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Design of Vibration Signal Acquisition System for Condition Monitoring of Plastic Extrusion Machine

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Abstract

Traditionally used vibration acquisition systems for condition monitoring of machine are complicated and costly ones. For small industries the vibration acquisition system should be cost effective and simple in use. This paper aims to enlighten the details of such developed vibration acquisition system. Data acquisition hardware is designed and fabricated using MMA7260QT Micro machined accelerometer. The hardware has the task to sense vibration of surface and then converts them proportionally to the electrical voltages in the range of the voltage required for the line in port of sound card. The device is interface with computer through in port of sound card and application software Matlab is used to get in and process these signals. The performance of this designed system has been tested by acquiring several vibration signals on plastic extrusion machine for normal and abnormal conditions. The result shows that it is cheap and best vibration acquisition system.

1. Introduction

Plastic extrusion is a machine-intensive continuous process. It involves heating and melting plastic granules and pushing them to a die to get the product. Extruded plastic products have wide variety such as Plastic bags, Plastic film, Plastic pipe, Plastic insulated wire, Plastic coated paper, Plastic sheet etc. The plastic extrusion industry needs to run continuously by eliminating downtimes. Traditionally maintenance, lubrication and replacement of other components such as gearboxes, bearings, shafts etc. were done on a set schedule to avoid unexpected failures. But still Machine is not reliable. It may go out of action or may run in faulty condition that can lead to a catastrophic fault with time. In faulty running condition the quality of product also suffer. Such an erroneous situation motivates to monitor the parameter of machine condition i.e. condition monitoring [1] [2] [3].

There are a number of parameters that vary with the change in machine condition and can be used to monitor the condition of machine. Machine vibration is one of the most reliable and widely used parameter for monitoring purposes because it exhibits directly machine health condition. Each and every component of machine vibrates with its natural frequency in running condition and coupled sections transmit these vibrations. Then machine has its own unique vibration signature that shows healthy machine behavior. When any defect comes into existence, the frequency components in the spectrum will change and give distinct vibration pattern. In another way increased machinery vibration is the indication of developing problems. Vibration monitoring technique is capable of detecting more faults than other techniques and is a noninvasive one i.e. vibration acquisition doesn't affect the working or operation of machine [4] [5] [6].

Vibration signal acquisition and interfacing of acquisition system with PC have been discussed in few papers. In [7] Accelerometers (ICP-IMI, SN98697) is used to sense Vibration signals, vertically measured signal for analysis and the horizontally one for verification. Data acquisition board (NI PCI-4472) having in built anti aliasing filter, is used for signal collection. In [8] Vibration acquisition is done by Dytran 3035AG accelerometer. The signal is amplified by the Dytran 4105C and low pass filtered. It is not very clear that how interfacing is done. In [9] Vibration signal is amplified and converted into digital by ADC 0808. The processing part is done by using ATMEL89c51 and for interfacing to PC data acquisition card PCL-207 is used. The GPIB, USB, RS-232 and IEEE 1394 are the standard interfaces for exchange of data with instruments. The DAQ devices which are compatible with serial port (RS232) and

USB port are more common. In [10] ADXL330, a tri axial, MEMS type piezoelectric accelerometer is preferred because of their high frequency response and rated output voltage is within the range of DAQ card used. Vibration data acquired and saved in the computer using National Instruments' SCB-68 Shielded Collector Block, PCI-MIO-16E4 (NI 6040E) DAQ card and LABVIEW 8.6. In [11] simple and low cost instrument system for on line structural vibration monitoring is developed using MEMS accelerometer MMA7260QT, issued by Freescale Semiconductor. The system is based on RS-485 network topology which consists of one master unit and four slave units. Master is a control unit interfaced with PC through RS-485. Slave is a sensing unit equipped with vibration sensor and microcontroller based data acquisition system.

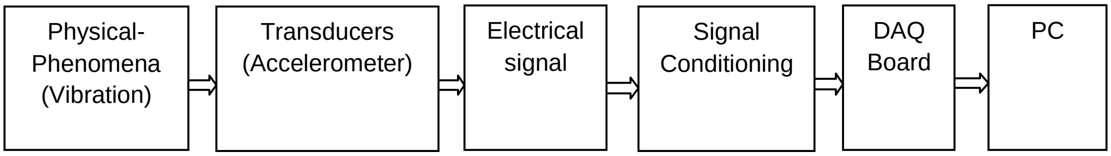

Figure 1. Traditionally used block diagram of data acquisition system

Most of the past researches concerning with machine vibration are using technically old accelerometers and the method of interfacing with pc is generally through RS-232 port or USB port. So the normally used block diagram for data acquisition system is as shown in figure 1. The major drawback of these vibration acquisition systems is they are costly; bulky in size and complicated due to old sensor and its interfacing method. This paper presents the design of economical and useful vibration data acquisition system for small machines by using latest, low cost, small size, capacitive micro machined accelerometer MMA7260QT of new technology like MEMS (Micromachined Electromechanical system) and interfacing with PC through line in port of sound card. This sensor features signal conditioning, a 1-pole low pass filter, temperature compensation and g-select which allows for the selection among 4 sensitivities (1.5g, 2g, 4g and 6g). The main advantage of surface mount Micromachined capacitive accelerometer is small size, compact, sensitive, lightweight, and relatively cheap, on board signal conditioning [12]. Preconditioned analog output eliminates need for charge amplifier; multi axis sensor reduces cost and simplified packaging. The signal produced is amplified, conditioned, and filtered by circuit components mounted inside the same IC package. So signal conditioning is no more required [13]. Sensor along with its 5 volt regulated power supply circuit is mounted on PCB board. This acquisition system is interfaced with computer through line in port of sound card. DAQ card is not required so this is the cheapest way to interface with pc. The block diagram of presently used data acquisition system is shown in figure 2. This practical work is carried out on plastic extrusion machine having following specifications- Induction motor 7.5 Hp, 1400 rpm, Gear Box Step down (1:25) worn &worn wheel type.

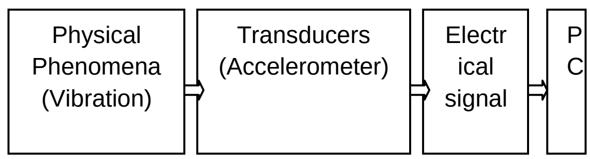

Figure 2. Presently used block diagram of data acquisition system

2. A brief Introduction to plastic extrusion machine and its vibration signals

The purpose of the plastic extrusion machine is to convert raw plastic material into a finished one by melting and forcing it through a die. It consists of an extruder that is made up of a hollow cylinder known as a barrel. A screw is located inside the barrel. The space between screw diameter and width of the barrel is normally in the range of 0.1-0.2 mm. The screw is driven at one end by a gear reducer and motor. At the drive end of the barrel, hopper is top mounted through which raw plastic material is gravity fed. The driven screw pushes the pellets towards the other end of the barrel where a die is located. As the pellets move through the barrel, heat is applied and pressure is generated. So when the raw material reaches the other end of the barrel, it is completely melted into a homogenous fluid. The extruder is typically composed of a feeding hopper, barrel, single or twin screws, and the die and screw– driving unit i.e. motor and gear box [14] [15] [16]. As shown in the figure 3.

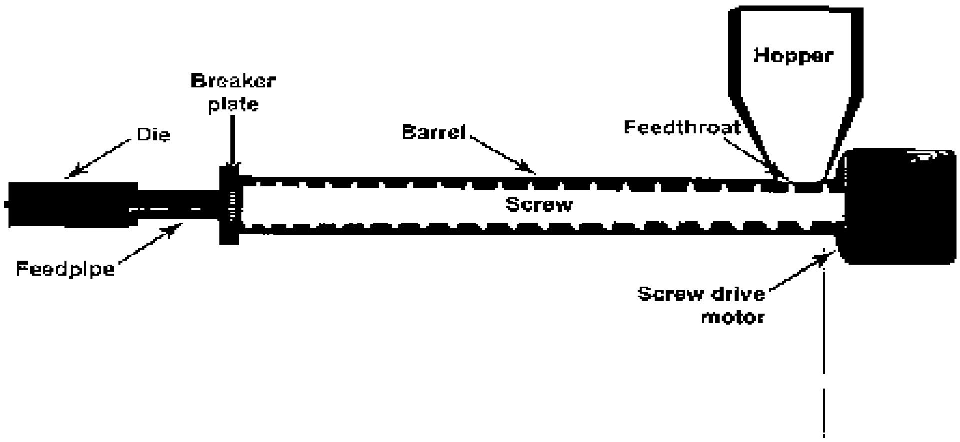

Figure 3. Plastic Extrusion Machine

Plastic extrusion machine having Induction motor of 7.5 Hp, 1440 rpm, Gear Box of Step down (1:25) worn &worn wheel type is used in this practical work. So gear box is reducing speed 1440/25 = 57.6 rpm i.e. 57.6/60 rps means near about slightly less than one revolution per sec. Expected vibration frequencies of machine are directly related to its rotational speeds. The expected frequencies of induction motor will be 1440/60 = 24 Hz and integer or fractional multiple of it and frequency of gear box also depends on (gear shaft rpm × no of teeth of gear) and its harmonics. Typically frequency range of machines is 10 Hz to 10 KHz [4] [6].

3. Design of signal acquisition system

3.1. Selection of sensor, mounting and interfacing method

The selection of a suitable vibration transducer depends on the specification of the machine to be monitored and its rpm and the required accuracy of information to be collected. In general most high frequency sensors have low sensitivity and conversely high sensitivity sensors have low frequency range. So compromise should be made between sensitivity and frequency range. In market a no. of sensors are available. The most commonly used sensors are Piezoresistive type, piezoelectric type and MEMS. Piezoelectric (PE) accelerometers are the most widely used accelerometers. They offer a very wide measurement frequency range (a few Hz to 30 kHz) and are available in a wide range of sensitivities, weights, sizes and shapes. PE accelerometers are available with a charge output or voltage (IEPE) output. When the device is supplied with built-in preamplifier/impedance converter, it is called an Integrated Electronic Piezo-Electric sensor (IEPE sensor), having low output impedance. These sensors can be expensive. When device is supplied without additional signal conditioning circuits, the unit is called a “charge sensor”, having high output impedance. These sensors require additional signal conditioning circuits. Piezoresistive (PR) accelerometers generally have low sensitivity making them desirable for shock measurements [17] [18] [19]. With the advent of new technology known as MEMS or MICROMACHINES (technology of very small mechanical devices driven by electricity), a variety of new sensors are on the market. With surface Micromachined Capacitive approach prices of sensor have gone down dramatically and cost/Performance ratio is also improving. The main advantage of surface mount Micromachined capacitive accelerometer is low cost and on board signal conditioning. In this practical work accelerometer MMA7260QT is selected as vibration sensor. Sensor along with its 5 volt regulated power supply circuit is mounted on PCB board. There are a number of ways to mount an accelerometer to the target. Mounting method contributes in the overall performance of any accelerometer so it should be chosen properly. The best mounting method is threaded stud or screw mount because it has best transmissibility. Adhesive mounting is another method required especially on small surfaces and PCB boards [20] [21]. Magnetic mounting method is also used but not reliable and repeatability of results is affected. For PCB mounted accelerometer MMA7260QT adhesive mounting is most suitable and best hence used. For wired technologies USB, GPIB, RS-232, and IEEE 1394 and for wireless technologies such as Zig Bee, Bluetooth, IEEE 802.15.4 are standard interface to exchange data with standalone instruments. In the entire wired technology methods a DAQ card is required. In this work the most economical way line in port of sound card is used for interfacing instrument without the use of external DAQ card. The conversion (analog to digital or vice versa) takes place in the sound card itself.

3.2. Hardware

Firstly 5v regulated power supply circuit is designed using 9v transformer, 1N4007 diode, 2.2mF, 100uF and 220uF capacitors and IC-7805 as shown in figure 4. This supply is given to the sensor circuit.

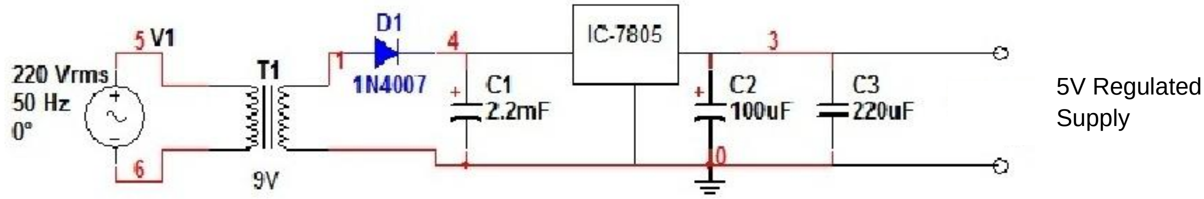

Figure 4. Circuit of 5v regulated power supply

The sensor circuit is having integral signal conditioning with low pass filter and high sensitivity 800mV/g at maximum acceleration1.5g. So no more preamplifier, filter is required. The output of sensor circuit is in the range of input of line in port of sound card. The developed acquisition system is shown in figure 5 and the connection of accelerometer is shown in figure 6.

Figure 5. Developed acquisition system

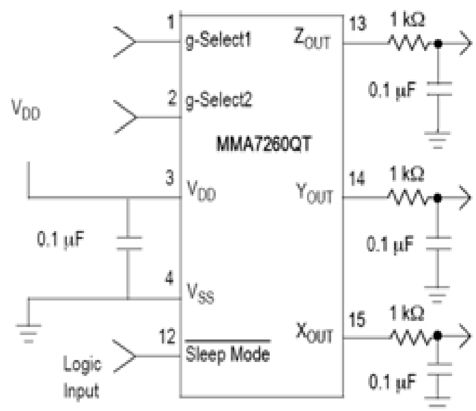

Figure 6. Connection of accelerometer

3.3. Software

Signal acquisition is done by Matlab Simulink block as shown in figure 7. and stored into pc. Simulink is an environment for multi domain simulation and Model-Based Design. It provides an interactive graphical environment and a customizable set of block libraries that let you design, simulate, implement, and test a variety of time-varying systems, including communications, controls, signal processing, video processing, and image processing. The details of used blocks are given below.

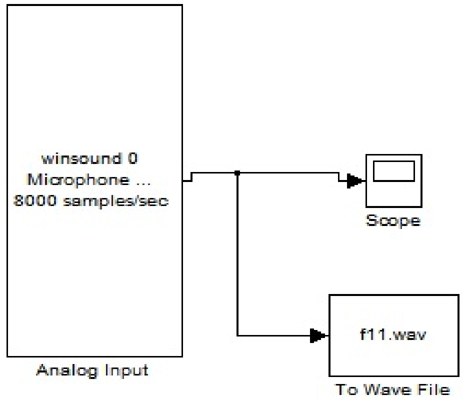

Figure 7. Matlab Simulink Block

The Analog Input block opens, initializes and configures an analog data acquisition device. The opening, initialization, and configuration of the device occur once at the start of the execution. During the model's run time, the block acquires data either synchronously or asynchronously. In synchronous acquisition mode the acquisition occur at each time step. The simulation will not continue until all data is acquired. In asynchronous mode the acquisition initiates when simulation starts. The block has no input ports. It has one or more output ports. In this model data acquired asynchronously.

The scope block lies in sink library and display signals generated during simulation with respect to simulation time. The Scope block can have multiple axes and all axes have a common time. If the signal is continuous, the Scope produces a point-to-point plot. If the signal is discrete, the Scope produces a stair-step plot. The Scope provides toolbar buttons. So signal can be modified according to the requirement.

The To Wave File block streams audio data to a Microsoft Wave (.wav) file in the uncompressed pulse code modulation (PCM) format. For compatibility reasons, the sample rate of the discrete-time input signal should typically be one of the standard Windows audio device rates (8000, 11025, 22050, or 44100 Hz), although the block supports arbitrary rates. In this software audio device rate is 8000.

4. Experimental results of developed acquisition system

Firstly vibrations of table are acquired just to prove that developed system has been functioning well. After that to determine the performance of developed system, it is used to acquire vibration signal in real field application i.e. from plastic extrusion machine. Many signals from machine are acquired in normal condition and this is confirmed with the help of working machine operator. One normal signal and its spectrum are shown in fig 7 and fig 8. An abnormal condition is created by losing the four base screws of foot of motor connected to the hard base. Then abnormal signals are acquired from motor at the same place. The abnormal signal and its spectrum are shown in fig 9 and fig 10.

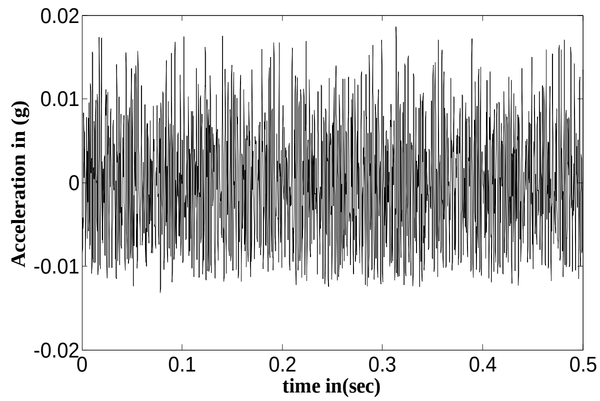

Figure 8. Vibration signal in normal condition

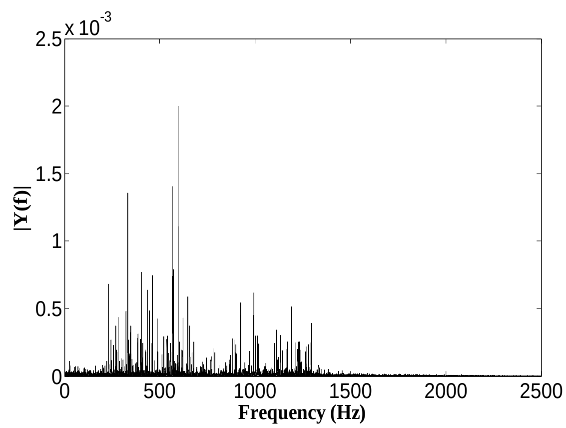

Figure 9. Spectrum of normal signal

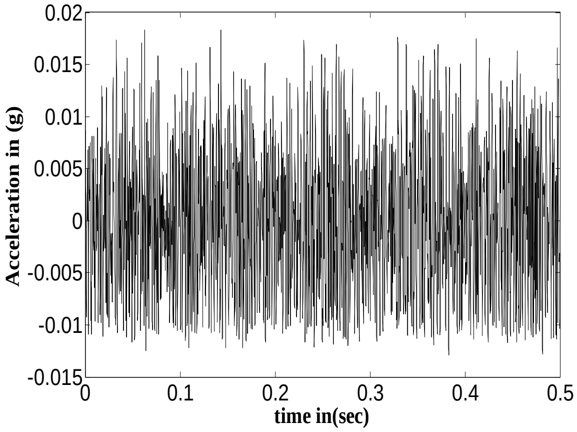

Figure 10. Vibration signal in abnormal condition

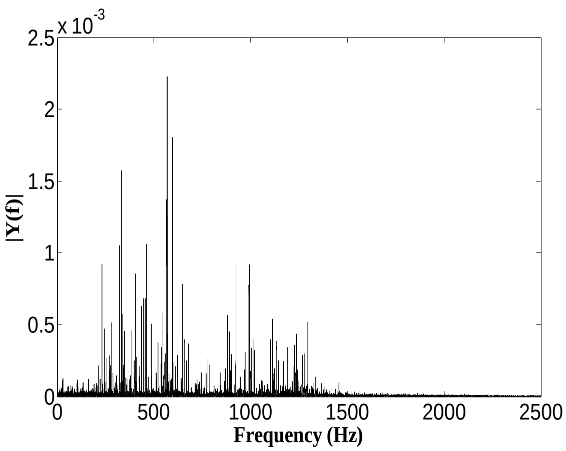

Figure 11. Spectrum of abnormal signal

By comparing the normal & abnormal figs. some conclusions can be drawn. In abnormal condition high frequency components are present hence spectrum range increases and Amplitudes of frequency components also increases. So, on the above basis faulty condition of machine can be easily detected by comparing any time vibration signals with the normal condition vibration signals taken from the same place using this newly developed vibration acquisition system.

5. Conclusion

To acquire vibration signals, this vibration signal acquisition system is developed. This acquisition system acquires vibration signals satisfactorily. The faulty condition can be detected by analyzing vibration signals. Normally the amplitude of vibration and the range of frequency in spectrum increases in the faulty conditions. This developed system is very useful for medium size machines because it can acquire the vibrations of moderate frequency range. For early prediction of faults the very high frequency vibration should be acquired.

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