PLC Based Automatic Control of Rheometer

A.M Gaur[1*], Rajesh Kumar [2], Amod Kumar[3] and Dinesh Singh Rana[4]

[1*] Department of Electrical Engg, MM University
Solan, India
gauranshu10@gmail.com

[2] Department of Electronics & Communication Engg, Y.I.E.T
Yamunanagar, India
rajeshakela06@gmail.com

[3] Bio Medical Instrumentation Unit, C.S.I.O
Chandigarh, India
csioamod@yahoo.com

[4] Instrumentation Engg, I.I.E
Kurukshetra University, Kurukshetra, India
dineshsrana24@rediffmail.com

Abstract

This paper describes the automatic control of disc type rheometer. This developed device will able to provide flexibility to operator for testing of rubber. The operator has to just enter the duration of test and parameters through man machine interface. All the operations will occur automatically without any intervention in a prescribed sequence stored in programmable logic controller (PLC). This developed apparatus is useful not only for testing purpose, but it can be used for research for other types of materials also. With this state of art apparatus one can control the quality of rubber for various applications such as tyre industry. Also this would help to increase the production of rubber as automatic control comes which reduces the test duration to few minutes only.

Keywords: *Rheometer, PLC, MMI, Ladder diagram, Curing, PID, Rheogram.*

1. Introduction

Rheology is science that has found the application to know the behavior of certain materials that behave in unusual manner. The rheometer is used to measure the viscosity of the rubber. The measurement of viscosity must be done in presence of temperature, so as to assess the cure state of the material which is of great importance [1] [2]. Today rubber is finding a wide variety of applications from daily usage to the industrial applications. Rheometer is classified into various types ranging from Drag flow type up to pressure driven flow [3]. They may be also classified as capillary type and oscillator disc type. It provides a capability to study the dynamics of material under investigation. The latter phase of cure is not reliable due to increase in stiffness in specimen, results in large number of errors [4] [5].

* Corresponding Author

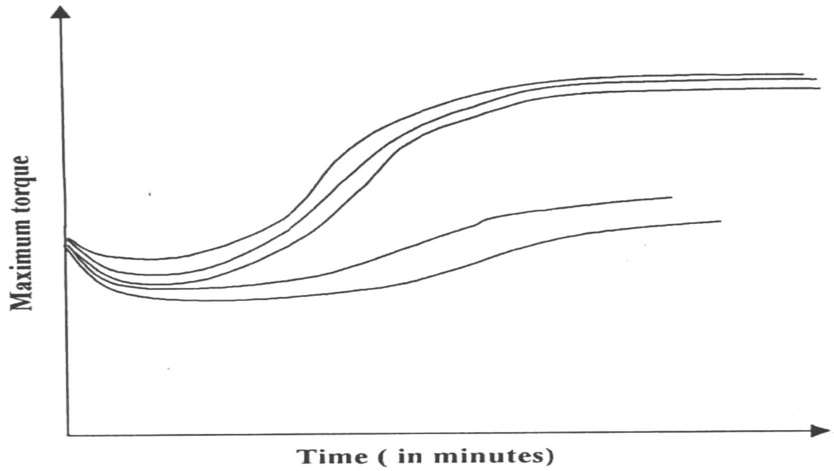

Figure 1. Variation in viscosity with time for rubber

The effects of compounding variations on curing characteristics are important in compound development studies or production control. By using rheometer for preliminary screening, some compounds can be eliminating from further testing if the rheometer trace indicate the compound doesn't exhibit the required curing characteristics. In industries, various filler materials are added to natural rubber, so as to obtain desired properties for specialized application [6]. By adding or removing proper additives curves can be straightened and desired product can be obtained. Figure 1 shows variation in viscosity with time for same Production stock (rubber). However the major variations are due to the cure system viz. miss weighing, dispersion etc.

2. Experimental Setup

Rheometer is mainly consisting of various units such as PLC unit, various system units and interfacing unit. The PLC unit includes the dc power supply 24 V that is heart of the whole system. The interfacing unit includes the computer together with analog to digital converter and printer for plotting the rheogram. The figure 2 is showing the block diagram of rheometer.

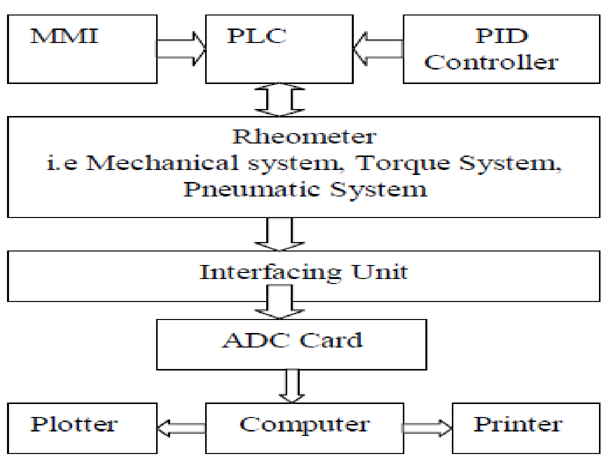

Figure 2. Block diagram of Rheometer

2.1 Hardware Implementation

The Rheometer basically consists of Pneumatic system, Mechanical system, heating system, Torque system, and Electrical system. The Pneumatic system consists of a pneumatic ram that goes up/down using compressed air. It is an electric motor driven centrifugal pump. After mixing with oil, it is fed to air cylinder that moves the ram to lift the upper die. After the sample is placed, again ram is positioned in same position (at the bottom) to hold the sample between upper and lower die (fixed die). The oil carried by the air also lubricates the piston and cylinder from within. Pressure of 5kg/cm² closes the pressure switch, thereby gives the signal to PLC that will energize one of the solenoid valves depending on the position of arm whether it is at top or bottom position. The position of ram is determined by the proximity sensors located at bottom and top most position of the platen. Depending on the position of arm one of the solenoid valves gets the signal from the PLC to move the platen up or down by connecting the air inlet to the air cylinder.

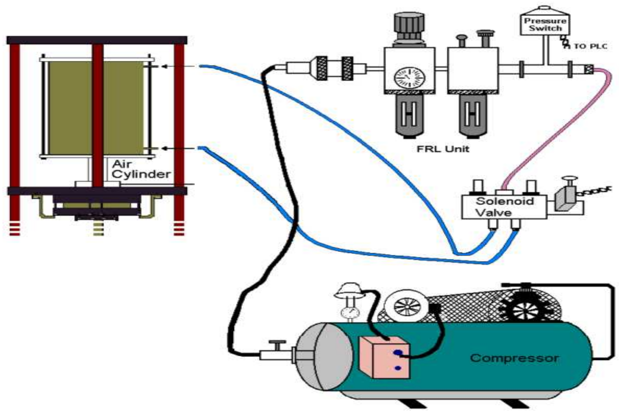

Figure 3. Design layout of Pneumatic system

The mechanical system includes the mechanical casing of the whole instrument, the dies and the platens, the dies and the platens, the shutter control arrangement that causes the shutter at the front to get closed or opened, and an arrangement for the movement of the top platens over cross wire pillars. The heating system is used to heat the dies. The Top and bottom platens have disc type heaters placed between two plates. Glass wool is filled within the cavity formed between the casing and platen die to arrangement to prevent heat losses via radiation. This insulation of the heating system from the external environment helps in maintaining a constant temperature with accuracy of about ± 0.5 °C in the temperature range of about 170 – 200 °C. This is desirable to get Rheogram that observe the exact properties of the rubber material whose quality is being checked. The entire heating system is shown in figure 4.

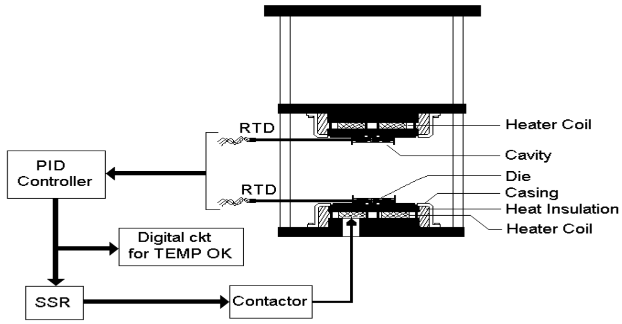

Figure 4. Layout of Heating system

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. 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. In auto mode PLC senses the switch position (a pulse) and gives the appropriate signal to motor to open or close the shuttle while in manual mode push button drive motor. 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. Torque motor rotates with a constant speed. The in built gear system reduces the speed to 100 rpm. 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. The heating losses in the system ought to be minimized. This is done by insulating the system by using glass wool around the platens and within the casing. This ensures minimum radiation losses.

Table 1.Various components of the heating system and their function.

S.No	Control or Device	Function
1	Circular plate heaters	These are used to heat the dies
2	Enclosing casing	This casing encloses the whole heating system and house glass wool
3	Glass wool	Prevents radiation heat losses from the dies
4	Asbestos parts	These prevent conductive heat losses to the base from the dies
5	RTD	Platinum RTD to measure temp. 0-800c
6	Silicon grease	Remove air gaps
7	PID controllers	Help maintain the desired set point temp.

The minimum heating losses prevent wastage of power as the heater remains ON for lesser time to maintain a particular temperature. This is actually a part of control system. It consists of different MCBs for the protection against overloading for mains supply, heater and PLC, These also protects against short circuit faults if occurs in the electrical system. It is also includes contactors, indicators relays which is operated at 24Vdc and 230V ac, switches, single phase induction motor for lifting shuttle, and three phase with gear crank induction motor for torque etc. An emergency which is manually operated switch is provided which when pressed halt the PLC from execution of instruction.

2.2 PID Controller

PID controllers have used for temperature control of the dies. PID controllers are used to control processes where a tight control of the required parameter is desired. The Proportional part helps in accelerating the control. The Derivative part helps remove fast change in errors. The Integral part reduces the error by summing the errors at previous instants [6]. The PID controller is a necessity for Rheometer as the temperature control of the dies is very critical. The temperature of the dies must be kept very stable to within ±0.5ºC. This is because the properties of rubber change with the small change in temperature and this change the Rheogram. This causes the reported quality of rubber to be actually wrong. Thus, the product which meets our requirement is a must for proper and satisfactory working of the Rheometer.

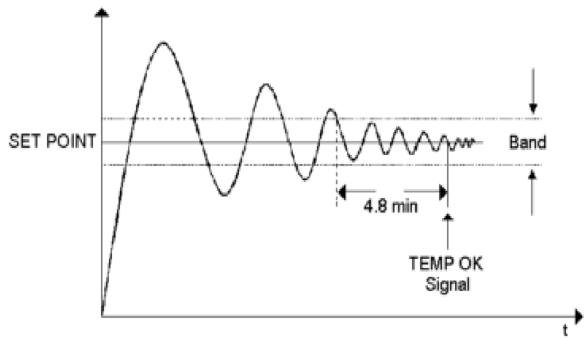

Figure 5.. PID controller behavior

The controller gives a time proportioned ON – OFF control. The ON – OFF time depends on the error input and is determined by controller. The controller gives two types of control signal direct acting Reverse acting. In Direct acting, the ON time is increased when the error decreases and is reduced when the error increases. In reverse acting, the ON time decreases, when the errors decrease and increases when errors increase. The pre-tune function of the controller decides upon the P, I and D parameters for optimum control of the process. The parameters are calculated from the rising of the control variable during initial setup of the process.

2.2 PLC and MMI

A Programmable logical controller can be viewed as an industrial computer that has a central processor unit, memory, input output interface and a programming device [7]. The central processing unit data, status information from various sensing devices like limit switches, proximity switches, executes the user control program store in the memory and gives appropriate output commands to devices like solenoid valves, switches etc. The pictorial view of the PLC MicroLogix 1000 (MAKE Allen Bradley, Rockwell Automation) is shown in figure 6. It is based on the architecture of the MicroLogix 1000 which brings high speed, powerful instructions and flexible communications to applications that demand compact, cost-effective solutions. The MicroLogix 1000 Programmable Controllers are designed to electronically control any of the application. The controllers are available in either 16 I/O points (10 inputs and 6 outputs) or 32 I/O points (20 inputs and 12 outputs) in 5 electrical configurations. The analog I/O circuitry is embedded into the base controller, not accomplished through add-on modules, providing compact and cost-effective analog performance [8].

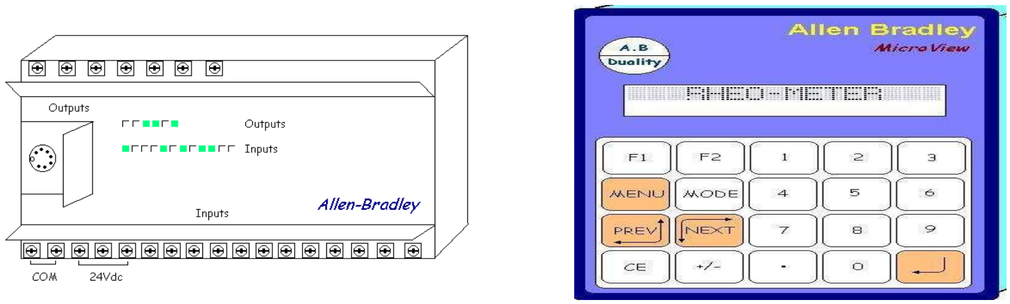

Figure 6. MicroLogix PLC and Man Machine Interface (MMI)

MMI provides an interface between the PLC and the user during program development, start up and troubleshooting. The instruction to be performed during each scan are coded and inserted into the memory with programmer. The programmer is a small hand held unit with LCD display. It has an online programming ability. Online programming allows cautious modification of program while PLC is controlling the process [9]. The off line facility is also provided so that user can write a control program on the programming unit and then take the unit to PLC in the field and the memory with new program without removing the PLC.

3. Programming of PLC

The Rheometer is powered ON. The MMI displays the welcome message, the Make and version of the MMI, and then the first option in the manual mode. If the first option is to be tested, return key is pressed and if it is to be skipped, NEXT key is pressed. When any option has been selected and the test for that device is complete, the previous options can again be chosen by pressing the PREV key. When all the components have been tested individually, the next and the most important requirement is the heating of the dies to the required temperature for tests. This is done by keeping the heaters ON option chosen in the manual mode. Before that the operator must bring the platen down and then close the shutter. Then it should be switch ON the heaters. The PID controllers try to bring the desire temperature in the upper and lower dies as quickly and with as much accuracy as possible. Once the operator comes out of the manual mode the PLC is always going to display the choices on the MMI. Now, after all the testing of the components of the Rheometer, the operator is going to enter the auto mode for the testing of rubber samples and plotting their rheogram. If one chooses the semi automatic mode, the sequence of operations will be as mentioned in Table 2.

Table.2. List of Sequence of operations

Input to PLC	Output from PLC
Temperature ok (from RTD)	Shutter up
Air pressure ok (from pressure switch)	Shutter down
Shutter open (from proxy switch)	Test under progress
Shutter close (from proxy switch)	Test completed
Platen up (from proxy switch)	Ready for test
Platen down (from proxy switch)	Torque motor on
Emergency switch	Solenoid coils
24V dc supply	Heater On

The upper platen goes up and the shutter opens. The operator puts the test sample and presses enter to continue. If the operator does not press enter, the PLC waits for 5 seconds and then brings the shutter and platen down and takes the machine into a state where the option for choosing the mode is presented to the user. The shutter closes, the platen comes down and torque motor starts. The envelope is the maxima of the torque values in each cycle. This graph actually is the rheogram that was to be plotted. When the test completes, the torque motor stops, the platen goes up, shutter open and the sample can now be changed.

3.1 Creating the Ladder Program for Rheometer

PLC can be programmed in variety of languages. One can use ladder programming language, functional Block diagram (FBD) language and statement list (STL). But we have use the ladder programming because programmer can view the status of each input output online. There are two software used for programming the Micrologix PLC i.e. RS link Software and RS logix500 software. The programmer has to follow following steps for programming the PLC. Figure 7 is showing the new project creation for ladder programming.

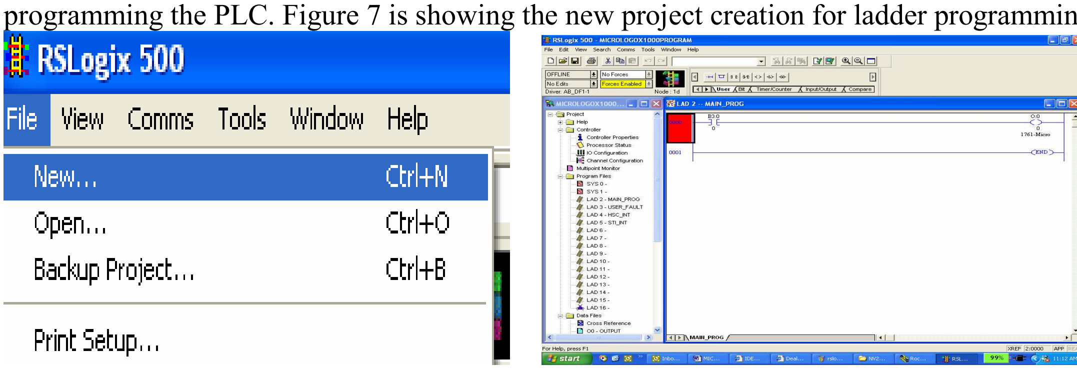

Figure .7. RS Logix software main screen and ladder Diagram Creation For Rheometer

There is sequence of steps for transferring ladder program to PLC. Connect programming cable from PC to PLC programming port. Launch the RS Logix500 Software and select File/New. RS Logix500 links AB devices into Windows applications. Select the Processor type and the I/O Configuration. Click the Read I/O Configuration button to display the type of I/O modules is with the CPU. Select Channel Configuration to configure the communication ports. Select the Channel 1, and channel 0 System tab and set the settings. Select Channel 0 user tab and Driver is Shutdown. Select the General tab make sure all settings are done. Now select the baud rate settings as 19200bps.Create simple ladder logic as shown below. The normally open contact is assign with B3:0/0 and the output coil is assign with O0:0/0. Then download the whole project by selecting Commas / Download into the PLC and reset the whole system before operating Rheometer.

3.2 Communication of PC with PLC

For communicating with PLC a communicating cable is to be designed. One of the terminals is to be connected to the PLC communication port and other to the PC/laptop. After connecting cable user has to select host Interface, then select Connection to a PLC. The figure 8 is showing the cable connection of PLC with PC/Laptop.

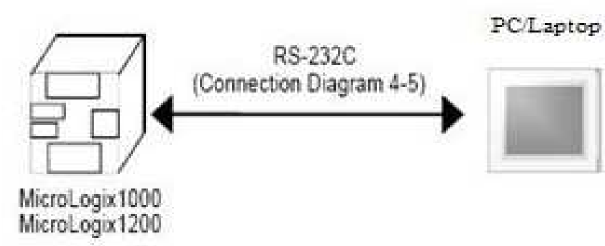

Figure .8. Interfacing of PLC with PC/Laptop

4. Result

The operation of rheometer is successfully done with use of PLC. The ladder program is developed in the RS link 500 software and checked for any bugs before downloading into PLC. And after that rheometer is operated and rheogram is plotted is plotted for the rubber sample as shown in the figure 9. In the present industrial world, a flexible system that can be controlled by user at site is preferred. Systems, whose logic can be modified but still, used without disturbing its connection to external world, is achieved by PLC. Utilizing the industrial sensors such as limit switches, ON-OFF switches, timer contact, counter contact etc., PLC controls the total rheometer. The drive to the solenoid valves, motors, indicators, enunciators, etc are controlled by the PLCs. With the ladder diagram programming of PLC the rheometer was operated in its both modes i.e. auto mode as well as manual mode.

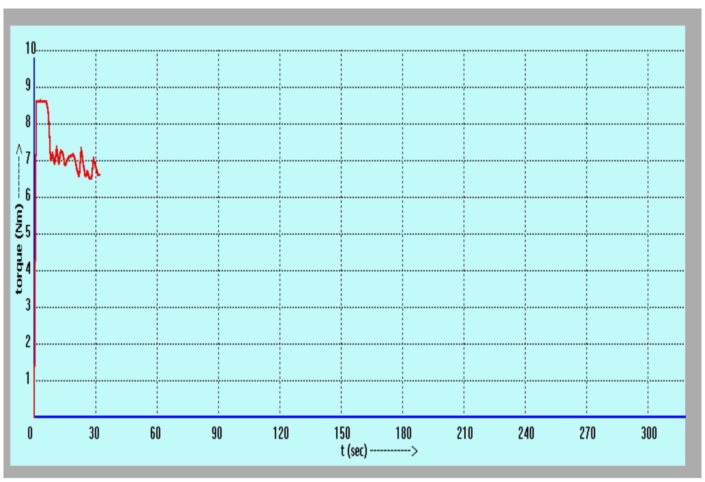

Figure 9. Rheogram Plot for Rheometer

4. 1 Future Scope

The PLC offers a compromise between advance control techniques and present day technology. The future enhancement would be adding some intelligence to the rheometer system, such as automatic detection of the sample present on the die or not. This can be done by use of some advance PLC having artificial intelligence or neural fuzzy based processors. It will also reduce the operator intervention. The MMI may be used with touch sensitive screens making easier for the operators.

ACKNOWLEDGMENT

We wish to thank Mrs. Shashi Sharma, CSIO Chandigarh for helping out in this work.

References

[1] Bode B, Auge J, Trettin T, "Micro-rheometer for inline oil quality detection," IEEE Transl. Electronics, ICSENS IEEE Sensor Conference proceedings, Oct 2004, pp.802-805.
[2] I. D. Rosca and J. M., "Rheometers in scanning mode by changing the rates of linear temperature programming for the cure of rubbers," Polymer Testing journal of Elsevier Science, Volume 23, Issue 1, February 2004, pp. 59-67.
[3] Johanna Aho and Seppo Syrjala , "Measurement of the pressure dependence of viscosity of polymer melts using a back pressure-regulated capillary rheometer," Journal of Applied Polymer Science, wiley publications, Volume 117, Issue 2, pp. 1076–1084, July 2010.
[4] A.A. Collyer and D.W. Clegg, "Rheological Measurement, Second Edition", Chapman and Hall, 1998.
[5] Martin Rides, Crispin R.G. Allen and Graham D. Sims, " Rheological characterization of a highly filled curing system using a disposable extrusion rheometer", Polymer Testing, Journal of Elsevier Science Volume 29, Issue 2, April 2010, pp. 164-169
[6] A Kumar and S Sharma, "Development of Rheometer", IE (I) Journal –ET, vol.84, July 2003, pp.30-32.
[7] Carlos A Smith and Armando B Corripio, "Principles And Practices of Automatic Process Control", John Wiley & Sons July 2005.
[8] Krishan kant, "Computer-based Industrial Control", Prentice hall of India Pvt. Ltd, 2004.
[9] Product Manual, " MicroLogix TM 1000 Programmable Controllers ", Rockwell Automation, Allen- Bradley, 1999, pp.39-73

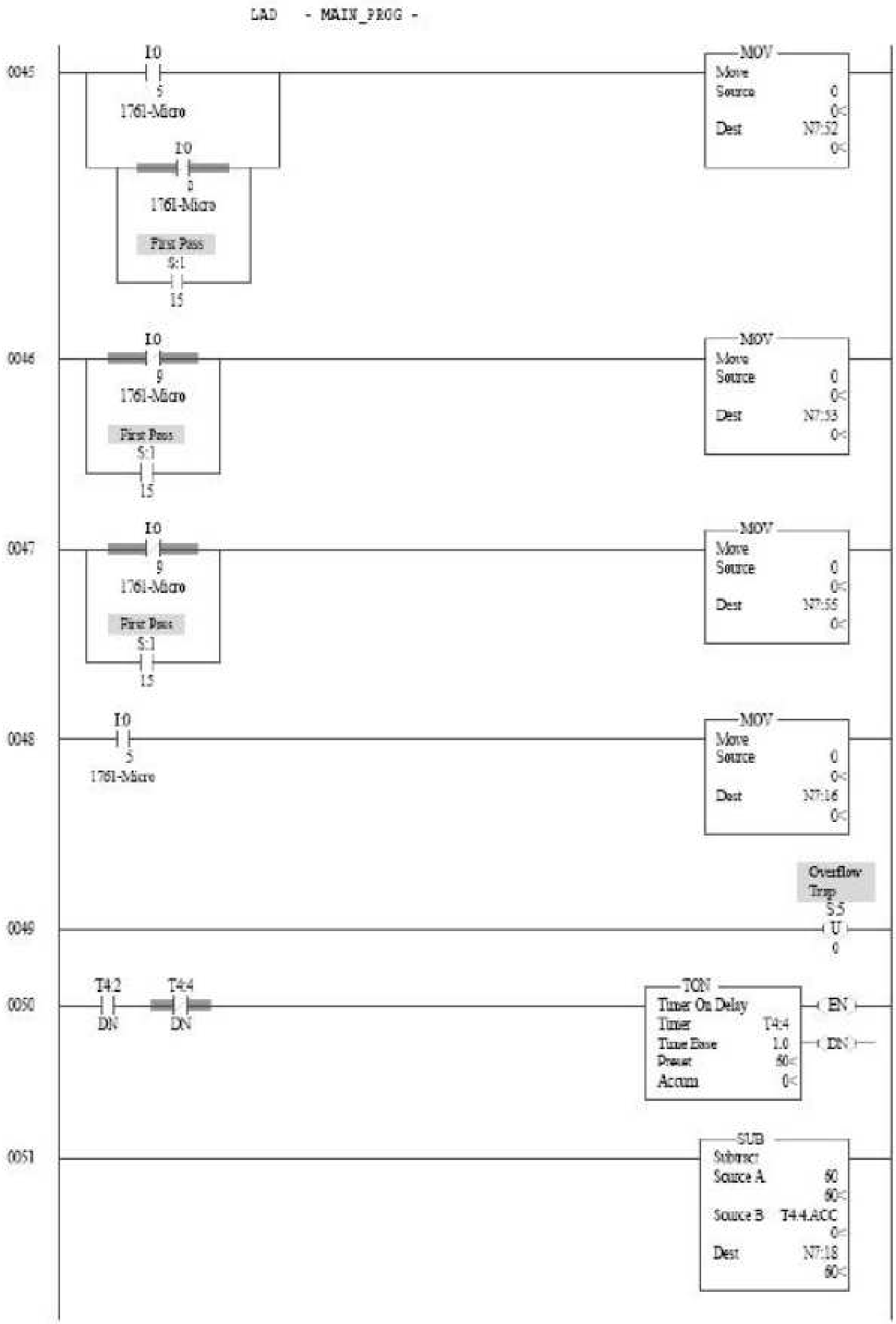

Fig.10. Ladder Diagram Rung of Rheometer