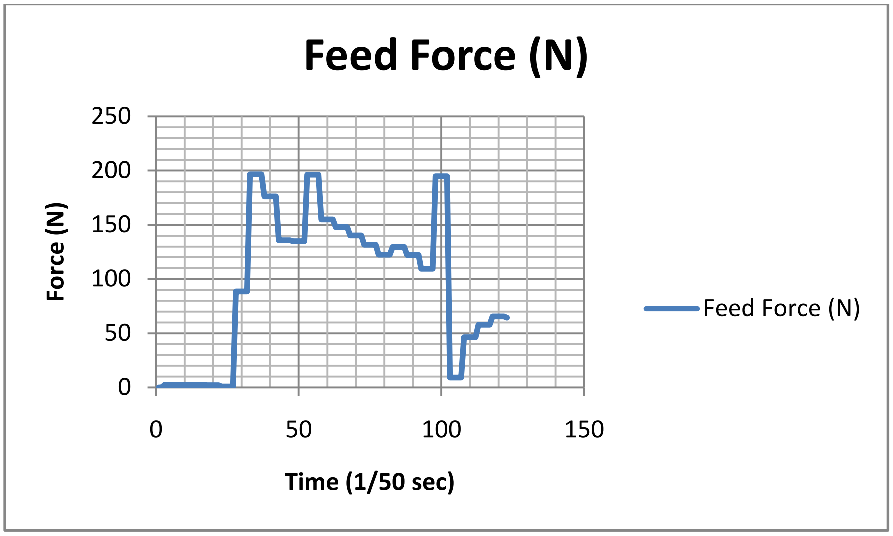


Fig 5.7 Feed force for 1st experiment

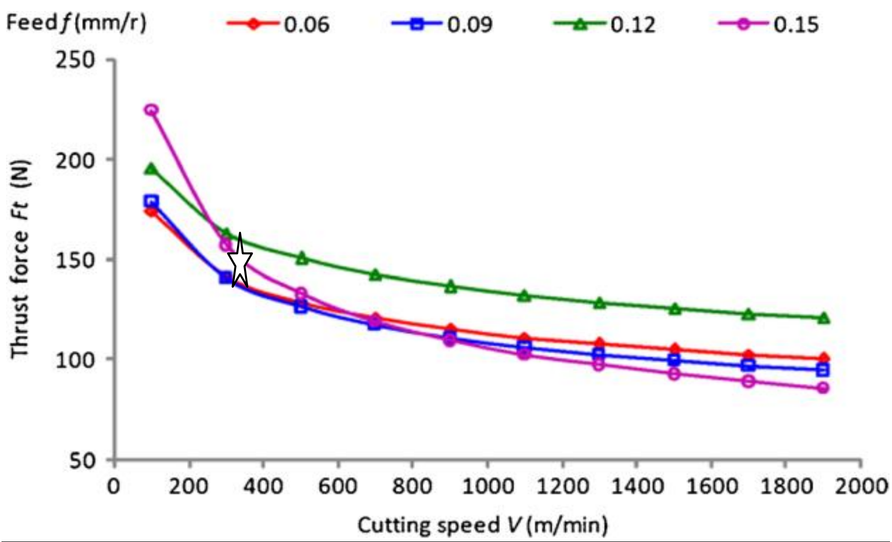


Fig 5.8 Feed force from literature [27]

Comparison:

Mean Feed force value obtained in this experiment = 150 N

Feed force value from literature [27] = 140 N

Discussion: Difference between both values is around 10 N

5.3 Third Experiment

Third experiment was performed for parameters mentioned against "**Trial 10"** of DOE table 5.1. The results obtained are discussed below.

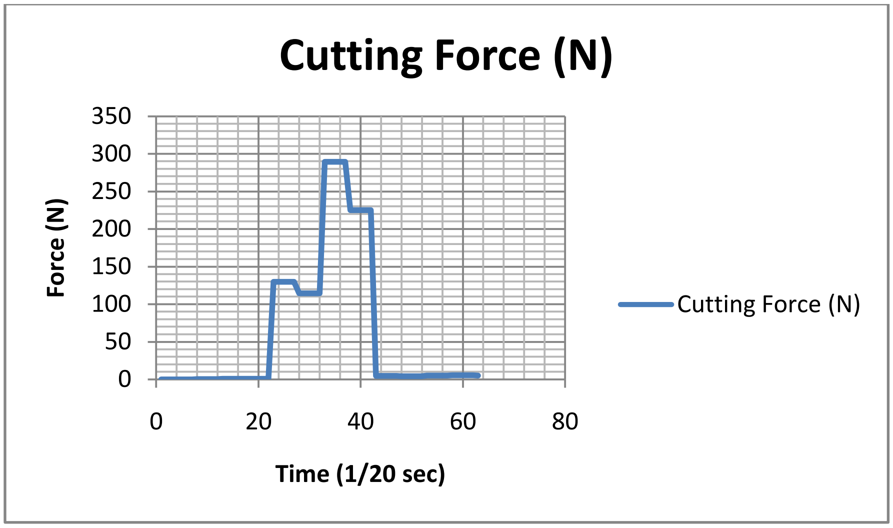


Fig 5.9 Cutting Force for 3rd experiment.

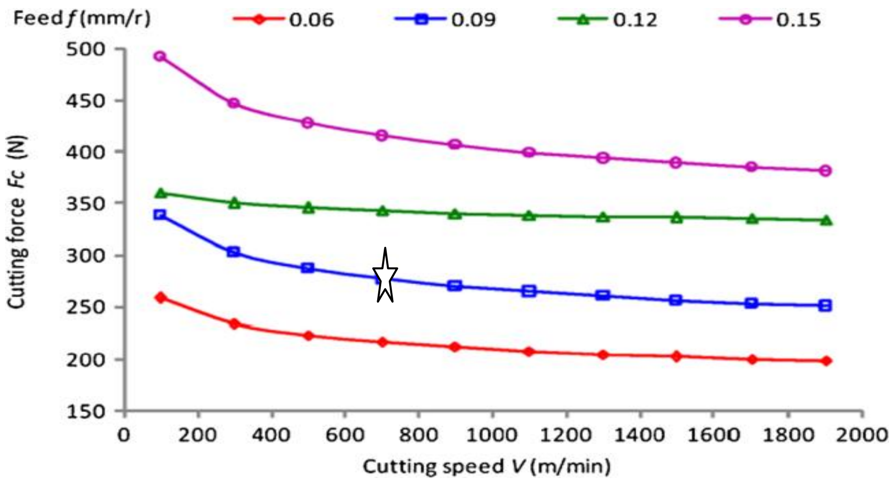


Fig 5.10 Cutting force
from literature [27]

Comparison:

Mean Cutting force value obtained in this experiment= 270 N

Cutting force value from literature [27] = 240 N

Discussion: Difference between both values is around 10 N.

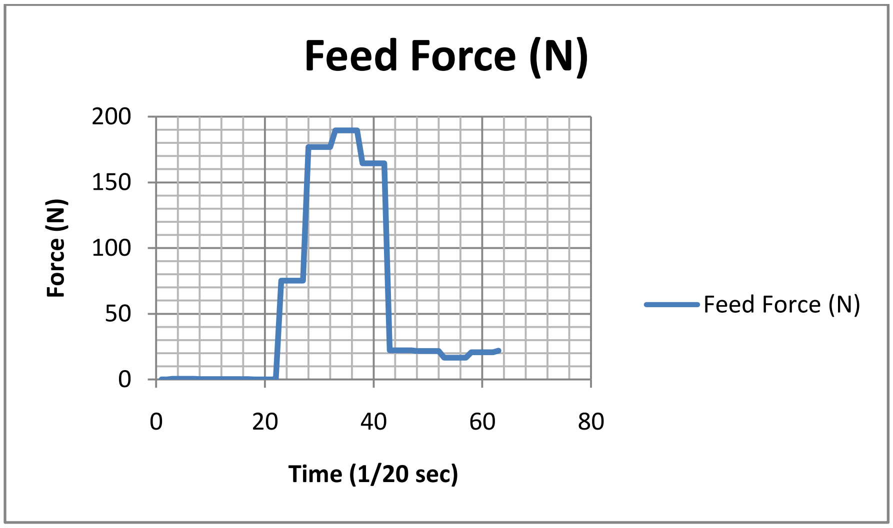


Fig 5.11 Feed force from 3rd experiment

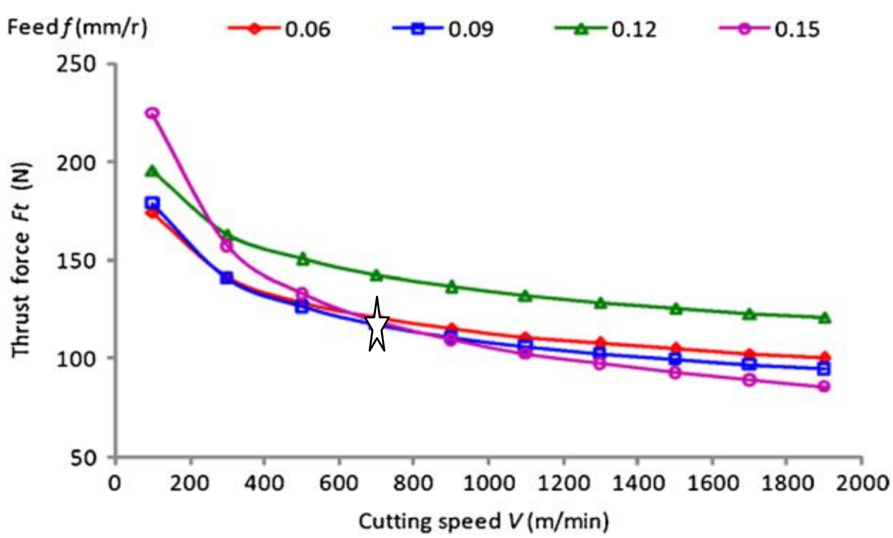


Fig 5.12 Feed force from literature [27]

Comparison:

Mean Feed force value obtained in this experiment = 130 N

Cutting force value from literature [27] = 120 N

Discussion: Difference between both values is around 10 N.

5.4 Experimental Set Up

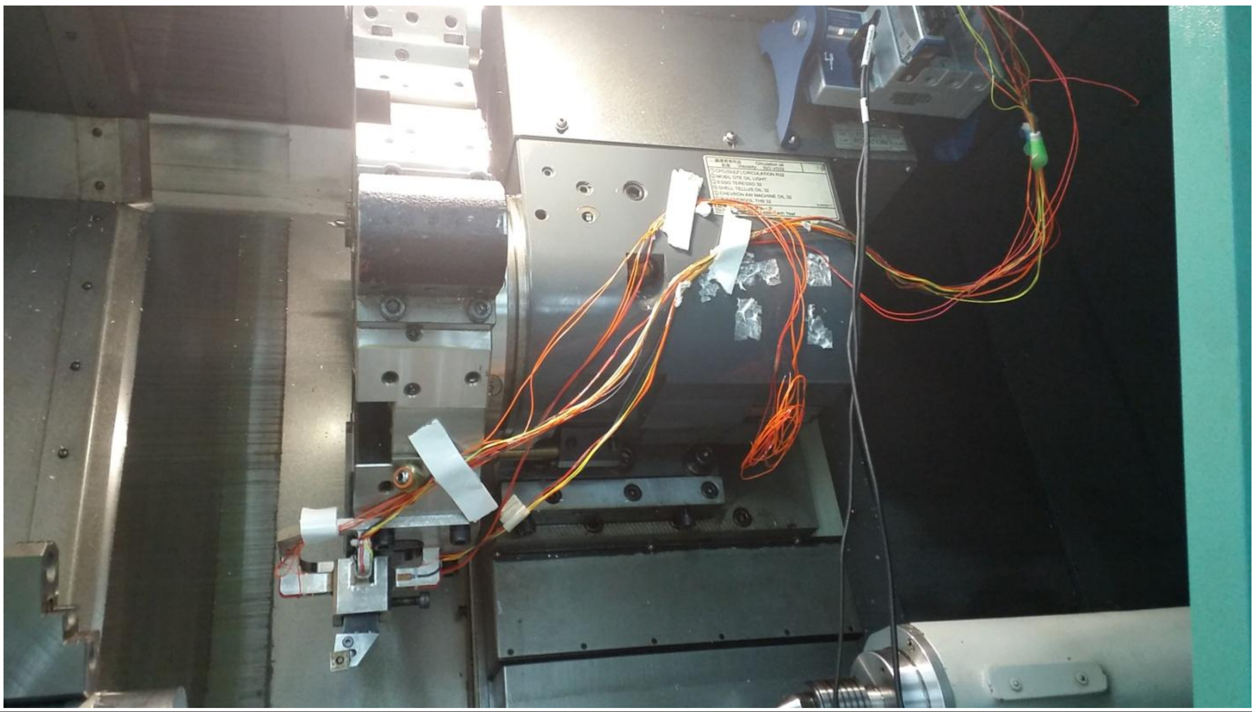


Fig 5.13 DAQ, dynamometer and machine interfacing

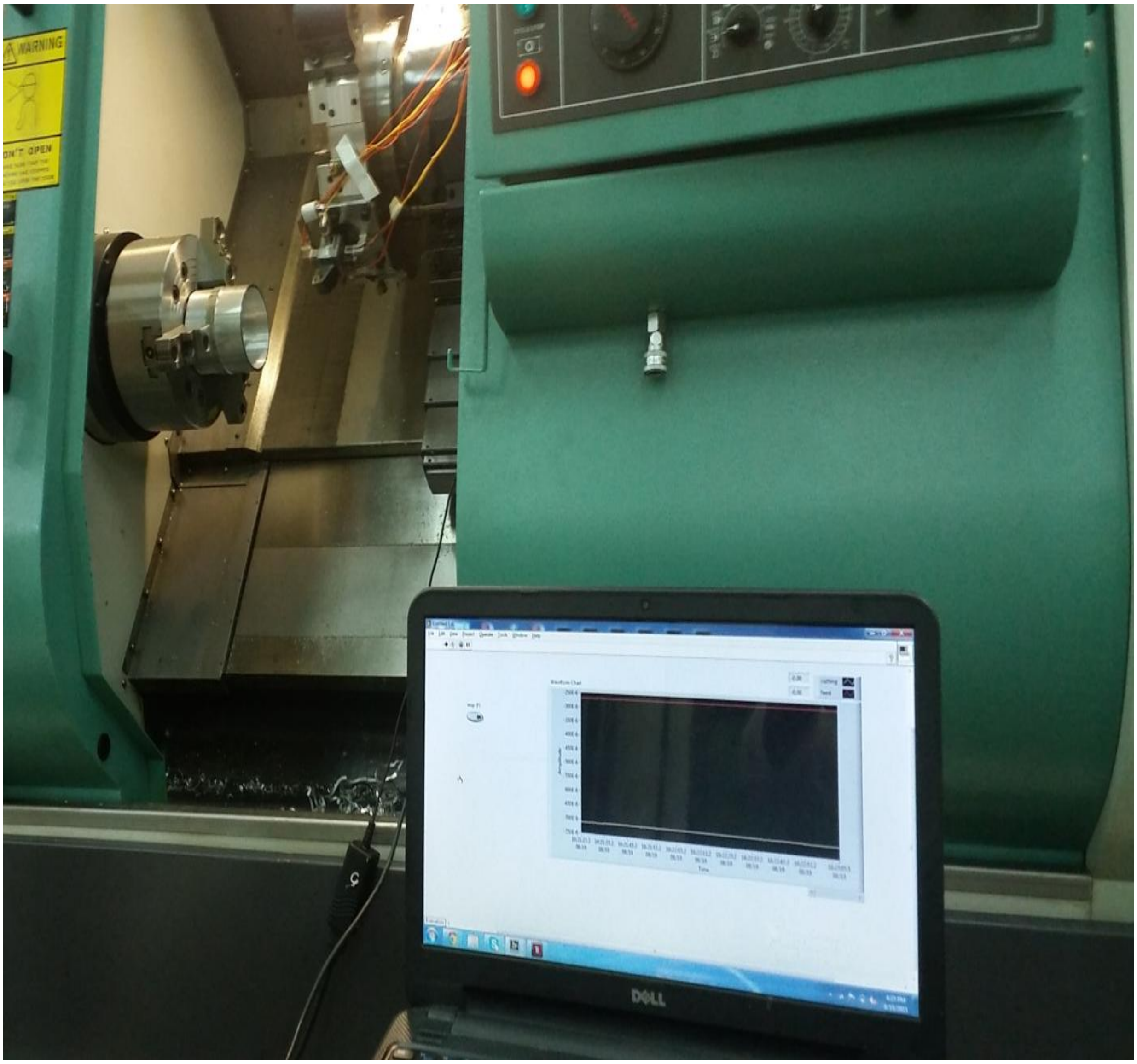


Fig 5.14 PC and DAQ Interfacing

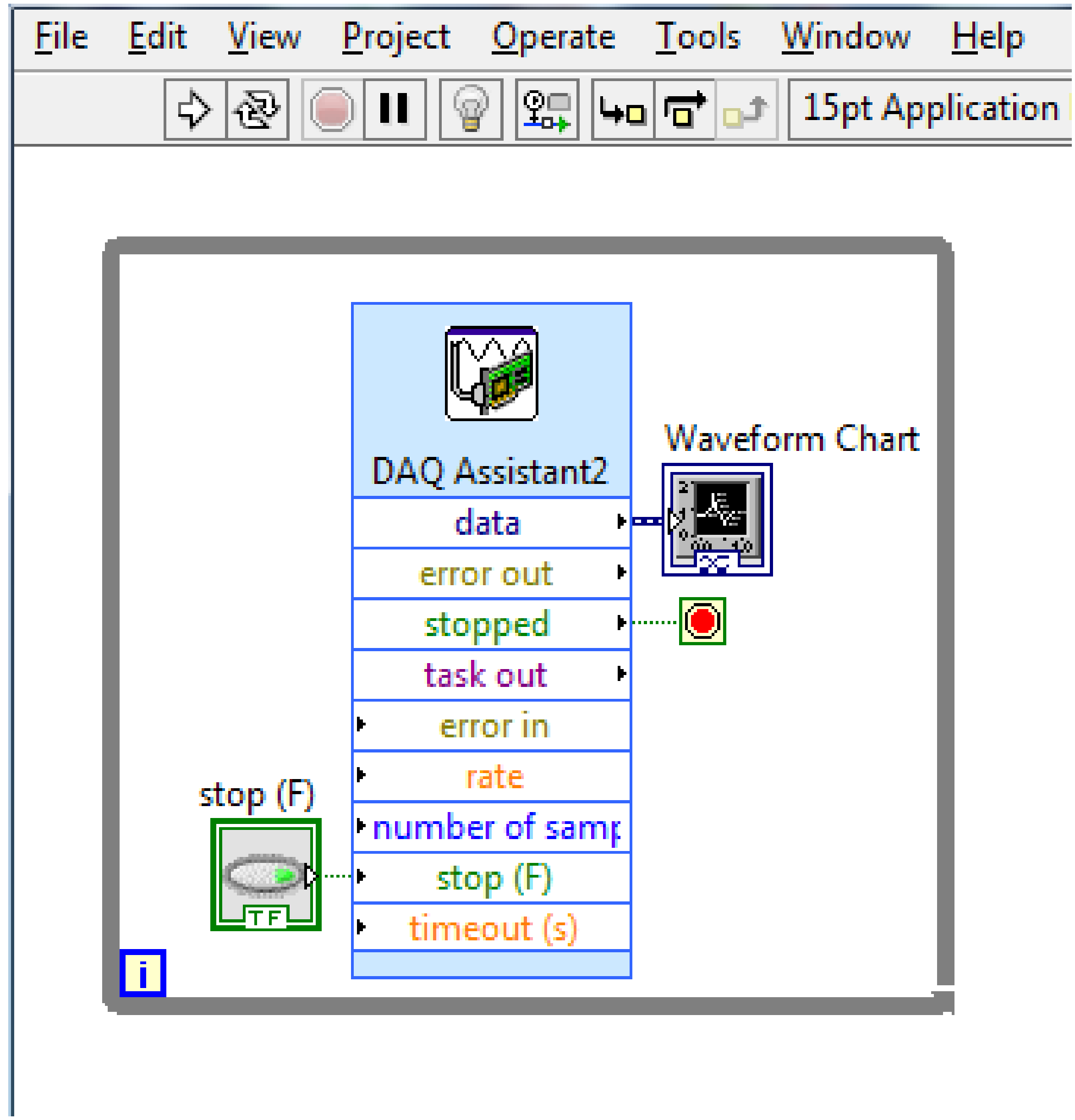


Fig 5.15 Program in LabVIEW for data acquisition

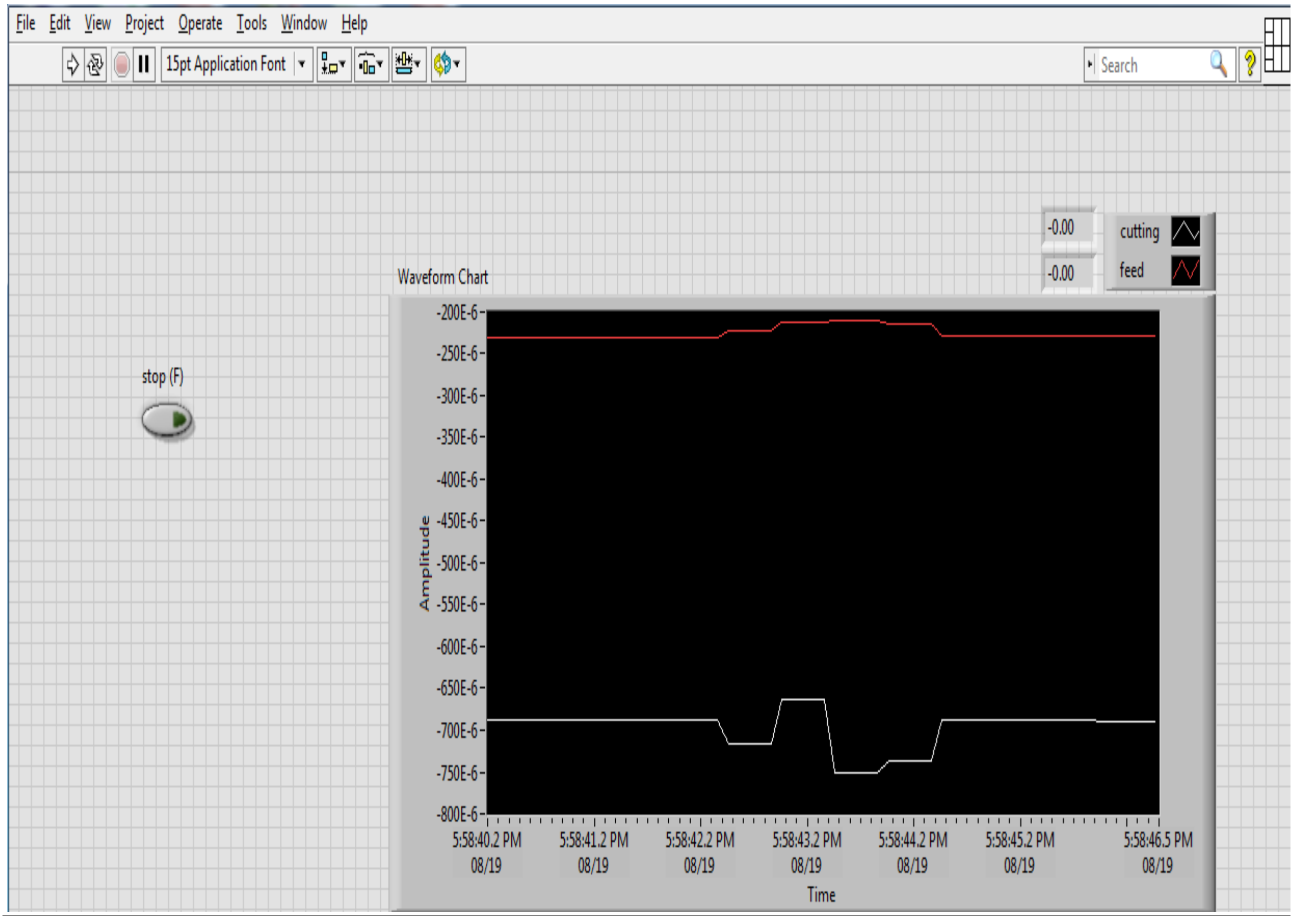


Fig 5.16 Acquired cutting force component and feed force component values in LabVIEW during turning.

5.5 Conclusions

Through this project an attempt is being made to design, develop, calibrate and experimentally test a dynamometer, with strain gauges as sensors mounted, for measuring cutting forces generated during orthogonal turning of metallic parts. The constructed device is experimentally tested against experimental results acquired via highly reliable commercial dynamometer by comparing forces results for cutting of Aluminum 6061-T6. Obtained results proved the excellent characteristics of the designed device and its effectiveness for investigating advanced machining applications. This device can be used to measure machining force components such as cutting force and feed force simultaneously in orthogonal turning with maximum value or single force component of 1000N to a variation of about 10N. DAQ System consisting of DAQ card, DAQ chassis and PC with LabVIEW software installed was interfaced with strain signals from strain gauges to acquire and store runtime force component values of calibration and machining. Beam type elastic element was designed and strain gauges installation points were determined to obtain strain with minimum cross sensitivity and the results have proved this. These results are also proved only the static calibration if carried out carefully can be very effective for determinations of dynamic loads.

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