Developing of Data Acquisition System of Rheometer for Plotting the Rheogram (Graphical User Interface)

A. M. Gaur, Rajat Joshi, Amod Kumar, and Dinesh Singh Rana

Abstract—**In this paper, our aim was to the measure the viscosity of rubber at various stages of its curing by taking a sample out of the raw material and using the rheometer to test its composition from its Rheogram. The key features of the design are its ability to test small sample volumes and to retain the presence of a hydrating layer. The rheometer uses a piezoelectric actuator and sensor to induce an oscillatory stress and to measure the corresponding strain. The other objective is to design and implement data acquisition system for acquiring Torque and Synchronize signal and plot the rheogram on computer by the developing the Graphical user interface.**

Index Terms—**Viscosity, rheogram, polymerization, vulcanization, signal processing system, ADC card.**

I. Introduction

Science of Rheology (from the Greek rheo, a flowing) which employs Rheogram to determine and define the characteristics of any fluid. A Rheometer is a quality control instrument that is used in rubber-related manufacturing industries for testing the quality of rubber/polymer materials, such that the product that is produced complies with international standards. The long ability of the product also increases if the raw material used, i.e. the rubber is of the desired quality with the properties and characteristics. Therefore the measuring of viscosity must always be combined with measuring of temperature [1]. The Rheometer is thus an important part of the industries using rubber of their raw material. The rheometers are of two main types, namely: the controlled shear rate instruments and controlled stress instruments [2]. The uncured sample is placed between two hot plates and a reciprocating disk in the cavity between the two hot plates churns the polymer pad. As it undergoes polymerization the torque required is recorded. The graph output that is recorded torque versus time is called Rheogram. The experimental results calculated by computer, output by printer and plotter [3]. From this, the chemist can predict final product quality and can control the additives/plasticizers to adjust its properties according to the application.

The force causing deformation is plotted against the resulting flow (shear rate) under constant condition of temperature and pressure. Such plots, sometimes called shear diagrams, are vital guides for proper understanding of the measurement of viscosity or consistency. The rheogram provides a direct method for determining the Initial viscosity, minimum viscosity, maximum viscosity, induction time scortch time, optimum cure time, cure rate and reversion time [4].

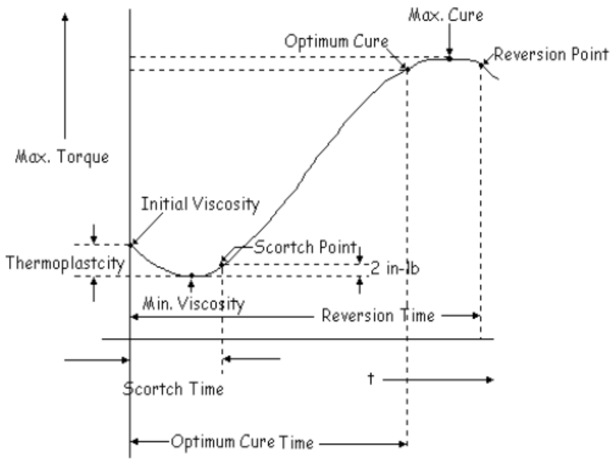

Fig. 1. Rheogram curve with parameters

Generally liquids can be classified into Newtonian liquids and non Newtonian liquids. These are liquids or suspensions in liquids which obey the Newtonian law (i.e., shear force-flow relation is linear), and thus produces a rheogram consisting of a straight line passing through the graph origin Generally, pure liquids, most oils (e.g., lubricating, fuel, and hydraulic oils), true solutions, and dilute suspensions are Newtonian, or very nearly so. the slope of straight line is much steeper for more viscous liquids like heavy lube oil than for less viscous liquids like water and a non-Newtonian fluid is a fluid whose flow properties cannot be described by a single constant viscosity. Many polymer solutions and molten polymers are non-Newtonian fluids, as are many commonly found substances such as ketchup, starch suspensions, paint, blood and shampoo. In a Newtonian fluid, the relation between the shear stress and the strain rate is linear, the constant of proportionality being the coefficient of viscosity. In a non-Newtonian fluid, the relation between the shear stress and the strain rate is nonlinear, and can even be time-dependent. Therefore a constant coefficient of viscosity can not be defined.

II. Operation of Rheometer

A polymer specimen is confined in a die cavity located between the large electrically heated two aluminum platens

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and several dynamic signals were input to the instrument to determine characteristics of material [5]. The temperatures of the platens and dies are maintained to within ±1 degrees F (± 0.5 degrees C) by PID controllers. The polymer specimen softens and then it surrounds the bi conical disk. The cavity consists of a fixed lower disc and a movable upper disc which is capped closed during tests by pneumatic ram [6].

The square shaft of the rotor is manually clamped by tightening the draw bar of collate to the torque shaft. It is oscillated through a small arc of ±1, 3 or 5 degrees by an eccentric attached to the motor shaft. The reciprocal motion is transmitted from the eccentric through a connecting link and a torque arm to the torque shaft and disk. The stage on which sample rest should be light [7]. The force required to oscillate the disk and thus apply a shearing strain to rubber specimen is measured electronically by the torque arm transducers. The torque applied to the disk causes the voltage proportional to the stiffness of the rubber to be developed across the strain gauge bridge bonded to each side of the torque arm.

III. Development of Hardware

A. Pneumatic and Mechanical System

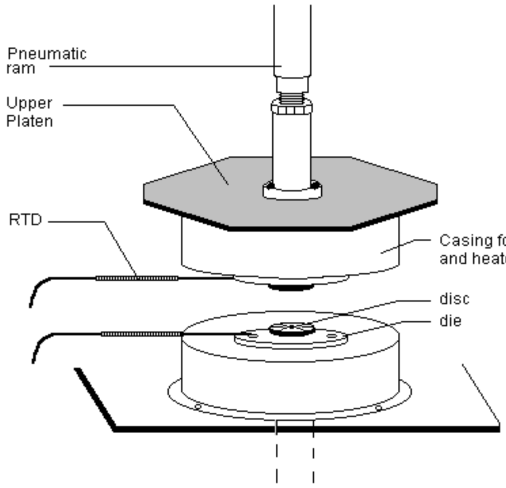

Fig. 2. Pneumatic system

The pneumatic system is the main part of rheometer to start with Main parts. Air compressor is an electric motor driven attached with centrifugal pump. It takes the air from atmosphere, cleans it and raises its pressure from atmosphere to 10 kg/cm ^{2}through centrifugal action. This compressed air is used to move the platen up or down. It is consist of bi-conical disc which is embedded in an elastomeric specimen contained in a specially designed cavity that oscillates around 1, 3, 5 degrees. Mechanical housing protects the whole mechanical, electrical, control, torque and electric system from the dust and other environment conditions e.g., temperature, pressure etc. It is made of stainless steel with nickel plating. RTD should be placed in such a way that most of the heat will be transferred to it only from the dies and the dissipation of heat to the surroundings should be the negligible. This increases the stability of the system.

Two proximity sensors/switches (one at the completely closed position of the shuttle and other at its completely opened position) are mounted to lift the shuttle up or down. Two proximity sensors/switches (one at the completely closed position of the platen and other at its completely opened position) are mounted to move the ram up or down.

B. Torque System

This system includes the torque motor arrangement that oscillates the disc inside the cavity formed by the dies. Torque motor rotates with a constant speed. The in built gear system reduces the speed to 100 rpm (1.66 Hz). The crank mechanism converts the rotations to Oscillation (1, 3, 5 degrees). The rubber melt produces torque on the disc which is transmitted to transducer by a torque arm.

Strain gauge type transducer is used to sense the torque acting on the bi-conical disc. The dynamic measurement of torque transmitted by a rotating shaft is based upon the angular displacement or twist in the shaft in a calibrated length of torque arm/tube attached to the shaft. The strain is sensed and is measured. The strain measurements are then interpreted in terms of torque by proper calibration. Four strain gauges are mounted on a shaft at an angle of 45 ^{o}to each other.

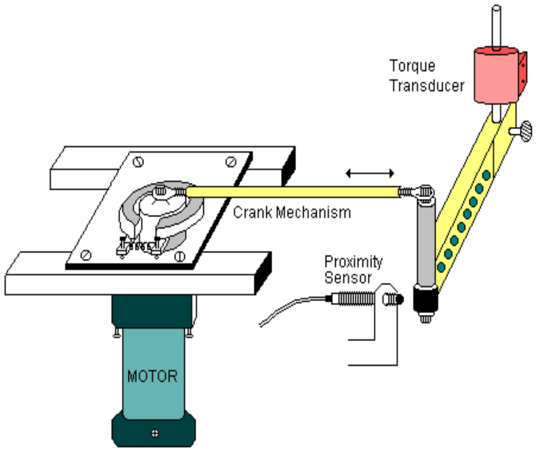

Fig. 3. Torque system

The torque is given by equation

$$T = \pi G(R^3 - r^3)\theta/2L$$

where,

G = modulus of rigidity, N/m

R = outer radius of shaft, m

r = inner radius of shaft, m

L = length of shaft, m

θ = angular deflection of shaft, radians

The arrangement has advantages that it is fully temperature compensated; provide automatic compensation for bending and axial loads and gives maximum sensitivity for a given torque. The strain is measured by electrical means to indicate the torque. The proximity sensors houses active coil closer to target (a conductive material) and a compensating coil, is fed with high Frequency voltage source. The magnetic flux lines from active coil pass through the conductive material (target) surface producing in it eddy currents whose density is greatest at the surface and decreasing fast with depth. As target comes closer to the active coil, the eddy currents in it become stronger and this changes the effective impedance of the AC and the bridge becomes unbalance, which is related to the target position. The bridge output is filtered by the low pass filter and dc output is obtained which is finally fed to the storage element so that the torque vs. time characteristics can be drawn afterwards by the computer.

C. Electrical System

It consists of different MCB (miniature circuit breakers) for the protection against overloading for mains supply, heater and PLC (Programmable logical control). These MCB also protects against short circuit faults if occurs in the electrical system. Electrical system also includes contactors, relays, switches, motor for lifting shuttle etc. An emergency manually operated switch is provided which when pressed halt the PLC from execution of instructions hanging the whole process in between. One can stop the process at any stage of operation of Rheometer manually by the switch. Before going to auto mode, it is better to start the process in manual mode. In manual mode all tasks can be seen individually, ensures that all the components of the system are working ok. Then the process can be changed over to auto mode.

D. Torque Signal Processing

First task in this process is the torque data acquisition. For this, Dynalog's ADC (Analog to Digital converter) card PCL- 1800 has been fitted in the one slot of the PC. This card has 12 bit ADC converter, 16 single ended input analog lines and many digital I/O lines. A program has been written in Visual C++ to make the data file of the torque value. This program finds the maximum torque in each cycle of oscillation of disc. These peaks of each stress cycle correspond to the low frequency dynamics modulus of specimen. The synchronizing input is derived from the proximity sensor placed near the torque arm. It gives the 24 Volt O/P pulses each time arm comes near it.

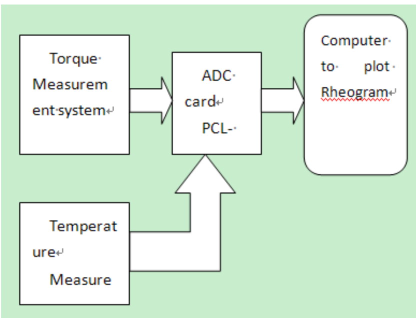

Fig. 4. Block diagram of Signal processing system

PCL -1800 card is used for the interface between pc and the two signals which are Torque and second of Synchronization signal. The PCL-1800 is a very high speed, high performance multifunction plug-in DAS card for the IBM PC/AT and compatible systems. It features a 330 KHz 12-bit analog-to-digital converter, on board 1K word FIFO buffer, two 12-bit digital to analog output channels, 16 digital input channels, 16 digital output channels and one 16-bit counter channel.

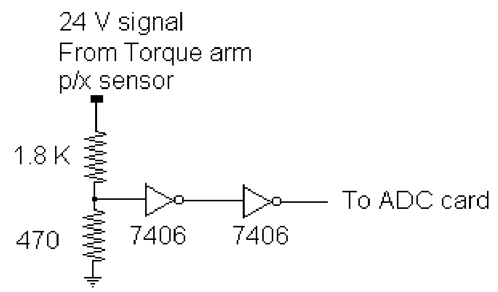

Fig. 5. Torque measurement system

The PCL-1800 also includes a 16-channel, 8-bit analog comparator, which can be used as analog watchdog to monitor the card's 16 analog input signals. If a signal goes above or below a triggering value, the PCL-1800 can generate an interrupt and transfer data. The card provides DMA data transfer on one of its two 12-bit digital to analog output channels.

IV. Software Development

A. Developing the Graphical Interface

This step requires a windows application in which the operator can enter the detail for each test specimen such as date and time of test, shift number, Operator name, Batch number, amplitude of arc, test duration, and die temperature.

B. Plotting the Rheogram and Developing File structure

In this step, the torque signal from the Rheometer must be read so that the rheogram can be plotted. The torque signal is inputted to the ADC card – Dynalog's PCL 1800. It was required to develop a module to read the torque signals coming to the ADC card and plot them simultaneously to obtain the rheogram.

The rubber technologist may require viewing the results for a particular rubber specimen tested before. For that the application must provide functionalities like saving a record, Opening a record, deleting a record, printing a record, generating daily Report. The programming language used in the development of the project is Visual C++.

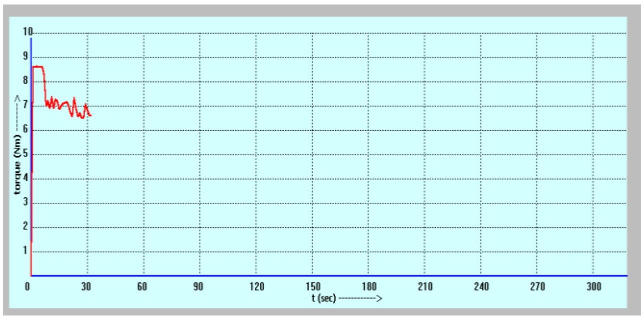

Fig. 6. Graphical user interface screen

As per the requirement of the project, our application's main screen prompts the operator for entering various details before testing a rubber specimen. The user need not enter the current date and time as they are displayed implicitly. Test results are displayed as per the calculation done by our module which will be discussed in details under the section calculating Various Parameters. The progress bar indicates the progress of the graph display by displaying a colored bar inside a horizontal rectangle. The length of the bar in relation to the length of the rectangle corresponds to the percentage of the test that is complete. The progress of plotting of rheogram is indicated with the help of a progress bar and time remaining for the test to be completed is also shown. The plotting of rheogram can be quitted before the specified test duration (in case of any emergency) by clicking the Stop button. As soon as the test ends or is quitted, the result of the test are displayed and Start and Exit buttons are enabled.

C. Testing of Rheometer

Sample of diameter approx. 44 mm and thickness approx. 4 to 5 mm are cut from a sheet type rubber sample flattened by a roller to include the least possible air. A cellophane sheet can be wrapped around the sample before putting into the die so that more viscous sample does not stick to the dies. The thickness of the cellophane must be maximum 0.3 mm.

Fig. 7. Dialog box during card testing

This testing menu item helps the user to check the status of the ADC whether it is functioning properly or otherwise. The application tests the ADC card by giving it a digital number to perform conversions. The card first converts the number to analog and then again converts it to digital. If the difference between resulting number and the original number is within 0 –10 (considering the losses during conversions), the card is perfectly alright Number equations consecutively.

V. Results

A rheometer was successfully developed to obtain visco plastic parameters. The instrument can be also used for other type of materials also. By this investigation we test the quality of rubber/ polymer materials, such that the product that is produced complies with international standards. The long ability of the product also increases if the raw material used, i.e. the rubber is of the desired quality with the properties and characteristics. From the cure instrument can also calculate the various parameters.

During the plotting of rheogram, we calculated the maximum value of torque for each cycle and placed them in an array. The maximum out of these elements gives us the maximum torque. Similarly, minimum torque is also calculated. The application reads the values for each field that have been stored in a text format. The torque values have also been stored in similar fashion. They are plotted against time to obtain the rheogram.

VI. Future Scope

In this research we have developed rheometer with data aquistion system. The data is transferred to PC via ADC card. The future scope in this design would be that we can connect PC with some Wireless/ Bluetooth device so that fast transmission of data can take place. Moreover we can connect a printer to the instrument for graphical layout of characterstics of material under test.

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