# "Real Time Measurement of Axial Cutting Forces of Lathe Machine Using ARM7 Microcontroller"

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## ABSTRACT

*The purpose of this paper is to study the effect of cutting parameters on cutting force (Fc) & feed force in turning Process. In machining process, phenomena that can be measured such as cutting force, vibration, acoustic emission, torque, surface finish, sound etc. commonly occurred. Cutting force is very important because it relates to the design of tools, power consumption, vibration, machine design parts, precision parts, and etc. Cutting is a process of extensive stresses and plastic deformations. The high compressive and frictional contact stresses on the tool face result in a substantial cutting force F. Cutting forces are the background for the evaluation of the necessary power in machining (choice of the electric motor). They are also used for dimensioning of machine tool components and the tool body. The direct approach to study cutting forces in machining is very expensive and time consuming, especially when a wide range of parameters is included: tool geometry, materials, cutting conditions, etc. In this study, a lathe tool dynamometer that can measure cutting force, feed force and also thrust/Axial force by using strain gauge accelerometer has been Studied and used. The dynamometer used in this project is a 500kg force 3-component system. The dynamometer is connected to a data acquisition system. As the tool comes in contact with the work piece the various forces developed are captured and transformed into numerical form system. Cutting force signals were captured, amplified, conditioned, converted to digital signals and read by a microprocessor. The corresponding force readings thus obtained after a series of tests and calculations are displayed on a standard LCD.*

**Keyword: -**   *Conversion, Signal Conditioning Embedded system, Microcontrollers, Plotting graphs.*

## 1. Introduction:

The metal cutting process is extensively used in many manufacturing industries such as automobile, aerospace and household items. The metal cutting process carried out by a relative motion between work piece and edge of the cutting tool. This operation performed either by a single point cutting tool or multi point cutting tool. Three types of cutting forces such as tangential, radial and thrust generates during operation [1].To measure cutting forces accurately strain gauge based dynamometer is used .The voltage signals in the analog form is to be amplified and converted into digital form. These obtained values displayed on LCD and real time graph of forces are to be plot on MATLAB. This whole system is based on ARM7 Microcontroller [2].
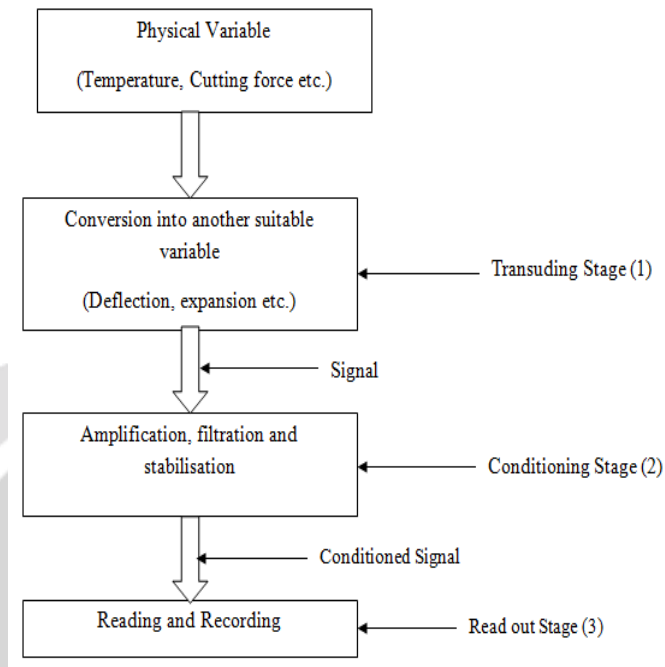
## 2. General principle of measurement:

The existence of some physical variables like force, temperature etc. and its magnitude or strength cannot be detected or quantified directly but can be so through their effect only. The amount of effects like elastic deflection, deformation, pressure, strains etc. These effects, called signals, often need proper conditioning for easy, accurate and reliable detection and measurement. The basic principle and general method of measurement is schematically shown in Figure 2.1. The measurement process is comprised of three stages:

**Stage 1:** The target physical variable is converted proportionally into another suitable variable called signal, by using appropriate sensor or transducer.

**Stage 2:** The feeble and noisy signal is amplified, filtered, rectified (if necessary) and stabilized for convenience and accuracy of measurement.

**Stage 3:** where the conditioned signal (say voltage) is quantitatively determined and recorded by using some read out unit like galvanometer, oscilloscope and recorder.
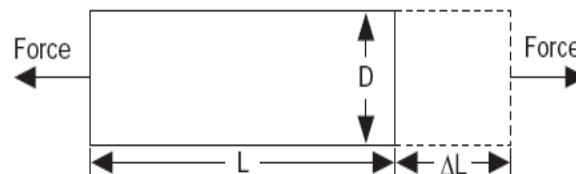


**Figure 2.1: General principle of measurement.**

### 2.1 Strain Gauge and signal conditioning:

Strain is the amount of deformation of a body due to an applied force. Strain can be positive (tensile) or negative (compressive). Although dimensionless, strain is sometimes expressed in units such as in or mm. The magnitude of measured strain is very small. Figure 2.2 shows the general working of strain gauge.

There are several methods of measuring strain. The most common method is a device whose electrical resistance varies in proportion to the amount of strain in the device.

**Principle of Strain Gauges:**

The strain gage is tightly bonded to a measuring object so that the sensing element contract according to the strain borne by the measuring object.



$$\varepsilon = \frac{\Delta L}{L}$$

**Figure 2.2: General working of strain gauge (Courtesy [4]).**

When bearing mechanical elongation or contraction, most metals undergo a change in electric resistance. The strain gauge applies this principle to strain measurement through the resistance change. Generally, the sensing element of the strain gage is made of a copper-nickel alloy foil. The alloy foil has a rate of resistance change proportional to strain with a certain constant. Figure 2.3 shows the structure of strain gauge.

### 2.2 Signal Conditioning:

Signal conditioning circuits are used to process the output signal from sensors of a measurement system to be suitable for the next stage of operation. Operational amplifiers are the basic elements in signal conditioning modules. The functions of the following signal conditioning circuit include the following items:

 1) Signal amplification.
 2) Linearization.
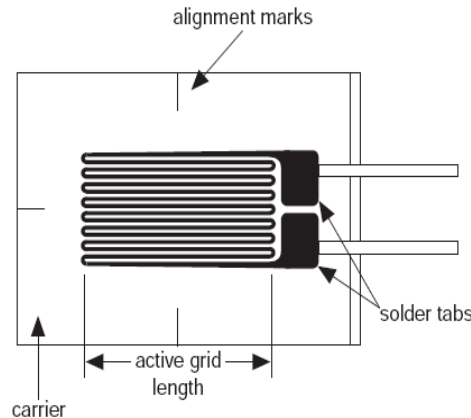 3) Resistance change circuit.
 4) Current to voltage change circuit.



**Figure 2.3: Structure of Strain gauge (Courtesy [4]).**

### 2.2.1 Wheatstone bridge:

Wheatstone bridge is an electric circuit it is used to measure resistance changes of strain gauge. The bridge is configured by a combination of four resistors as shown in Figure 2.4.Whatever the voltage applied to the input, output is zero. Such a bridge is called as balanced bridge. When the bridge loses the balance, it outputs a voltage corresponding to the resistance change.
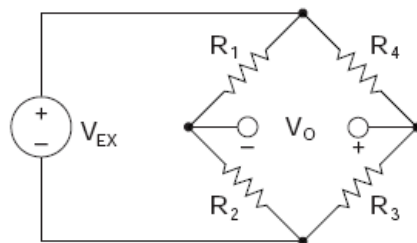


**Figure 2.4: Wheatstone bridge (Courtesy [4]).**

### 2.2.2 Differential amplifier:

Figure 2.5 shows that the differential amplifier. We have used only one of the operational amplifiers inputs connect to the amplifier, using either the inverting or non inverting input terminal to amplify a signal input signal with the other input being connected to ground. But we can also connect signals to both of the inputs at the same time producing another common type of operational amplifier circuit called a differential amplifier.
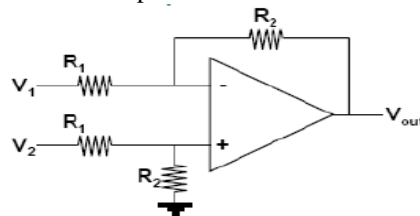


**Figure 2.5: Differential amplifiers (Courtesy [4]).**

### 2.2.3 Data Acquisition and Display:

Once the voltage readings from the strain gauge were obtained, conditioned and amplified, they are still in analogue form as voltage. These analog signals need to be digitalized i.e. converted to digital signals. This can be done using an A-to-D converter. However, there is a need for calibrating the data thus obtained in the form of corresponding force measurements. The actual process is shown in figure 2.6.

In block diagram, Strain gauge sensor is a device which is used to change the resistance to measure the strain. The change in resistance is a measure of its mechanical motion. When the pressures of forces are applied on the strain gauge, then the resistance of the strain gauge is varied. Due to this bridge is unbalanced, Output voltage across the two arms of a bridge changes, this voltage proportional to the force applied in it. The voltage produce by bridge is very low which is in mV, we have to amplify this voltage so we use LM 324 as an instrumentation amplifier. This output is given to the ADC pin of the ARM7 microcontroller.ADC pin convert the analog data into digital data .This data is displayed on LCD in the form of force.
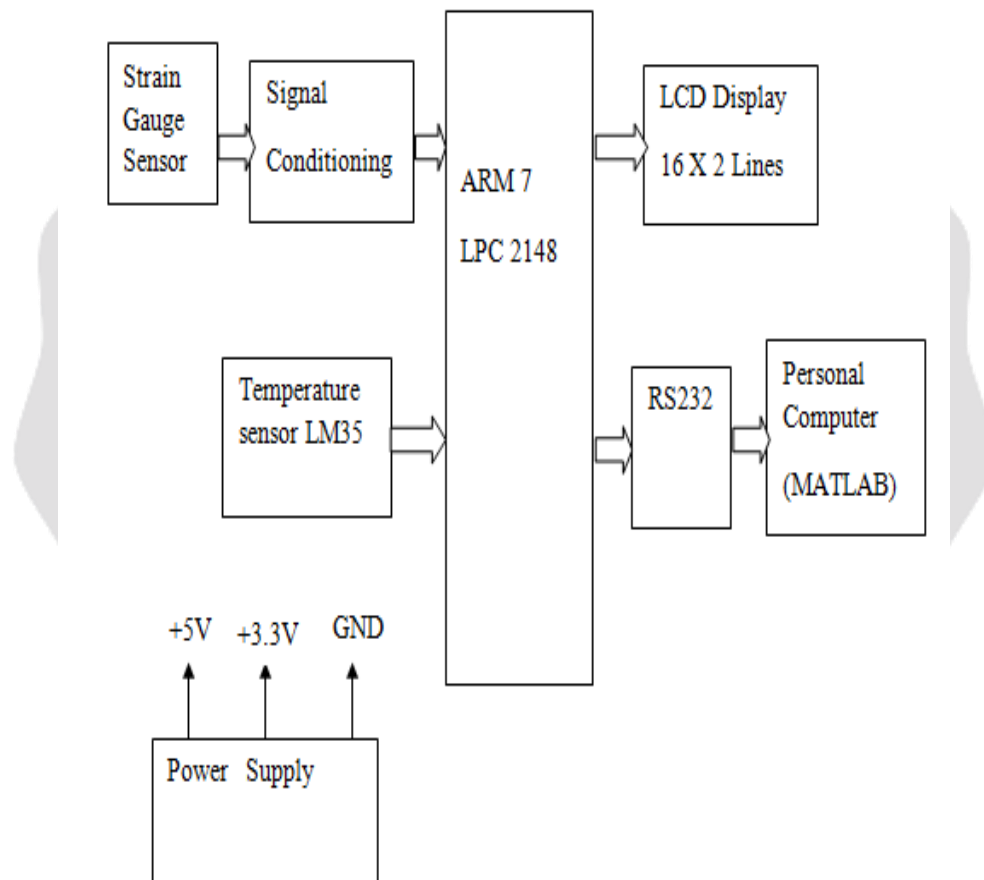


**Figure 2.6: System architecture.**

## 3. SYSTEM COMPONENT:

**HARDWARE**
- ARM7 Microcontroller (LPC 2148):
- Temperature Sensor (LM 35):
- Strain gauge sensors :

**SOFTWARE**
- SCARM:

- MATLAB R 2014b:
- Proteus 8 Professional:
- Flash Magic:

## 4. RESULTS:
### 4.1 Output Voltage of the Signal Conditioning:
Table 4.1 shows the data available on terminal.

**Table 4.1:** Data on Comport

| Temperature(degree) | Weight(gm) |
|---|---|
| 31 | 0028 |
| 31 | 0218 |
| 43 | 0218 |
| 61 | 0420 |
| 74 | 0407 |
| 80 | 0420 |
| 69 | 0508 |
| 48 | 0521 |
| 47 | 0698 |
| 47 | 0711 |
| 42 | 0900 |
| 41 | 0888 |
| 38 | 1027 |
| 37 | 1039 |
| 34 | 1229 |
| 34 | 1406 |
| 34 | 1419 |
| 31 | 1899 |
| 31 | 1899 |
| 31 | 2000 |

**4.2 Graph of data generated on MATLAB:**

Below Figure 4.1 shows the graph of temperature and force verses time as shown in table 4.1. Blue line indicates the temperature and green line indicate the change in resistance with respect to time. Figure 4.1 indicates the MATLAB analysis. As shown in above Figure 4.1 our resistance increases with increase in pressure on strain gauge. The graph is also indicator of temperature. Now the screenshots of the result will clear all the statements of above part.
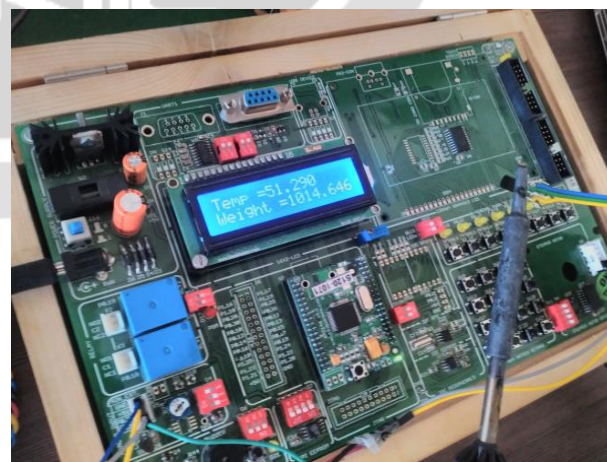
The Figure 4.2 shows the screenshot of our 1st statement. This is the part of strain gauge. Strain gauge is clearly visible in above image. As we know when pressure or weight on strain gauge increases the resistance of across it increases. We have placed the weight of 1KG on the strain gauge. Also LCD screen is visible in the image. With the help of LCD screen we can observe the force given by weight. It is showing 989.355 value of force. At that time how much resistance is changed, we can observe it with the help of theoretical readings.
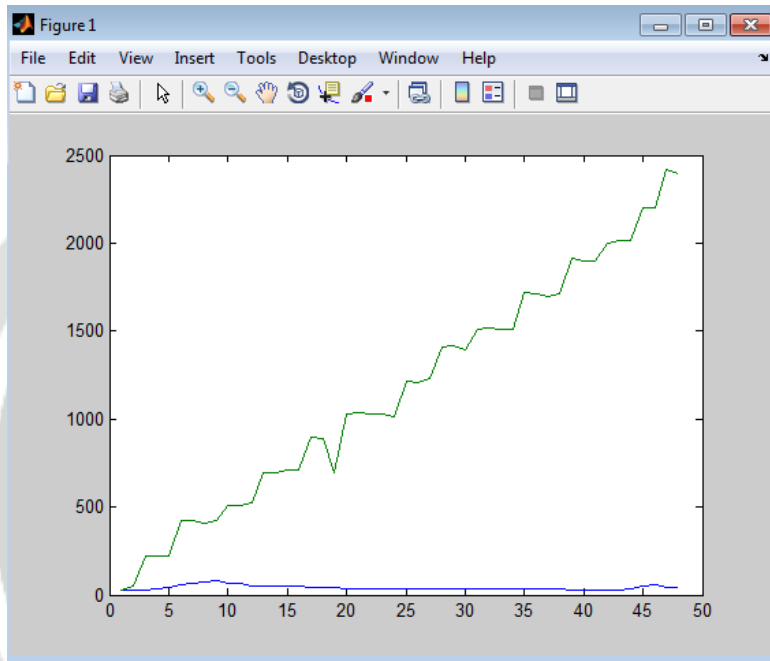


**Figure 4.1: Graph of Temperature and Force.**



**Figure.4.2: Display temperature and force on LCD**          **Figure 4.3: Temperature produced on tool.**

This figure 4.3 is another part of our system. LM35 is the IC which is used for temperature sensing purpose. Initially when there is no external temperature is on it, it shows the normal room temperature. But as shown in above screenshot when we apply external temperature, it will show rapid change in temperature. Both screen and LM35 is visible in the above screenshot. When the temperature is given to him the LCD displays the temperature across it. In above screenshot it indicates the 51.290 temperature. If we lead to increase temperature the readings on the LCD will vary in proportion with temperature.

Figure 4.4 indicates the data of strain gauge and temperature on the computer. We have used the ARM microcontroller. When the temperature or pressure increases ARM senses the data from the system. It immediately informs to the LCD screen and LCD displays it
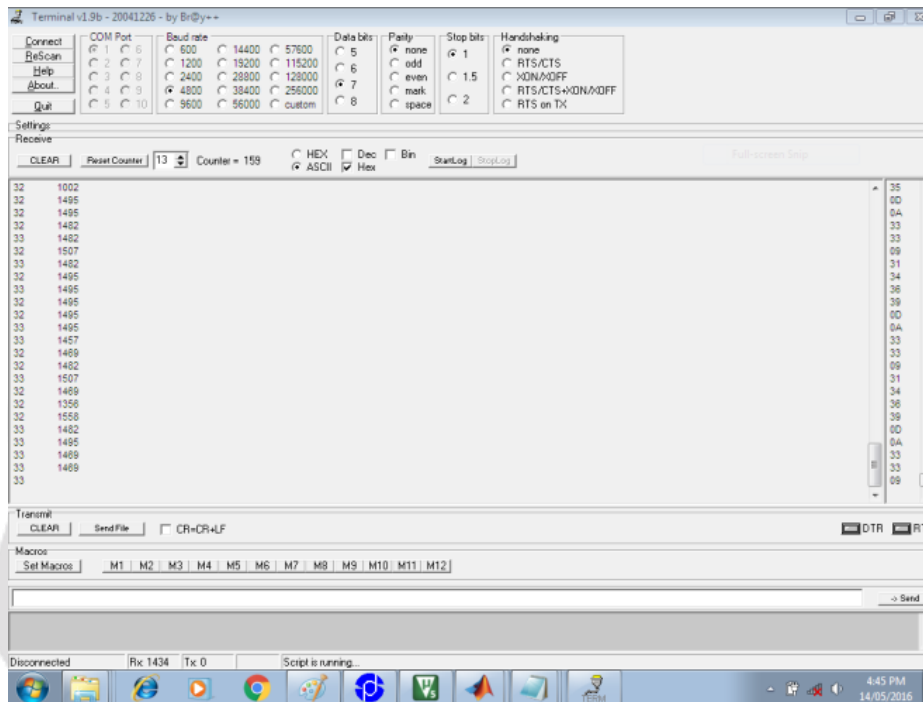


**Figure 4.4: Result is on SPJ Terminal**

## 5. CONCLUSIONS

After observing the practical working as well as theoretical values we can conclude that the part which is expected or proposed in the information is working successfully. We can state that, when the force on tool of lathe machine increases the resistance of strain gauge increases also we can observe it on the LCD screen. So we can easily measure how much force is present there. As well as when the temperature across LM 35 increases the LCD shows the indication of temperature. This is also visible on the LCD screen with the help of ARM7 microcontroller and this is theoretically available on MATLAB software in the form of graph. Finally we can conclude that we have an system which is capable of measuring the forces on lathe machine as well as indication of temperature also.

## 6. REFERENCES

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