بسم الله الرحمن الرحيم

Sudan University of Science and Technology

College of Graduate Studies

Controlling of Sponge Coke Feeder Using Microcontroller

التحكم في مغذي الفحم الاسفنجي بإستخدام المتحكم الدقيق

A Thesis Submitted for Partial Fulfillment for the Requirements of the Degree of M.Sc. in Mechatronic Engineering

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بسم الله الرحمن الرحيم

قال تعالى:

﴿يَرْفَعِ اللَّهُ الَّذِينَ آمَنُوا مِنكُمْ وَالَّذِينَ أُوتُوا العِلْمَ دَرَجَاتٍ وَاللَّهُ بِمَا تَعْمَلُونَ خَبِيرٌ﴾

صدق الله العظيم

المجادلة (11)

DEDICATION

I dedicate this work:

To…

Soul of my father and to my mother who introduce me to the joy of reading from birth, enabling much study to take place today.

To…

all those who directed me to the way studying and rat me on the right study tract.

To….

my close friend Mutwakil Mohammed.

ACKNOWLEGMENT

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ABSTRACT

The boilers it is the main parts in Garri4 station, but the cost of fuel and extend the life of boilers parts it is the big problems facing the station, the main goals for this research it is control the sponge coke to operate the boiler using the microcontroller according to boiler temperature. The measured temperature by temperature sensor it is send to microcontroller to compare this temperature with the set point temperature range, and then send command to the motor to change the speed according to the comparison result. A simulation results shows that this control strategy it is effective to control the feeding system.

المستخلص

تعتبر المراجل من الأجزاء الرئيسية في محطة قري 4 . ولكن تعتبر تكلفة الوقود وإطالة عمر أجزاء المراجل هي أحد أهم المشاكل التي تواجه المحطة. الهدف الأساسي لهذا البحث هو التحكم في الفحم الإسفنجي لتشغيل المرجل بإستخدام المتحكم الدقيق وفقاً لدرجة حرارته. ثم محاكاة النظام بإستخدام برنامج Proteus. وترسل درجة حرارة المرجل المقاسة بواسطة حساس درجة الحرارة إلى المعالج الدقيق و الذي يقارنها مع درجة الحرارة المرجعية ثم يرسل أمراً إلى المحرك لتغير سرعته حسب نتيجة المقارنة بينهما. أظهرت نتائج المحاكاة أن هذه الاستراتيجية فعالة للتحكم في النظام.

TABLE OF CONTENTS

LIST OF FIGURES

LIST of TABLES

LIST of ABBREVIATION

CFB	Circulating fluidized bed
LCD	Liquid crystal display
PLC	Programmable logic control
BFB	Bubbling fluidized bed
I/O	Input/output
IC	Integrated circuit
RAM	Random access memory
ROM	Read only memory
ADC	Analog to digital converter
DAC	Digital to analog converter
CMOS	Complementary metal–oxide–semiconductor
AVR	Aboriginal Voices Radio
RISC	Reduced instruction set computing
DC	Direct current motor
EMF	Electromagnetic force
TC	Thermocouple
RTD	resistance temperature detectors
CJC	Cold junction compensation
LED	Light emitted diode
ASCII	American standard code for information interchange
EEPROM	Electrically erasable programmable read- only memory

USBISP	Universal serial bus in-system programing
μC	Microcontroller
PWM	Pulse width modulation

CHAPTER ONE

INTRODUCTION

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INTRODUCTION

1.1 General Review

Fuel cost and extends the life of the boiler parts are the single most important operating cost in a Circulating Fluidized Bed (CFB) boiler. In Garri4 power plant the operator continuously monitor the temperature of the boiler and manually change the set point of sponge coke to maintain the temperature in the operating range, when the temperature of the boiler is below than 900C° this reduce efficiency of the boiler and then power generated, when the temperature exceed 950C° this lead to overheat and thermal stresses on boiler parts. A well-designed CFB boiler can burn sponge coke with a fairly high efficiency and within acceptable levels of gaseous emission. In this research it is proposed that by accurate metering of sponge coke fed to boiler to maintain constant boiler temperature range. A temperature sensor senses the boiler temperature and send it to microcontroller, the microcontroller compare sensed temperature of boiler with set point temperature range and send order to vary the speed of motor and which affects to mass flow rate of sponge coke to boiler. The mass flow rate of sponge coke is found by multiplying the speed of motor by weight sensed on the belt and display it on LCD. This research presented examples of feed rate control according to boiler temperature range and offers recommendations for a successful feed rate control upgrade.

1.2 Problem Statement

The boiler temperature must not below 900C° to achieve peak boiler efficiency and must not exceed 950C° to reduce overheat and thermal stresses on the boiler parts and save fuel consumption. Manual manipulation of feed will not achieve the optimum working temperature for the boiler.

1.3 Objectives

The main intention of this research is design and simulates a control system for the feed rate of sponge coke to boiler according to boiler temperature range using microcontroller.

1.4 Methodology

The thesis methodology is undertaken according to these stages:

1. Study the previous works.
2. Understand the Garri4 power station and its main parts.
3. Study and understand the system component such as microcontroller, direct current motor (DC motor), L293D, LM35 temperature sensor, thermocouple and LCD.
4. Understand the Bascom and Proteus Software’s.
5. Build the complete system using Proteus software.
6. Evaluate the system performance based on simulation results.

1.5 Thesis Outline

This research consists of five chapters including chapter one. Chapter two presents the previous study and general overview about the techniques used to control feeder, feeder types, definition of control system and CFB boiler. Chapter three discusses the components of feeding system control. Chapter four gives simulation results under different values of temperature. Chapter five consists of conclusion and proposes recommendations for future work.

CHAPTER TWO

FEEDER AND CONTROL SYSTEM

CHAPTER TWO

FEEDER AND CONTROL SYSTEM

2.1 Previous Study

Recent research works have discussed the control of coke feeder by using different types of control systems. G. D. ALvoRD has developed the study which related generally to method and apparatus for material feeding machines and more particularly to the method and apparatus of a continuous batch feeder control for regulating the flow of material that is delivered from the feeder conveyor. This study is particularly advantageous for use in controlling feeder conveyors The principal object of this study is the method and apparatus providing an accurate control of' the volume of the material delivered by a feeder machine, Another object of' this study is the provision of a feeder machine arranged to supply an accurate volume of material over a predetermined period of time. Another object is the provision of a feeder machine arranged to accurately deliver equal volumes of material over similar periods of time another object is the provision of a feeder machine having a relatively high volumetric accuracy [1].

R. N. BATEsoN has developed the study which related to a conventional feeder or conveyor frequently uses a constant speed conveyor such as a belt conveyor and utilizes an adjustable gate for varying the amount of material placed upon the belt conveyor. The gate is used to adjust the load per foot of conveyor belt required for a desired feed rate assuming a constant density for the load. In the usual system, a weight sensing device normally is physically displaced from the gate so that a time lag will occur between the time that the material is metered by the gate and the time that the sensing device measures the load on the belt. This time lag is determined by the physical separation of the gate and the sensing device and the speed of the belt. This physical separation results in a time lag which makes the measurement and ultimate control of the feed rate at the discharge end of the belt difficult. The difficulty is amplified if the feed rate is low and where the belt speed must be low due to some feeding requirement [2].

Kenneth W. Bulllvant has compared between analog and digital feeder types. In the analog type where belt speed is multiplied by load and compared with a set mass flow, belt speed is increased or decreased to match the present. Analog mass flow control systems require calibration and are not computer compatible. A digital mass flow control system never needs calibration, has greater accuracy, and is computer compatible so as to be coupled to a printer or blender. In a digital control system, all signals are either on or off as opposed to a voltage signal which is only as accurate as the meters detecting the same. Analog systems involve a feedback concept wherein a comparison is made and a corrective action taken. In a digital control system, there is a continuous measuring of the load and a continuous computation of the speed required, thereby eliminating control system turning and hunting as well as any feedback signal. The digitally controlled mass flow feeder of the present study which for purposes of disclosure is presented in the form of a gravimetric feeder continuously measures the load and computes the required speed for the conveyor belt [3].

Tian Shuai1, Zhang Yu-yan1, Fu Guoxiu have developed the study which related to the coal feeder control system based on digital weighing sensor is designed. Digital weighing sensor is used for weight acquisition, S7-200PLC is used for measurement and control, and touch screen is used for developing user interface. On the one hand, the system extends the function of the Programmable Logic Controller (PLC) and constitutes the independent system of the interactive interface. On the other hand, the operating number of stage buttons, switches and instruments can be reduced greatly and the peripheral circuit of PLC is simpler, which improve greatly security and reliability, enhance event recall ability and improve the measurement accuracy [4].

2.2 Garri4 Power Plant General Description

The Garri 4 power plant include the two CFB boilers with rated capacity 240 t/h, two steam turbine-generators with rated capacity 55MW, divided into block 1, block 2 and common plant equipment. The composing of the power plant is as below [3]:

- CFB combustor and boiler with auxiliaries system.
- Flue gas system.
- Ash handling system.
- Air supply system.
- Fuel storage and supply system.
- Steam turbine unit system.
- Generators system.
- Condenser and condensate system.
- Feed water system.
- Auxiliary Boiler (AB) system.
- Emergency diesel.
- Cooling water systems.
- Water supply and discharge system.
- Chlorination plants system.
- Water demineralization plant system.
- Industrial waste water treatment plant system.
- Sanitary waste water treatment plant System.
- Potable service water system.

- Chemical dosing system.
- Sampling system for the boiler and water / steam cycle.
- Fire protection system.
- Laboratory for sample analysis.
- Emission monitoring system.
- Service and instrument air system.
- Electrical systems.
- Connection to the grid.
- Instrumentation and control.
- Civil works and building facilities.

- Workshop equipment and installations, mobile equipment [1].

Figure 2.1 shows photo for Garri4 plant.

Figure 2.1: Garri4 plant

2.3 Coke Preparation and Transportation System

The sponge coke conveying system is composed of the outside conveying system and the power plant inside conveying system. The outside conveying system is in the Khartoum Refinery Company (KRC) scope. The Power Plant inside conveying system is in scope of the plant. The outside sponge coke conveying system will start from receiving station which is located in the sponge coke pool of KRC. The receiving station is comprised with four hoppers. A vibrating feeder was installed under each hopper.

The four vibrating feeders will discharge the sponge coke to 01# belt conveyor and then transfer the sponge coke to sponge coke yard in the Garri4 power plant via 02#, 03#, 04#, 05#, 06# and 07# belt conveyors. Specification of belt conveyors from receiving station to sponge coke yard in the Garri4 power plant was: belt width is 800mm, belt speed is 1.6m/s and rated capacity is 200t/h. The 07# belt conveyors are installed in the sponge coke storage shed which is in the power plant.

The capacity of sponge coke storage shed is 27000t. It will last for 30 days for operation at 2x240t/h boilers Maximum Continuous Rating (MCR) as design fuel. The sponge coke conveying system in power plant transport the coke from sponge coke storage shed to the day coke silos which are in the main power building. It consists three sections which are named 1#, 2# and 3#. These sections are arranged with double-line, one run one stand-by generally. Two lines can be permitted to operate at the same time if needed. When one operates, the output is 80t/h. These conveyor belts will have a width of 800/650mm, from the U shaped type and will run approximately 800mm above the surrounding ground level. The traveling speed of the belts is 0.8m/sec, and 1.0m/sec. The crushers are arranged between 1# belt conveyor and 2# belt conveyor. The magnetic separator is adopted as twin-stage. The continuous weight measuring devices is installed on 1# belt conveyor which is in the power plant [1].

2.4 Description of Sponge Coke Feeding System to Boiler

Appropriate size sponge coke is fed into sponge coke silo by belt conveyor. Sponge coke leaving silo hopper outlet passes through a manual gate. Then sponge coke fed into furnace via corresponding gravimetric belt feeder, manual silo discharge gate is provided to isolate sponge coke silo and gravimetric belt feeder.

The abrasion-resistant rotary airlock feeder which is downstream gravimetric belt feeder is used as final feed equipment to feed the sponge coke into combustion area customized. Sponge Coke Fuel Trip (SpCFT) valve will prevent high temperature furnace gases come into the gravimetric belt feeder and protect the belt. The SpCFT valve can endure 1100˚C. High pressure sealing air it is provided at the inlet of feeder to prevent reversible flow. Figure 2.2 shows sponge coke feeding system to boiler [1].

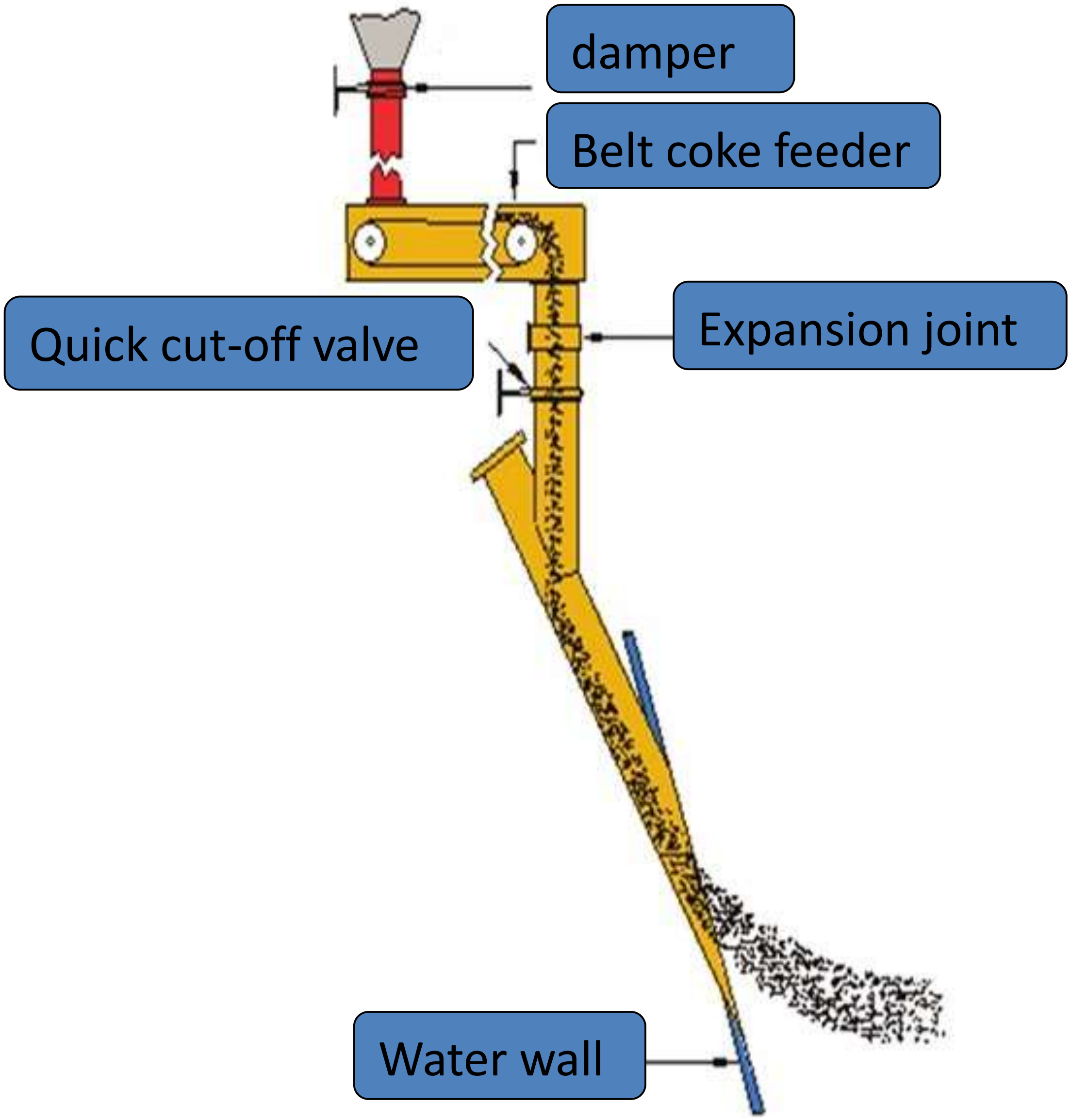


Figure 2.2: Sponge coke feeding system to boiler in Garri4

2.5 Garri4 Feeder Theory of Operation

The feeder measures the actual density of sponge coke and varies the belt speed to match actual with demanded combustion control delivery requirements. The microprocessor system continuously sample the weight signal from the load cell measure the weight (force) on the weight span and transmit a signal which is directly proportional to the weight sensed by the microprocessor. Belt speed is determined from a tachometer proportional to motor rpm, whose signal is then converted to belt speed travel per second value by the microprocessor.

The load cell (weight per unit length) and motor (belt travel per second) values are then multiplied together, resulting in a weight per second deliver. This value is then compared against the equivalent demand delivery and, if different, an error signal is sent by microprocessor to adjust the motor control to match actual with demanded delivery. The microprocessor unit also integrates the actual delivery data in time to display feed rate per hour and provide totalized delivery record. Figure 2.3 shows the schematic diagram for Garri4 feeder [1].

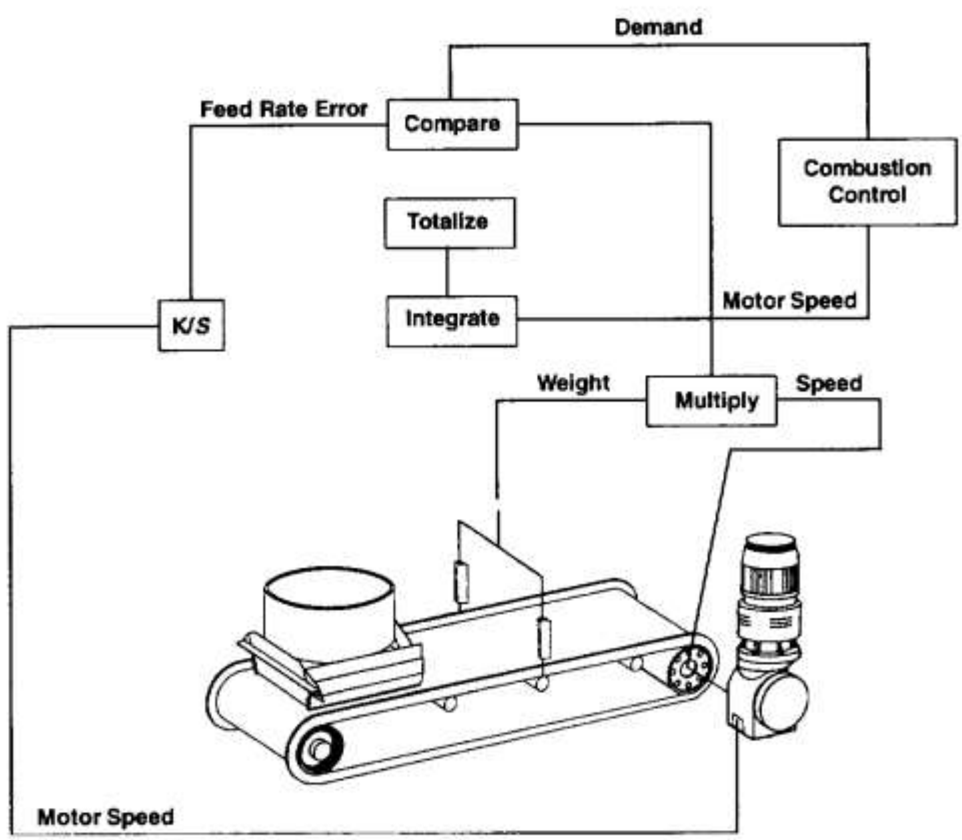


Figure 2.3: Schematic diagram for Garri4 feeder

2.6 Garri4 Feeder Technical Specifications

Model: EG 18.

Feeder body material: stainless steel.

Capacity: 2–10 t/h.

Motor power: 2.2kw.

Belt width: 600mm.

Feeding distance (length): 8388.5mm.

Belt thickness: 10mm.

Belt material: rubber.

Clean out motor power: 0.37kw.

Clean out motor speed: 1380r/min.

Reducer 2.2r/min.

Torque: 1150nm [1].

2.7 Feeder

A feeder is an extremely important element in a bulk material handling system, since it is means by which the rate of solid flow from a bin is controlled. When a feeder stops solids flow should ease. When a feeder is turned on, there is should close correlation between it is speed of operation and the rate of discharge of the bulk solid. Feeder differs from conveyor in that the latter is only capable of transporting the material, not modulating the rate of flow. Discharger also not feeder. Such devices are sometimes used to encourage material to flow from a bin, but they cannot control the rate at which material flows. This requires a feeder. Figure 2.4 shows the schematic diagram of feeder [2].

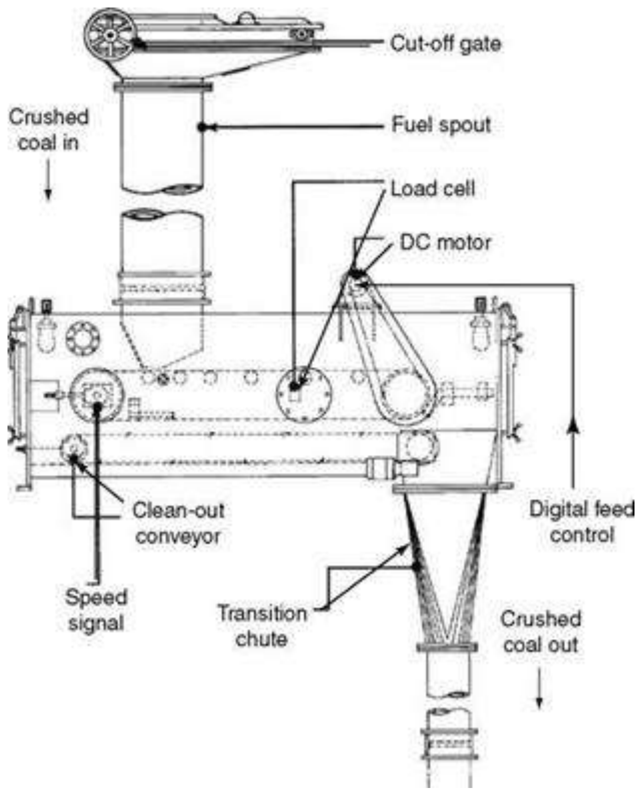


Figure 2.4: Schematic diagram of feeder

2.8 Types of Feeder

There are two basic types of feeders used in industrial plant as follows:

2.8.1 Volumetric feeder control

A volumetric feeder, for example, controls the feed rate by adjusting the speed of motor, but it can measure controlled variables in different ways to control feeding:

- It can measure one key controlled variable, such as the feeding device's motor speed (from the speed pickup sensor), and then send this measurement back to the controller, which compares the measured speed to the required speed set point. If the measured speed doesn't match the set point, the controller sends a feedback signal to automatically change the motor speed so this controlled variable is adjusted to match the set point.

- A sensor on the motor’s shaft can measure the shaft velocity (in revolutions per minute) and send this measurement to the controller, which converts the velocity to a mass flow rate using a formula established when the feeder is calibrated. The controller then sends a feedback signal that continuously adjusts the motor shaft velocity to match the desired mass flow rate; volumetric feeders rely on a uniform supply of material from the storage bin at a consistent bulk density for their operation. Volumetric feeders meter material in direct relation to the capacity of the transfer or conveying media. The discharge rate is dictated by the volume of this media, rotational or translational speed and bulk density. Volumetric feeders are used in many cases as Pre feeding devices for gravimetric type feeders [3].

2.8.2 Gravimetric feeder control

A gravimetric feeder controller automates feeding by comparing key measured variables with their required set points. These comparisons generate an output signal that the controller uses to adjust a feeder control parameter, such as the feeding device’s motor speed. Gravimetric feeders are utilized where an accurate control of material is necessary. Gravimetric feeders are especially useful when handling a material whose basic physical characteristics vary. Gravimetric feeders meter and control the rate of discharge irrespective to material changes.

A gravimetric feeder can be utilized in several different ways: continuous metering with control, wild flow and as a batching feeder. Gravimetric metering devices meter material as a direct function of weight per time interval. A weight sensing device and velocity transmitter send a signal to a multiplier where the two signals are integrated. The output from the multiplier represents an electronic equivalent to the amount of material being metered at that instant [3].

Figure 2.5 shows the volumetric and gravimetric feeders

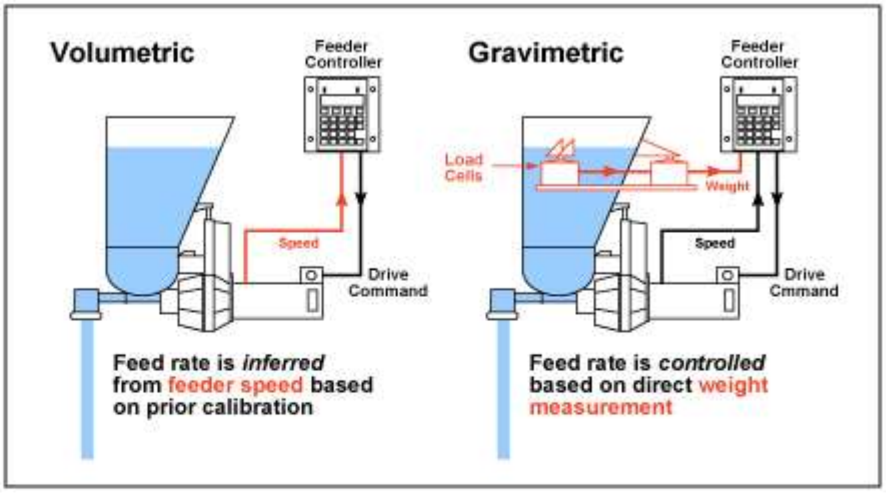


Figure 2.5: Volumetric and gravimetric feeders

2.9 Types of Gravimetric Feeder

There are four basic types of gravimetric feeders, as follows:

- The first type, that which was used on the first generation of gravimetric feeders, utilizes a weight counterbalance. This type of unit uses a weight of known value to counterbalance a metering belt with a desired feed weight (rate). This is accomplished through the utilization of levers, as show in Figure 2.6

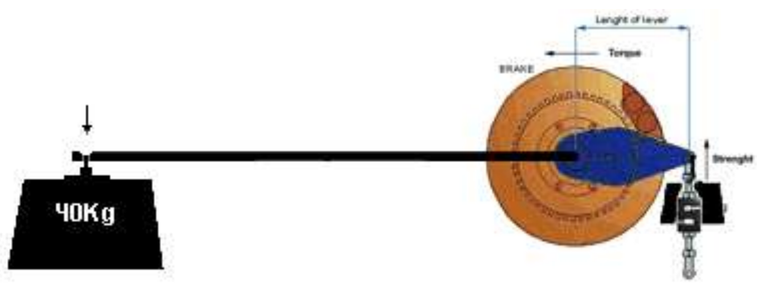


Figure 2.6: Weight counterbalance feeder

- The second type is most similar to the balance beam scale. The deflectional or spring counterbalance type feeder senses a load across its belt. The load causes an elastic element to deflect, either tension or compression and within the elastic limits of the material through the position of equilibrium where the internal forces resist the load force applied. These forces are sent by either strain gage load cells or linear voltage differential transformers. This type of unit is most often used in today's gravimetric feeders, as show in Figure 2.7

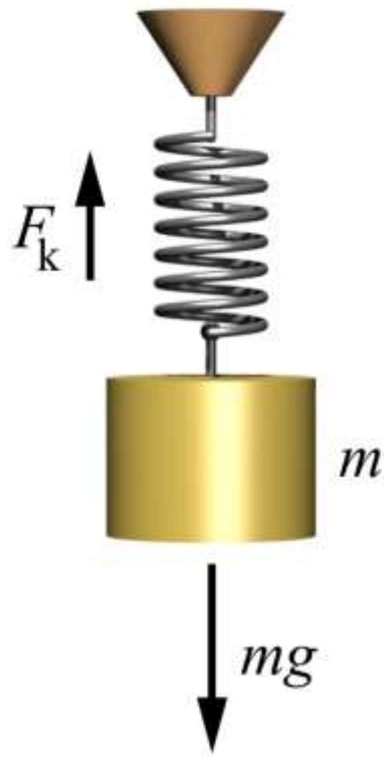


Figure 2.7: Spring counterbalance feeder

- The third type is either pneumatic or hydraulic force counterbalance type feeder is similar to the deflectional or spring counterbalance feeder described above. This type of unit utilizes a hydraulic or pneumatically weight is directly related to the pressure being sensed and is converted and controlled accordingly, as show in Figure 2.8 and 2.9 respectively.

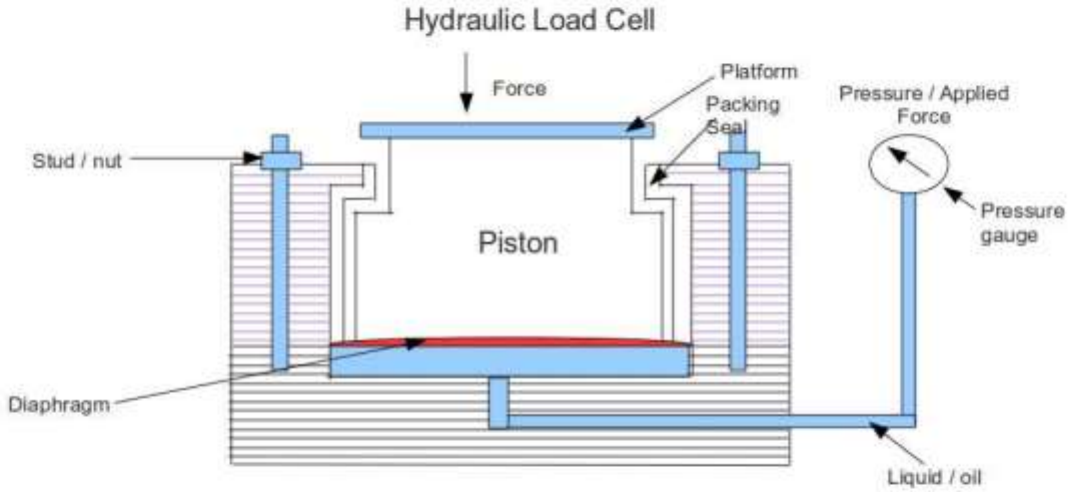


Figure 2.8: Hydraulic force counterbalance feeder

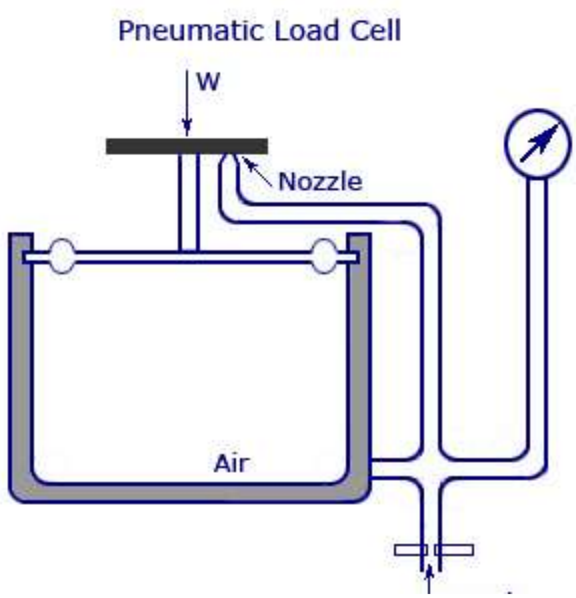


Figure 2.9: Pneumatic force counterbalance feeder

- The last fourth type of gravimetric feeder utilizes nuclear radiation. Radiation is directed at a flow of material on a belt. This type of unit uses the absorption of energy as related to the mass of the absorbing material. Conversion and control then take place. This type of unit has not to date been fully exploited [4]. Figure 2.10 shows the nuclear radiation feeder.

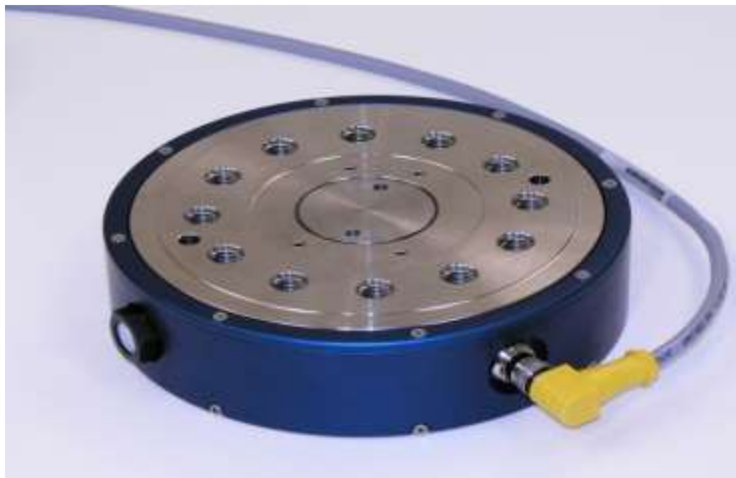


Figure 2.10: Nuclear radiation feeder

2.10 Feeder Selection

There are four main differences between volumetric and gravimetric feeders that will influence equipment selection:

1. Volumetric feeder is open loop devices while gravimetric feeders are close loop. A volumetric feeder is a set speed device that is dependent on constant, coke fed, and it is feed by volume only. The term open loop feeder applies only to a volumetric feeder since there is no feedback information between the feeder output and the drive control system. In contrast, a gravimetric feeder feeds material by weight and provides close loop feedback information about the actual weight being discharged over time.

2. Feed accuracy requirements are different with volumetric and gravimetric control. A volumetric device requires a uniform, consistent, and reliable material

supply to provide feed accuracies without process feedback. If the material feed is inconsistent, feed accuracy will suffer proportionally. On other hand gravimetric device will make operating adjustment using process feedback to correct for inconsistent material properties.

3. In-house maintenance differs between simple volumetric and more complex gravimetric feeders. Volumetric feeder require basic mechanical and electrical skills, whereas gravimetric feeder it is more complex

4. Volumetric and gravimetric feeders have a major cost difference primarily because of the more complex controls required for the gravimetric feeder that may not be necessary for the volumetric feeder [4].

2.11 Control System

A control system is a collection of components working together under the direction of some machine intelligence. In most cases, electronic circuits provide the intelligence, and electromechanical components such as sensors and motors provide the interface to the physical world. A good example is the modern automobile. Various sensors supply the on-board computer with information about the engine's condition. The computer then calculates the precise amount of fuel to be injected into the engine and adjusts the ignition timing. The mechanical parts of the system include the engine, transmission, wheels, and so on. To design, diagnose, or repair these sophisticated systems, must be understood the electronics, mechanics, and control system principles. In days past, so-called automatic machines or processes were controlled either by analog electronic circuits, or circuits using switches, relays, and timers. Since the advent of the inexpensive microprocessor, more and more devices and systems are being redesigned to incorporate a microprocessor controller. Examples include copying machines, soft-drink machines, robots, and industrial process controllers. Many of these machines are taking advantage of the increased processing power that comes with the microprocessor and, as a consequence, are becoming more sophisticated and are including new features. Taking again the modern automobile as an example, the original motivation for the on-board computer was to replace the mechanical and vacuum-driven subsystems used in the distributor and carburettor. Once a computer was in the design, however, making the system more sophisticated was relatively easy. For example, self-adjusting fuel/air ratio for changes in altitude. Also, features such as computer-assisted engine diagnostics could be had without much additional cost. This trend toward computerized control will no doubt continue in the future [5].

2.11.1 Open-loop control systems

Control systems can be broadly divided into two categories: open and closed loop systems. In an open-loop control system, the controller independently calculates exact voltage or current needed by the actuator to do the job and sends it. With this approach, however, the controller never actually knows if the actuator did what it was supposed to because there is no feedback. This system absolutely depends on the controller knowing the operating characteristics of the actuator. Open-loop control systems are appropriate in applications where the actions of the actuator on the process are very repeatable and reliable. Relays and stepper motors are devices with reliable characteristics and are usually open-loop operations. Actuators such as motors or flow valves are sometimes used in open-loop operations, but they must be calibrated and adjusted at regular intervals to ensure proper system operation [5]. Figure 2.11 shows the open loop control system

Figure 2.11: Open loop control system

2.11.2 Closed-loop control systems

In a closed-loop control system, the output of the process (controlled variable) is constantly monitored by a sensor as shown in Figure 2.12. The sensor samples the system output and converts this measurement into an electric signal that it passes back to the controller. Because the controller knows what the system is actually doing, it can make any adjustments necessary to keep the output where it belongs. The signal from the controller to the actuator is the forward path, and the signal from the sensor to the controller is the feedback (which closes the loop). The feedback signal is subtracted from the set point at the comparator (just ahead of the controller). By subtracting the actual position (as reported by the sensor) from the desired position (as defined by the set point), we get the system error. The error signal represents the difference between "where you are" and "where you want to be". The controller is always working to minimize this error signal. A zero error means that the output is exactly what the set point says it should be using a control strategy, which can be simple or complex, the controller minimizes the error. A simple control strategy would enable the controller to turn the actuator on or off. For example, a thermostat cycling a furnace on and off to maintain a certain temperature. A more complex control strategy would let the controller adjust the actuator force to meet the demand of the load [5].

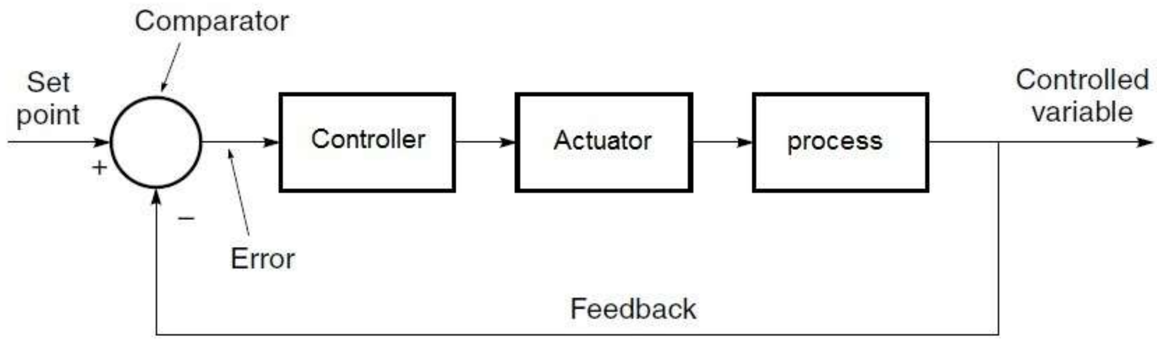


Figure 2.12: Closed loop control system

2.11.3Analog and digital control systems

In an analog control system, the controller consists of traditional analog devices and circuits, that is, linear amplifiers. The first control systems were analog because it was the only available technology. In the analog control system, any change in either set point or feedback is sensed immediately, and the amplifiers adjust their output (to the actuator) accordingly. In a digital control system, the controller uses a digital circuit.

In most cases, this circuit is actually a computer usually microprocessor or microcontroller-based. The computer executes a program that repeats over-and-over (each repetition is called an iteration or scan). The program instructs the computer to read the set point and sensor data and then use these numbers to calculate the controller output (which is sent to the actuator). The program then loops back to the beginning and starts over again. The total time for one pass through the program may be less than 1 millisecond (ms). The digital system only “looks” at the inputs at a certain time in the scan and gives the updated output later. If an input changes just after the computer looked at it, that change will remain undetected until the next time through the scan. This is fundamentally different than the analog system, which is continuous and responds immediately to any changes. However, for most digital control systems, the scan time is so short compared with the response time of the process being controlled, for all practical purposes, the controller response is instantaneous [5].

2.11.4 Motion control

Motion control is a broad term used to describe an open-loop or closed-loop electromechanical system wherein things are moving. Such a system typically includes a motor, mechanical parts that move, and (in many cases) feedback sensor(s). Automatic assembling machines, industrial robots, and numerical control machines are examples [5].

2.12 Petroleum Coke

The petroleum coke belongs to a group of materials with high carbon content. It is produced by coking of feed stocks obtained from residue of primary and secondary oil refining processes. At present, these are three different types of coking processes: delayed, fluid and flexi coking, the delayed coke is mostly used. Coke products from a delayed coker are classified as shot, sponge or needle coke depending on their chemical and physical characteristics. Shot coke, almost always solid as fuel is hard, having spherical form and physically produced through precipitating asphaltenes, sponge coke, mostly used for anode-grade is dull and black, having porous, amorphous structure; and needle coke, not used in anode production is silver-gray, having crystalline broken needle structure, and chemically produced through cross linking of condensed aromatic hydrocarbons during coking reactions [6].

2.13. Petcoke Uses

Petcoke may be combusted as fuel in industrial and power generating plants. Cement plants and power plants are currently the two greatest consumers of petcoke. There is some limited use as space heating and in commercial brick furnaces in Europe, and a small but emerging market as a metallurgical coal blending component for the steel industry. In the United States, the high sulfur content may limit the petcoke in a coal/petcoke blend in a plant designed for coal. However, more recently designed CFB boilers can accommodate 100% high sulfur coke. Fuel grade petcoke can substitute for “steam coal” in power plant boilers, having the advantage of a higher heating value. Conventional coal-fired boilers can blend petcoke with steam coal, and newer boiler designs have replaced steam coal with petcoke entirely. Cement plants consume fuel-grade petcoke in rotary furnaces [7].

2.14 Petcoke Composition

Petcoke is composed primarily of carbon. The specific chemical composition of petcoke depends on the composition of the petroleum feedstock used in refining. Petcoke impurities (i.e., the nonelemental carbonaceous substances) include some residual hydrocarbons left over from processing (referred to as volatiles), as well as elemental forms of nitrogen, sulfur, nickel, vanadium, and other heavy metals. These impurities exist as a hardened residuum captured within coke’s carbon matrix. Table 2.1 provides an observed range of petcoke properties for green and calcined petcoke [7].

Table 2.1: Petcoke elemental composition (By weight percent)

Composition	Green	Calcined
Carbon	89.58–91.80	98.40
Hydrogen	3.71–5.04	0.14
Oxygen	1.30–2.14	0.02
Nitrogen	0.95–1.20	0.22
Sulfur	1.29–3.42	1.20
Ash (including heavy metals such as nickel and vanadium)	0.19–0.35	0.35
Carbon – Hydrogen Ratio	18:1–24:1	910:1

Figure 2.13 show sponge coke.

Figure 2.13: Sponge coke

2.15 Fluidized Bed Boilers

Fluidized bed combustion was not used for energy production until the 1970's, although it had been used before in many other industrial applications.

Fluidized bed combustion has become very common during the last decades. One of the reasons is that a boiler using this type of combustion allows many different types of fuels, also lower quality fuels, to be used in the same boiler with high combustion efficiency. Furthermore, the combustion temperature in a fluidized bed boiler is low, which directly induce lower NOx emissions. Fluidized bed combustion also allows a cheap SOx reduction method by allowing injection of lime directly into the furnace [8].

2.15.1 Principles

The principle of a fluidized bed boiler is based on a layer of sand or a sand-like media, where the fuel is introduced into and combusted. The combustion air flows through the sand layer from an opening in the bottom of the boiler. Depending on the velocity of the combustion air, the layer gets different types of fluid like behaviour; this type of combustion has the following merits:

- Fuel flexibility; even low-grade coal such as sludge or refuse can be burned.
- High combustion efficiency.
- Low NOx emission.
- Control of SOx emission by desulfurization during combustion, this is achieved by employing limestone as a bed material or injecting limestone into the bed.
- Wide range of acceptable fuel particle sizes, pulverizing the fuel is unnecessary.
- Relatively small installation, because flue gas desulfurization and pulverizing facilities are not required [8].

2.15.2 Main types

There are two main types of fluidized bed combustion boilers: Bubbling Fluidized Bed (BFB) and CFB boilers. In the bubbling type, because the velocity of the air is low, the medium particles are not carried above the bed. The combustion in this type of boiler is generated in the bed. Figure 2.14 shows an example of a BFB boiler schematic. The CFB mode of fluidization is characterized by a high slip velocity between the gas and solids and by intensive solids mixing.

High slip velocity between the gas and solids, encourages high mass transfer rates that enhance the rates of the oxidation (combustion) and desulfurization reactions, critical to the application of CFB's to power generation. The intensive solids mixing insure adequate mixing of fuel and combustion products with combustion air and flue gas emissions reduction reagents. In the circulating type, the velocity of air is high, so the medium sized particles are carried out of the combustor. The carried particles are captured by a cyclone installed in the outlet of combustor. Combustion is generated in the whole combustor with intensive movement of particles. Particles are continuously captured by the cyclone and sent back to the bottom part of the combustor to combust unburned particles. This contributes to full combustion. The CFB boiler Figure 2.15 has the following advantages over the BFB boiler:

- Higher combustion efficiency.
- Lower consumption of limestone as a bed material.
- Lower NOx emission.
- Quicker response to load changes [8].

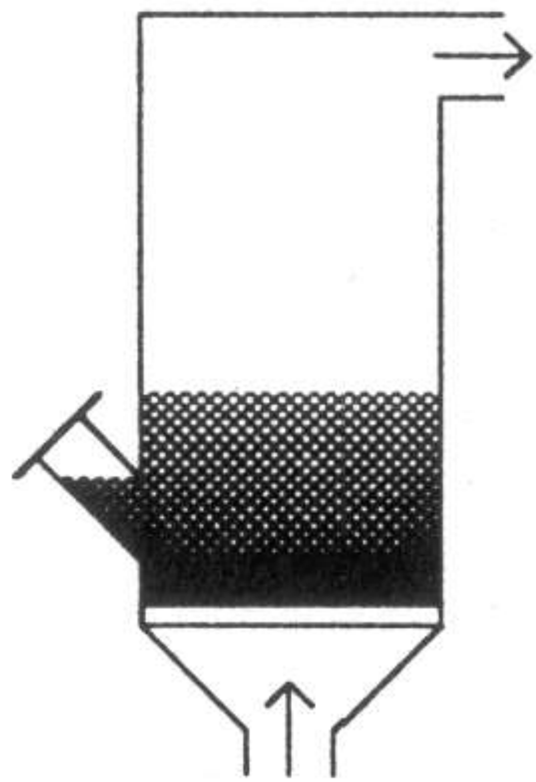


Figure2.14: BFB boiler

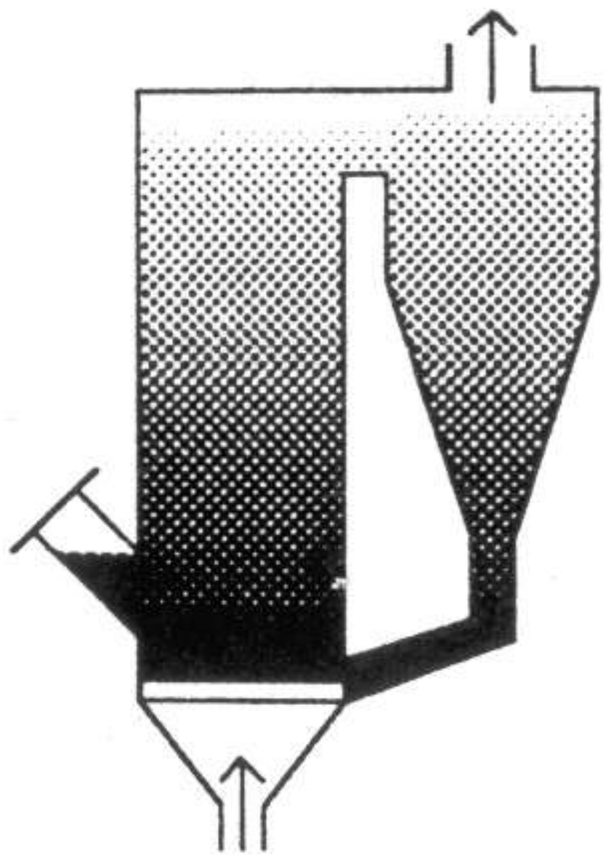


Figure2.15: CFB boiler

CHAPTER THREE

SYSTEM COMPONENTS

CHAPTER THREE

SYSTEM COMPONENTS

3.1 Microcontroller

A microprocessor by itself is not a computer. To be functional, the microprocessor must be connected to other integrated circuits that provide the memory and Input/output (I/O) capability. A microcontroller is a computer on a single Integrated Circuit (IC), designed specifically for control applications. It consists of a microprocessor, memory (both Random Access Memory (RAM) and Read Only Memory (ROM)), I/O ports, and possibly other features such as timers and Analog to Digital Converters (ADCs)/ Digital to Analog Converter (DACs). Having the complete controller on a single chip allows the hardware design to be simple and very inexpensive. Microcontrollers are showing up increasingly in products as varied as industrial applications, home appliances, and toys. In such uses as these, they are called embedded controllers because the controller is located physically in the equipment being controlled.

The main difference between microprocessors and microcontrollers is that microprocessors are being designed for use in microcomputers where greater speed and larger word size are the driving requirements, whereas microcontrollers are evolving toward reduced chip count by integrating more hardware functions on the chip. Most control applications do not need the 32-bit word size and 500MHz speed of the newer microprocessors. Eight or 16 bits and 1MHz will work just fine in many applications, and the single-chip microcontroller costs much less. Another difference between microprocessors and microcontrollers concerns the instruction set. The microprocessor tends to be rich in instructions dealing with moving data into and out of memory. The microcontroller has fewer memory-move instructions and more bit-handling instructions. The reason for the lack of memory-move instructions is that the microcontroller typically has only a small amount of RAM, which it uses only as a scratch pad. The additional bit-handling instructions were included because they are so useful in control system applications. For example, in a control system, each separate bit of a parallel output word might control a different device, such as a motor or indicator light. The bit-handling instructions allow the software to turn one device easily on or off without affecting the others [5].

3.2 Atmega32 Microcontroller

The ATmega32 is a low-power Complimentary Metal Oxide Semiconductor (CMOS) 8-bit microcontroller based on the Aboriginal Voices Radio (AVR) enhanced Reduced Instruction Set computing (RISC) architecture. By executing powerful instructions in a single clock cycle, the ATmega32 achieves throughputs approaching 1MIPS per MHz allowing the system designed to optimize power consumption versus processing speed. Figure 3.1 shows the pins diagram of the Atmega 32. Table 3-1 shows the Atmega 32 microcontroller pins descripition [9].

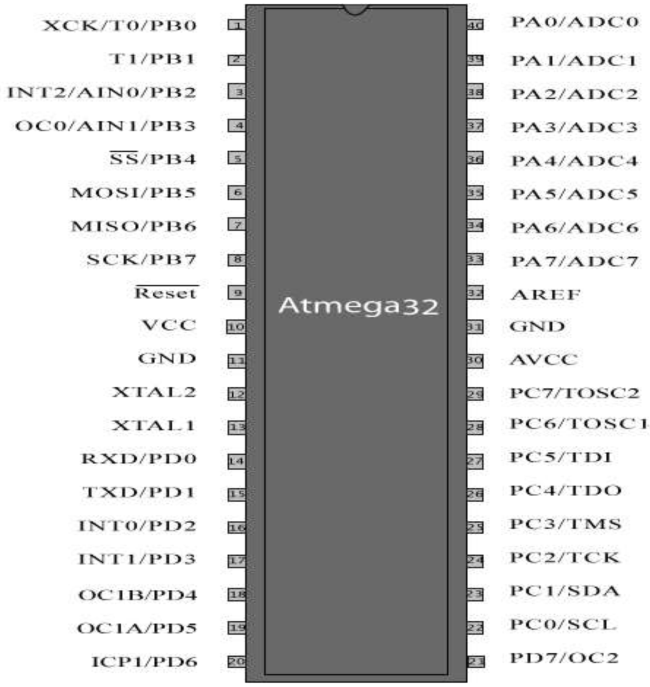


Figure 3.1: Atmega32 pins diagram

Table 3.1: Microcontroller pin description

Pin No.	Pin name	Description	Alternate Function
1	(XCK/T0) PB0	I/O PORTB, Pin 0	T0: Timer0 External Counter Input. XCK : USART External Clock I/O
2	(T1) PB1	I/O PORTB, Pin 1	T1:Timer1 External Counter Input
3	(INT2/AIN0) PB2	I/O PORTB, Pin 2	AIN0: Analog Comparator Positive I/P INT2: External Interrupt 2 Input
4	(OC0/AIN1) PB3	I/O PORTB, Pin 3	AIN1: Analog Comparator Negative I/P OC0 : Timer0 Output Compare Match Output

5	(SS) PB4	I/O PORTB, Pin 4	In System Programmer (ISP) Serial Peripheral Interface (SPI)
6	(MOSI) PB5	I/O PORTB, Pin 5	
7	(MISO) PB6	I/O PORTB, Pin 6	
8	(SCK) PB7	I/O PORTB, Pin 7	
9	RESET	Reset Pin, Active Low Reset	
10	Vcc	Vcc = +5V	
11	GND	GROUND	
12	XTAL2	Output to Inverting Oscillator Amplifier	
13	XTAL1	Input to Inverting Oscillator Amplifier	
14	(RXD) PD0	I/O PORTD, Pin 0	USART Serial Communication Interface
15	(TXD) PD1	I/O PORTD, Pin 1	
16	(INT0) PD2	I/O PORTD, Pin 2	External Interrupt INT0
17	(INT1) PD3	I/O PORTD, Pin 3	External Interrupt INT1
18	(OC1B) PD4	I/O PORTD, Pin 4	Pulse Width Modulation(PWM) Channel Outputs
19	(OC1A) PD5	I/O PORTD, Pin 5	

20	(ICP) PD6	I/O PORTD, Pin 6	Timer/Counter1 Input Capture Pin
21	PD7 (OC2)	I/O PORTD, Pin 7	Timer/Counter2 Output Compare Match Output
22	PC0 (SCL)	I/O PORTC, Pin 0	TWI Interface
23	PC1 (SDA)	I/O PORTC, Pin 1	
24	PC2 (TCK)	I/O PORTC, Pin 2	JTAG Interface
25	PC3 (TMS)	I/O PORTC, Pin 3	
26	PC4 (TDO)	I/O PORTC, Pin 4	
27	PC5 (TDI)	I/O PORTC, Pin 5	
28	PC6 (TOSC1)	I/O PORTC, Pin 6	Timer Oscillator Pin 1
29	PC7 (TOSC2)	I/O PORTC, Pin 7	Timer Oscillator Pin 2
30	AVcc	Voltage Supply = Vcc for ADC	
31	GND	GROUND	
32	AREF	Analog Reference Pin for ADC	
33	PA7 (ADC7)	I/O PORTA, Pin 7	ADC Channel 7

34	PA6 (ADC6)	I/O PORTA, Pin 6	ADC Channel 6
35	PA5 (ADC5)	I/O PORTA, Pin 5	ADC Channel 5
36	PA4 (ADC4)	I/O PORTA, Pin 4	ADC Channel 4
37	PA3 (ADC3)	I/O PORTA, Pin 3	ADC Channel 3
38	PA2 (ADC2)	I/O PORTA, Pin 2	ADC Channel 2
39	PA1 (ADC1)	I/O PORTA, Pin 1	ADC Channel 1
40	PA0 (ADC0)	I/O PORTA, Pin 0	ADC Channel 0

3.3 Direct Current Motor

A Direct Current (D/C) motor is any of a class of electrical machines that converts direct current electrical power into mechanical power.

3.3.1 Working principle of a DC motor

A motor is an electrical machine which converts electrical energy into mechanical energy. The principle of working of a DC motor is that whenever a current carrying conductor is placed in a magnetic field, it experiences a mechanical force. The direction of this force is given by fleming's left hand rule and it's magnitude is given by F=BIL. Where B is the magnetic flux density, I is the current and L is the length of the conductor within the magnetic field. Fleming's left hand rule as shown in Figure 3.2 If we stretch the first finger, second finger and thumb of our left hand to be perpendicular to each other and direction of magnetic field is represented by the first finger, direction of the current is represented by second finger then the thumb represents the direction of the force experienced by the current carrying conductor.

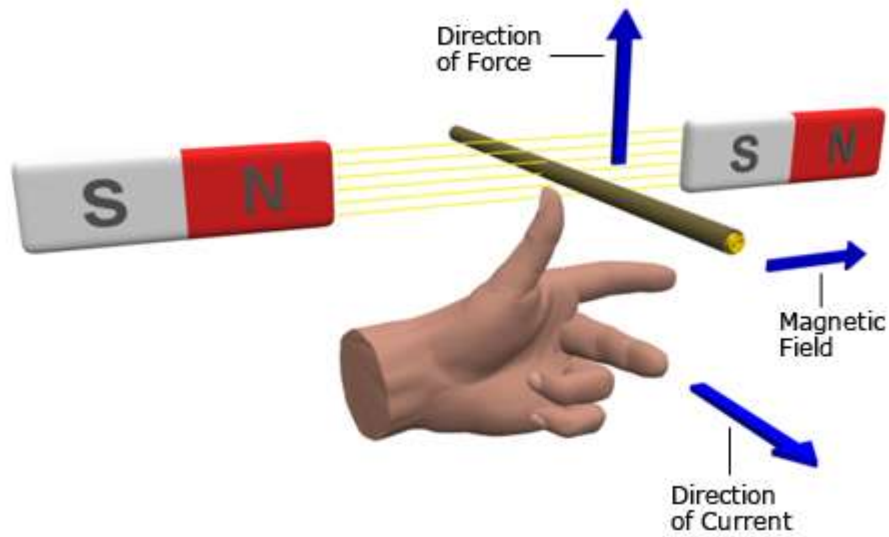


Figure3.2: Fleming’s left hand rule

When armature windings are connected to a DC supply, current sets up in the winding. Magnetic field may be provided by field winding (electromagnetism) or by using permanent magnet. In this case, current carrying armature conductors experience force due to the magnetic field, according to the principle stated above [10].

3.3.2 Speed control

Generally, the rotational speed of a DC motor is proportional to the Electro Magnetic Force (EMF) in its coil (equal to the voltage applied to it minus voltage lost on its resistance), and the torque is proportional to the current. Speed control can be achieved by variable battery tappings, variable supply voltage, resistors or electronic controls. The direction of a wound field DC motor can be changed by reversing either the field or armature connections but not both. This is commonly done with a special set of contactors (direction contactors). The effective voltage can be varied by inserting a series resistor or by an electronically controlled switching device made of thyristors, transistors, or, formerly, mercury rectifiers[10].

3.3.3 Types of DC motors

DC motors are usually classified of the basis of their excitation configuration as follows:

- Separately excited (field winding is fed by external source) as shown in Figure 3.3
- Self-excited as shown in Figure 3.4 can be classified into the following categories:
  - Series wound (field winding is connected in series with the armature).
  - Shunt wound (field winding is connected in parallel with the armature).
  - Compound wound.
  - Long shunt.
  - Short shunt [10].

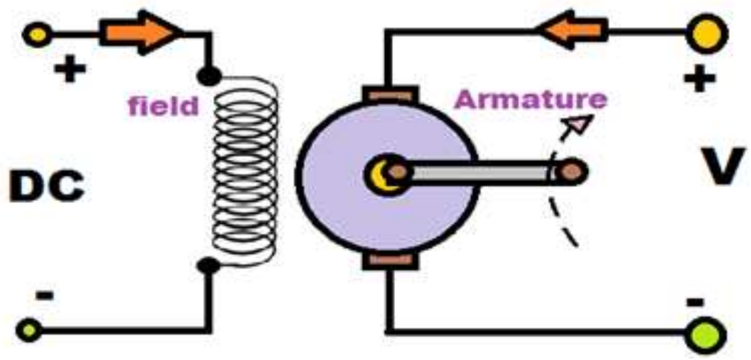
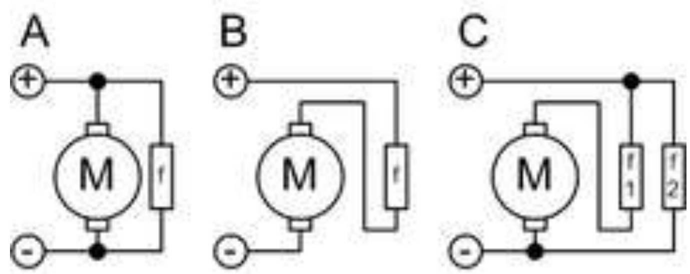


Figure 3.3: Separately excited



(A) Shunt (B) Series (C) Compound

Figure 3.4: Self excited

3.3.4 Protection

To extend a DC motor’s service life, protective devices and motor controller are used to protect it from mechanical damage, excessive moisture, high dielectric stress and high temperature or thermal overloading. These protective devices sense motor fault conditions and either annunciate an alarm to notify the operator or automatically de-energize the motor when a faulty condition occurs. For overloaded conditions, motors are protected with thermal overload relays. Bi-metal thermal overload protectors are embedded in the motor's windings and made from two dissimilar metals. They are designed such that the bimetallic strips will bend in opposite directions when a temperature set point is reached to open the control circuit and de-energize the motor. Heaters are external thermal overload protectors connected in series with the motor's windings and mounted in the motor contactors. Solder pot heaters melt in an overload condition, which cause the motor control circuit to de-energize the motor. Bimetallic heaters function the same way as embedded bimetallic protectors. Fuses and circuit breakers are overcurrent or short circuit protectors. Ground fault relays also provide overcurrent protection [11].

3.3.5 DC motor control using pulse-width modulation

Pulse-width modulation is an entirely different approach to controlling the torque and speed of a DC motor. Power is supplied to the motor in a square wavelike signal of constant magnitude but varying pulse width or duty cycle. Duty cycle refers to the percentage of time the pulse is high (per cycle). Figure 3.5 shows the waveforms for four different speeds. For the slowest speed, the power is supplied for only one-quarter of the cycle time (duty cycle of 25%). The frequency of the pulses is set high enough to ensure that the mechanical inertia of the armature will smooth out the power bursts, and the motor simply turns at a constant velocity of about one-quarter speed. For a 50% duty cycle (power on one-half the time), the motor would turn at about half speed, and so on. In real life, nonlinear factors cause the motor to go slower than the straight proportions suggest, but the principle still holds that is the speed of a motor can be regulated by pulsing the power [12].

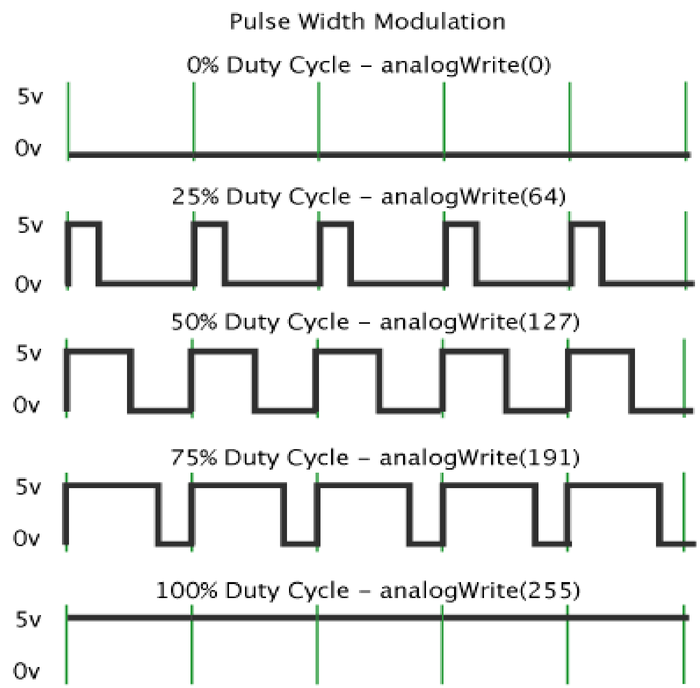


Figure 3.5: Waveforms for four different speeds

3.4 L293D

L293D is a dual H-bridge motor driver IC. Motor drivers act as current amplifiers since they take a low-current control signal and provide a higher-current signal. This higher current signal is used to drive the motors. L293D contains two inbuilt H-bridge driver circuits. In its common mode of operation, two DC motors can be driven simultaneously, both in forward and reverse direction. The motor operations of two motors can be controlled by input logic at pins 2, 7, 10 and 15. Input logic 00 or 11 will stop the corresponding motor. Logic 01 and 10 will rotate it in clockwise and anticlockwise directions, respectively.

Enable pins 1 and 9 (corresponding to the two motors) must be high for motors to start operating. When an enable input is high, the associated driver gets enabled. As a result, the outputs become active and work in phase with their inputs. Similarly, when the enable input is low, that driver is disabled, and their outputs are off and in the high-impedance state. Figure 3.6 shows pins diagram of the L293D. Table 3.2 shows the L293D pins Description [13].

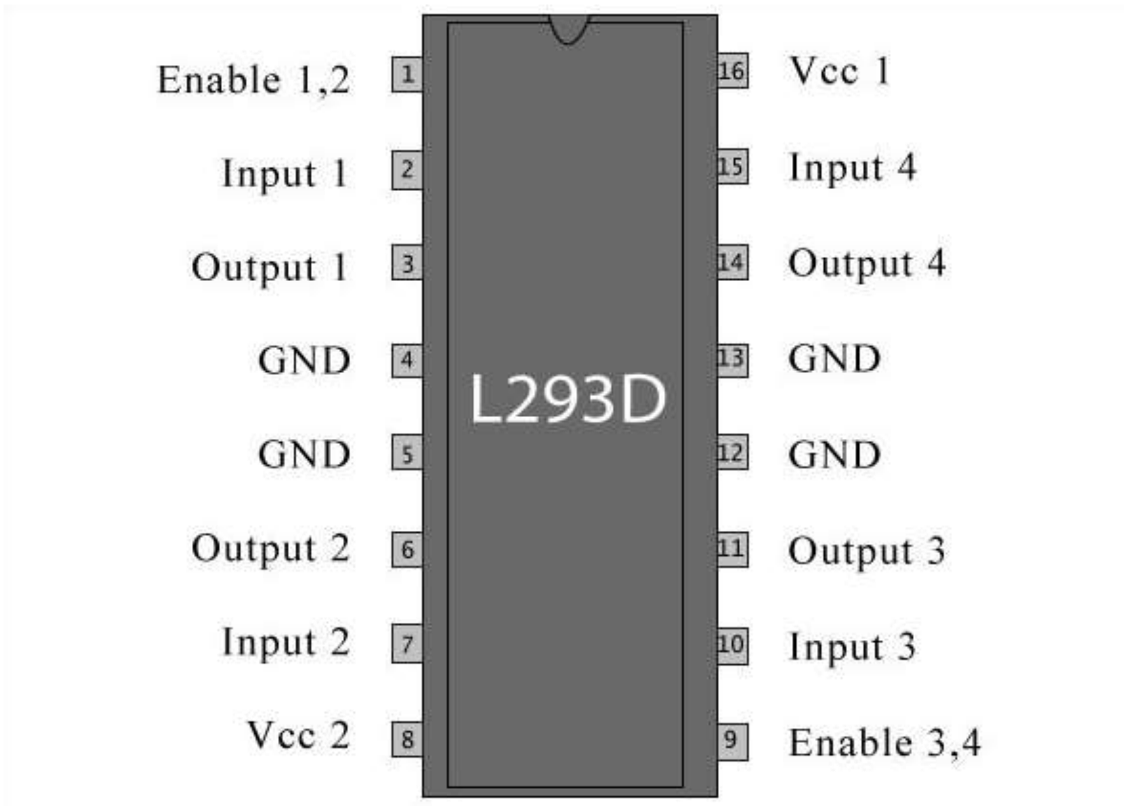


Figure 3.6: L293D pins diagram

Table 3.2: L293D pin description

Pin No	Function	Name
1	Enable pin for Motor 1; active high	Enable 1,2
2	Input 1 for Motor 1	Input 1
3	Output 1 for Motor 1	Output 1
4	Ground (0V)	Ground
5	Ground (0V)	Ground

6	Output 2 for Motor 1	Output 2
7	Input 2 for Motor 1	Input 2
8	Supply voltage for Motors; 9-12V (up to 36V)	Vcc_2
9	Enable pin for Motor 2; active high	Enable 3,4
10	Input 1 for Motor 1	Input 3
11	Output 1 for Motor 1	Output 3
12	Ground (0V)	Ground
13	Ground (0V)	Ground
14	Output 2 for Motor 1	Output 4
15	Input2 for Motor 1	Input 4
16	Supply voltage; 5V (up to 36V)	Vcc_1

3.5 LM35 Temperature Sensor

LM35 is a precision IC temperature sensor with its output proportional to the temperature (in °C). The sensor circuitry is sealed and therefore it is not subjected to oxidation and other processes. With LM35, temperature can be measured more accurately than with a thermistor. It also possesses low self-heating and does not cause more than 0.1°C temperature rise in still air. The LM35 thus has an advantage over linear temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient centigrade scaling. The operating temperature range is from -55 °C to 150 °C. The output voltage varies by 10mV in response to every °C rise/fall in ambient temperature, *i.e.*, its scale factor is 0.01V/°C. Figure 3.7 shows the pins diagram of the LM35 [14].

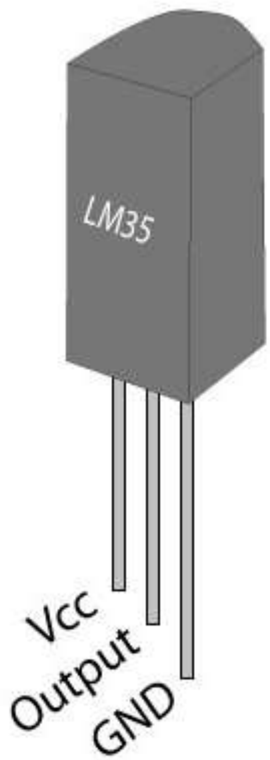


Figure 3.7: LM35 pins diagram

Table 3.3: LM35 pin description

Pin No	Function	Name
1	Supply voltage; 5V (+35V to -2V)	Vcc
2	Output voltage (+6V to -1V)	Output
3	Ground (0V)	Ground

3.6 Thermocouples

By far the most commonly used temperature sensor is the thermocouple or TC. The key reasons are that thermocouples are low cost, extremely rugged, can be run long distances, are self-powered, and there are many types of thermocouples available to cover a wide range of temperatures. Low cost speaks for itself in many applications. Ruggedness means they will last in many different environments, including outdoors and with exposure to harsh factory environments. Metal-sheathed TCs are available to help protect them in harsh or corrosive environments, or they can be run inside conduit piping. Different alloys allow different range and sensitivity of measurement. Some common types of TCs include J, K, T, E, R, S, B, and N, which refers to the type of material from which they are constructed as shown in Table 3.4. The type J, K, and T are the most common and are readily available in spools or pre-made forms. The ranges for all types of thermocouples can be found in National Institute of St (NIST) One important property of thermocouples is their nonlinearity, that is, thermocouple output voltage is not linear with respect to temperature. Consequently, to convert output voltage to temperature accurately requires mathematical linearization. Thermocouples consist of two dissimilar metals joined (either welded or twisted) together at one end and open at the other. They operate on the principle of the thermoelectric effect and can be thought of as the junction of two different metals producing a voltage when a thermal difference exists between the two metals (also known as the seebeck effect). The voltage signal at the open or output end is a function of the temperature at the closed end. As the temperature rises, the voltage signals increases. Here's what really happens. The open-end signal is a function of not only the closed-end temperature (the point of measurement) but also the temperature of the open end. Only by holding T2 at a standard temperature can the measured signal be considered a direct function of the change in T1. The open-end voltage, V1, is a function of not only the closed end temperature (the temperature at the point of measurement), but also the temperature at the open end (T2). The reason the voltage is developed is because different materials produce different voltage for the same temperature difference. This is the reason for the two different metals. If they were the same metals, then the voltage would be zero. The industry standard for T2 is 0ºC. Most tables and charts make the assumption that T2 is at 0ºC. In industrial instrumentation, the difference between the actual temperature T2 and 0ºC is usually corrected electronically within the instrument. This adjustment is known as cold junction compensation or ice-point reference [14].

3.6.1 Advantages

Thermocouples have many advantages over other types of temperature sensors. For one, they are self-powered, requiring no external power supply. They are also extremely rugged and can withstand harsh environments. Thermocouples are also inexpensive compared to Resistance Temperature Detectors (RTDs) and thermistors and come in a wide variety of types with wide temperature ranges [14].

3.6.2 Disadvantages

Thermocouples are nonlinear and require Cold-Junction Compensation (CJC) for linearization. Also, the voltage signals are low, typically in the tens to hundreds of microvolts, requiring careful techniques to eliminate noise and drift in low-voltage environments. Accuracies are typically in the range of 1-3% depending on wire alloy consistency and cold junction accuracies [14].

Table 3.4: Thermocouple types

Thermocouple Type	Materials	Range
J	Iron(+) Constantan(-)	-40º to 760ºC
K	Chromel (+) Alumel (-	-200º to +1200ºC
T	Copper(+)	-270º to 400ºC

	Constantan(-)	
B	Platinum 30% Rhodium (+) Platinum 6% Rhodium (-)	20º to 1820ºC
E	Chromel (+) Constantan (-)	-270º- 910ºC
N	Nicrosil (+) Nisil (-)	-270º-1300ºC
S	Platinum 13% Rhodium (+) Platinum (-)	-50º to 1760ºC

3.7 Load Cell

A load cell is a transducer that is used to create an electrical signal whose magnitude is directly proportional to the force being measured. The various types of load cells include hydraulic load cells, pneumatic load cells and strain gauge load cells. Figure 3.8 shows the schematic diagram of load cell [5].

Figure 3.8: Schematic diagram of load cell

3.7.1 Strain gauge load cell

Through a mechanical construction, the force being sensed deforms a strain gauge. The strain gauge measures the deformation (strain) as a change in electrical resistance, which is a measure of the strain and hence the applied forces. A load cell usually consists of four strain gauges in a Wheatstone bridge configuration. Load cells of one strain gauge (quarter bridge) or two strain gauges (half bridge) are also available. The electrical signal output is typically in the order of a few millivolts and requires amplification by an instrumentation amplifier before it can be used. The output of the transducer can be scaled to calculate the force applied to the transducer. Sometimes a high resolution ADC, typically 24-bit, can be used directly.

Strain gauge load cells are the most common in industry. These load cells are particularly stiff, have very good resonance values, and tend to have long life cycles in application. Strain gauge load cells work on the principle that the strain gauge (a planar resistor) deforms/stretches/contracts when the material of the load cells deforms appropriately. These values are extremely small and are relational to the stress and strain that the material load cell is undergoing at the time. The change in resistance of the strain gauge provides an electrical value change that is calibrated to the load placed on the load cell.

Strain gauge load cells convert the load acting on them into electrical signals. The gauges themselves are bonded onto a beam or structural member that deforms when weight is applied. In most cases, four strain gauges are used to obtain maximum sensitivity and temperature compensation. Two of the gauges are usually in tension, and two in compression, and are wired with compensation adjustments. The strain gauge load cell is fundamentally a spring optimized for strain measurement. Gauges are mounted in areas that exhibit strain in compression or tension. The gauges are mounted in a differential bridge to enhance measurement accuracy. When weight is applied, the strain changes the electrical resistance of the gauges in proportion to the load. Other load cells are fading into obscurity, as strain gauge load cells continue to increase their accuracy and lower their unit costs [5].

3.7.2 Common shapes

There are several common shapes of load cells:

- Shear beam, a straight block of material fixed on one end and loaded on the other.
- Double-ended shear beam, a straight block of material fixed at both ends and loaded in the centre.
- Compression load cell, a block of material designed to be loaded at one point or area in compression.
- S-type load cell, a S-shaped block of material that can be used in both compression and tension (load links and tension load cells are designed for tension only).
- Rope clamp, an assembly attached to a rope and measures its tension. Rope clamps are popular in hoist, crane and elevator applications due to the ease of their installation; they have to be designed for a large range of loads, including dynamic peak loads, so their output for the rated load tends to be lower than of the other types [5].

3.7.3 Common issues

- Mechanical mounting: The cells have to be properly mounted. All the load force has to go through the part of the load cell where its deformation is sensed. Friction may induce offset or hysteresis. Wrong mounting may result in the cell reporting forces along undesired axis, which still may somewhat correlate to the sensed load, confusing the technician.

- Overload: Within its rating, the load cell deforms elastically and returns back to its shape after being unloaded. If subjected to loads above its maximum rating, the material of the load cell may plastically deform, this may result in a signal offset, loss of linearity, difficulty with or impossibility of calibration, or even mechanical damage to the sensing element (e.g. delamination, rupture).
- Wiring issues: The wires to the cell may develop high resistance, e.g. due to corrosion. Alternatively, parallel current paths can be formed by ingress of moisture. In both cases the signal develops offset (unless all wires are affected equally) and accuracy is lost.
- Electrical damage: The load cells can be damaged by induced or conducted current. Lightings hitting the construction or arc welding performed near the cells, can overstress the fine resistors of the strain gauges and cause their damage or destruction. For welding nearby, it is suggested to disconnect the load cell and short all its pins to the ground, nearby the cell itself. High voltages can break through the insulation between the substrate and the strain gauges.

Nonlinearity: At the low end of their scale, the load cells tend to be nonlinear. This becomes important for cells sensing very large ranges, or with large surplus of load capability to withstand temporary overloads or shocks (e.g. the rope clamps) [5].

3.7.4 Hydraulic load cell

The cell uses conventional piston and cylinder arrangement. The piston is placed in a thin elastic diaphragm. The piston doesn't actually come in contact with the load cell. Mechanical stops are placed to prevent over strain of the diaphragm when the loads exceed certain limit. The load cell is completely filled with oil. When the load is applied on the piston, the movement of the piston and the diaphragm results in an increase of oil pressure which in turn produces a change in the pressure on a Bourdon tube connected with the load cells. Because this sensor has no electrical components, it is ideal for use in hazardous areas. Typical hydraulic load cell applications include tank, bin, and hopper weighing. By example, a hydraulic load cell is immune to transient voltages (lightning) so these types of load cells might be a more effective device in outdoor environments. This technology is more expensive than other types of load cells. It is a more costly technology and thus cannot effectively compete on a cost of purchase basis [5].

3.7.5 Pneumatic load cell

The load cell is designed to automatically regulate the balancing pressure. Air pressure is applied to one end of the diaphragm and it escapes through the nozzle placed at the bottom of the load cell. A pressure gauge is attached with the load cell to measure the pressure inside the cell. The deflection of the diaphragm affects the airflow through the nozzle as well as the pressure inside the chamber [5].

3.8 Liquid Crystal Display

Liquid Crystal Display (LCD) screen is an electronic display module and find a wide range of applications. A 16x2 LCD display is very basic module and is very commonly used in various devices and circuits. These modules are preferred over seven segments and other multi segment Light Emitted Diodes (LEDs). The reasons being: LCDs are economical, easily programmable, have no limitation of displaying special and even custom characters (unlike in seven segments), animations and so on.

A 16x2 LCD means it can display 16 characters per line and there are two such lines. In this LCD each character is displayed in 5x7 pixel matrix. This LCD has two registers, namely command and data. The command register stores the command instructions given to the LCD. A command is an instruction given to LCD to do a predefined task like initializing it, clearing its screen, setting the cursor position, controlling display etc. The data register stores the data to be displayed on the LCD. The data is the American Standard Code for Information Interchange (ASCII) value of the character to be displayed on the LCD. Figure 3.9 shows the LCD pins diagram of LCD [15].

Table 3.5 shows the LCD pins description.

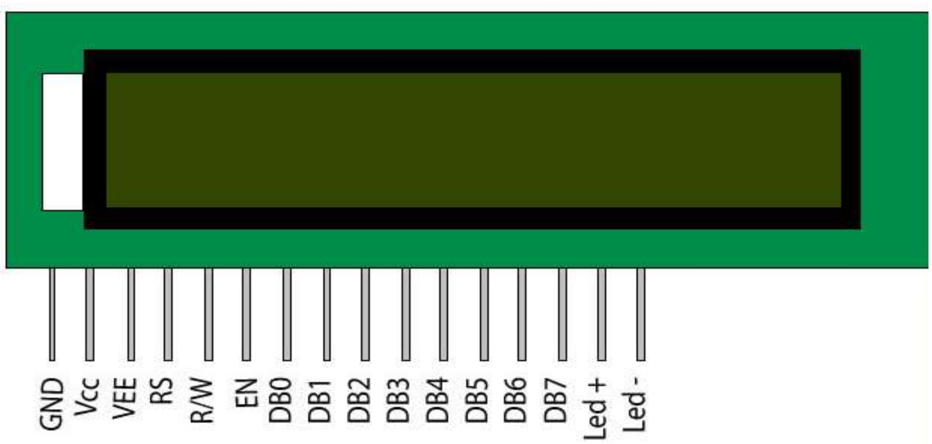


Figure 3.9: LCD Pins diagram

Table 3.5: LCD pins description

Pin No	Function	Name
1	Ground (0V)	Ground
2	Supply Voltage; 5V (4.7V – 5.3V)	Vcc
3	Contrast Adjustment; Through a Variable Resistor	V_{EE}
4	Selects Command Register When Low; and Data Register When High	Register Select
5	Low to Write to The Register; High to Read From The Register	Read/write
6	Sends Data to Data Pins When a High to Low Pulse is Given	Enable
7	8-bit Data Pins	DB0
8		DB1
9		DB2
10		DB3
11		DB4
12		DB5
13		DB6
14		DB7
15	Backlight V_{CC} (5V)	Led+
16	Backlight Ground (0V)	Led-

3.9 BASCOM

BASCOM AVR is a very powerful and easy-to-use compiler for the AVR series of microcontrollers developed by Atmel. The program comes with a very user-friendly interface and a set of simple commands, and provides more flexibility than other programs in this category. Anybody with some basic knowledge of C or C++ can write a successful program using BASCOM, as most of its functions and its statement structure is similar to those in C. Expert users will find many well-known commands and loops that can shorten a lengthy program, thus reducing the flash or Electrical Erasable Programmable Read Only Memory (EEPROM) memory required.

The best thing about BASCOM AVR is that it can directly burn any flash file into a microcontroller using just four wires connected to your computer’s parallel port (printer port, or LPT port). If you are using a laptop or a netbook with just a USB port, then you can compile and save your program as a hex or bin file and burn it later using Universal Serial Bus In-System Programming (USBISP) burners with any third-party flash burning tool. This version comes with a built-in PDF viewer, which helps you to have your circuit schematics and the pin configurations of your µC always handy when you're writing a program. The program's simulator, syntax checker, and emulator tools can help you scan your program for errors before turning it into any µC. The more than a hundred sample programs and free online tutorials included will help you to learn microcontroller programming at home without any extra help. Shortly, if you need to program an AVR this program is a must-have for you. As for the capabilities of its commands and its compiler, they are endless – from making a light bulb blink to controlling an autonomous robot [16].

CHAPTER FOUR

SYSTEM SIMULATION AND RESULTS

CHAPTER FOUR

SYSTEM SIMULATION AND RESULTS

4.1 Simulation Modeling

The purpose of controller is to control the feed rate of sponge coke to boiler according to boiler temperature were modeled in Proteus program which using for simulation. Proteus is a high performance simulator for multiprocessors. It is fast, accurate and flexible, it is one to two orders of magnitude faster than comparable simulators, it can reproduce results from real multiprocessors and it is easily configured to simulate a wide range of architectures. The simulation it is used to explain the control system for sponge coke fed to boiler according to boiler temperature by varying the speed of motor and displays it on LCD.

4.2 System Identification

An Atmega32 AVR microcontroller is used for carrying out all the required computations and control. It has an in-built analog to digital converter. Hence an external analog to digital converter is not required for converting the analog temperature input into digital value. An inexpensive temperature sensor is used for sensing the boiler temperature. The system will get the temperature from the sensor and will display the temperature on the LCD. This temperature is compared with the set point temperature declared by the user. Then the controller send order to motor to increase/decrease/fix the speed.

An Atmega32 AVR microcontroller also having dual function pin used as PWM. Hence an external PWM is not required to generate the waveform. Increase/decrease/fix control it is implemented for controlling the motor speed according to boiler temperature to control the feed rate. The temperature must be within a certain range (900-950 C°) otherwise continuous increase/decrease of the controlling elements (motor). If the boiler temperature less than 900 C° the motor speed increase so as to increase the feed rate of sponge coke. if the boiler temperature is greater than 950˚C the motor speed decrease so as to decrease the feed rate of sponge coke.if the boiler temperature in the range (900-950˚C) the motor speed fix so as to fix the feed rate of sponge coke, LCD is used to view temperatures value, motor speed, mass flow, weight of sponge coke, the microcontroller is used to make decision if motor increase/decrease/fix the speed according to result of comparing the actual temperature value with set point value. Figures 4.1 and 4.2 show the block diagram and simulation model of the system, respectively.

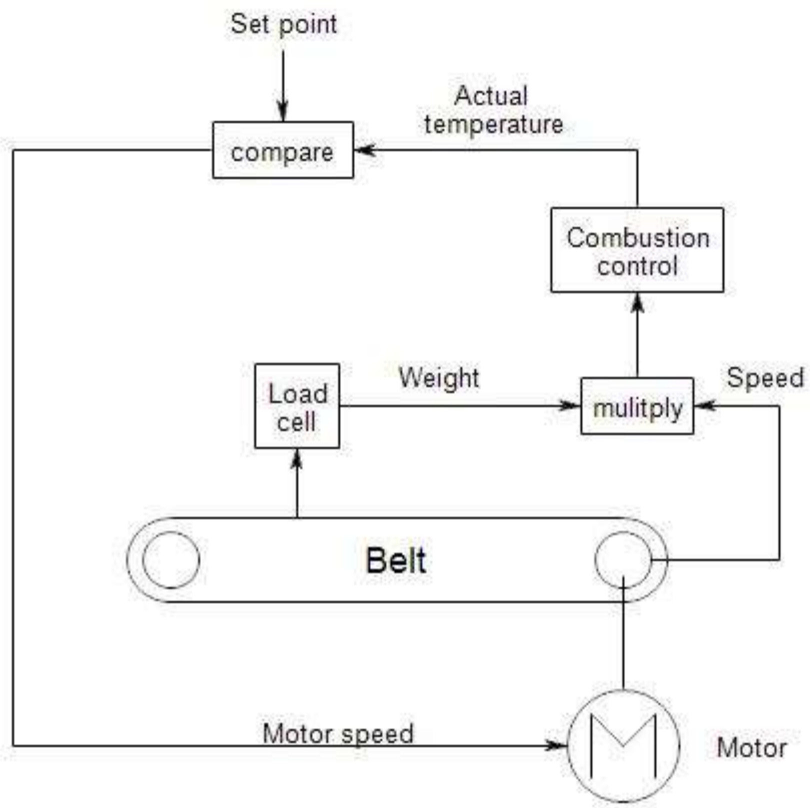


Figure 4.1:Block diagram of the system

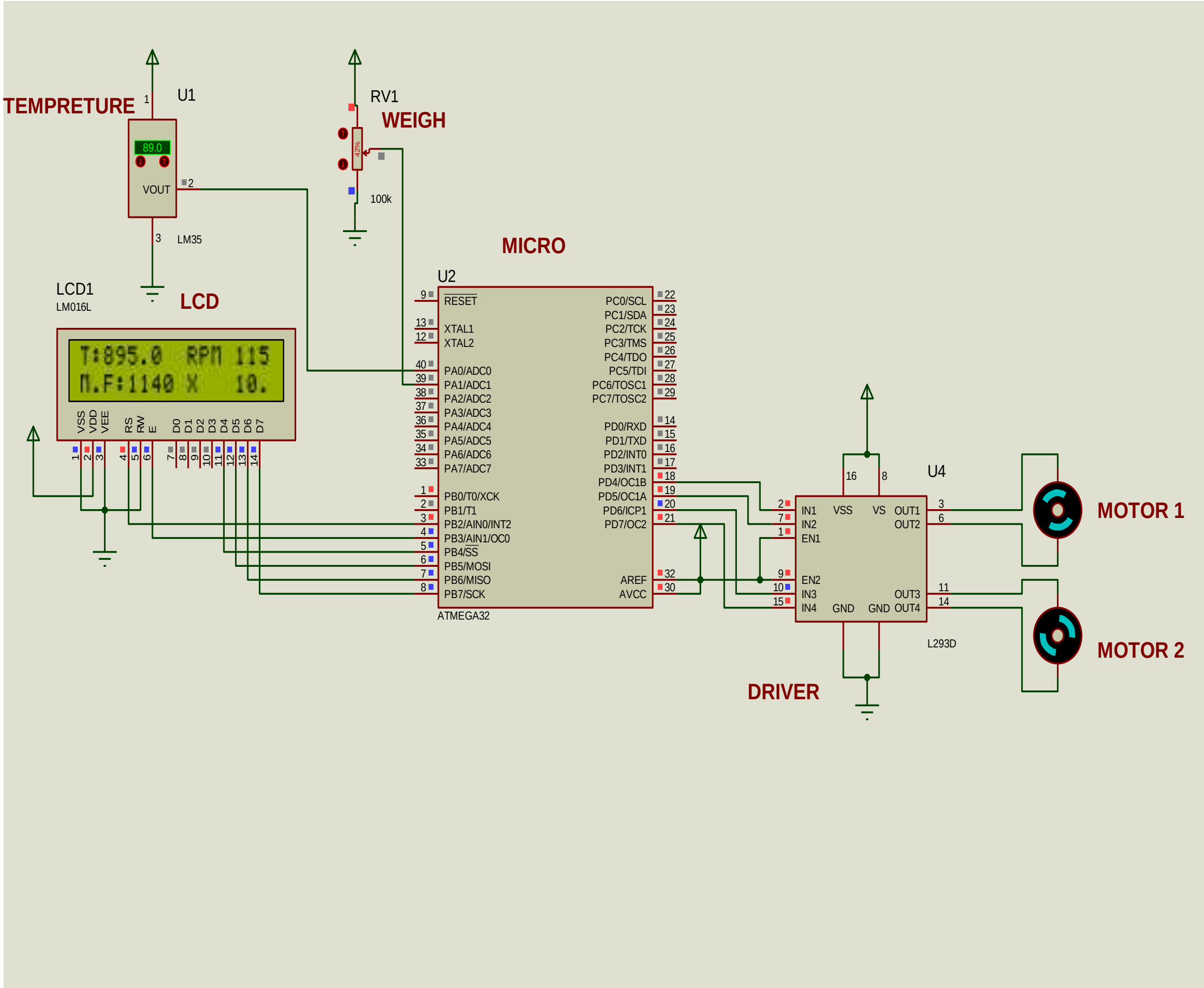


Figure 4.2: Proteus simulation model for control the feed rate according to boiler temperature

The main process sequence will scan all states and start again, there is three states every states check the temperature. The procedure for three states is same. Procedure starts with comparing actual temperature value with set point value, the comparing result which either one of three states:

- The temperature is more than 950˚C.
- The temperature is less than 900˚C.
- The temperature in the range (900-950˚C)

4.3 Circuit Analysis

The temperature sensor LM35 sense the boiler temperature and send it to microcontroller, the microcontroller having Analog to Digital Converter (ADC) which convert the temperature to digital value in the port A pin0 (PA0) this digital value is compared to set point temperature range (900-950°C), the comparison is done on port D in pin4 (PD4), this pin having another function as PWM, the result of comparison is send as pulses to drive the motor, this function is used as PWM to vary the speed of motor.

The signal out from this pin (PD4/OC1B) input to L293D driver at (IN1) which operated as current amplifier to amplify the signal at (OUT1), the pin (PD5/OC1A) always zero value (GROUND) input to driver at (IN2) and out at (OUT2). The cleanout motor is connected to (PD6) and (PD7) pins (0 VOLT) and (5 VOLT) which rotate with constant speed. AVCC used to power the microcontroller, AREF is used for analog to digital converter and to enable the L293D driver.

The load cell (load sensor or force sensor) which sense the force on the belt of the feeder due to gravity, this analog value is converted to digital value using ADC) at port A pin1 (PA1), this value is multiplied by the motor speed to provide mass flow of sponge coke per unit length of the belt. DC motor1 is used to drive the feeder and DC motor2 to clean the bottom side of the feeder. The LCD 16x2 is used to display the sensed temperature and the speed of motor, mass flow rate of sponge coke, and the load on the belt.

Port B is used to connect the LCD to microcontroller which used 4-bit mode, the PB4, PB5, PB6 and PB7 pins used to carry data from microcontroller to LCD, PB3 used to enable the LCD, PB2 used for register select on LCD.

4.4 Speed and Mass Flow Rate Control

The system tested under three state as follows:

4.4.1 State one

If the temperature is less than the set point range (900-950˚C) the microcontroller send order to the motor to increase the speed and then the mass flow rate of the sponge coke to maintain the temperature in the range.

4.4.2 State two

If the temperature is more than the set point range the microcontroller send order to the motor to decrease the speed and then the mass flow rate of the sponge coke to maintain the temperature in the range.

4.4.3 State three

If the temperature is in the set point range the microcontroller sends order to the motor to fix the speed and then the mass flow rate of the sponge coke because the temperature is in the range.

The flow chart showing in Figure 4.3 explain the three states.

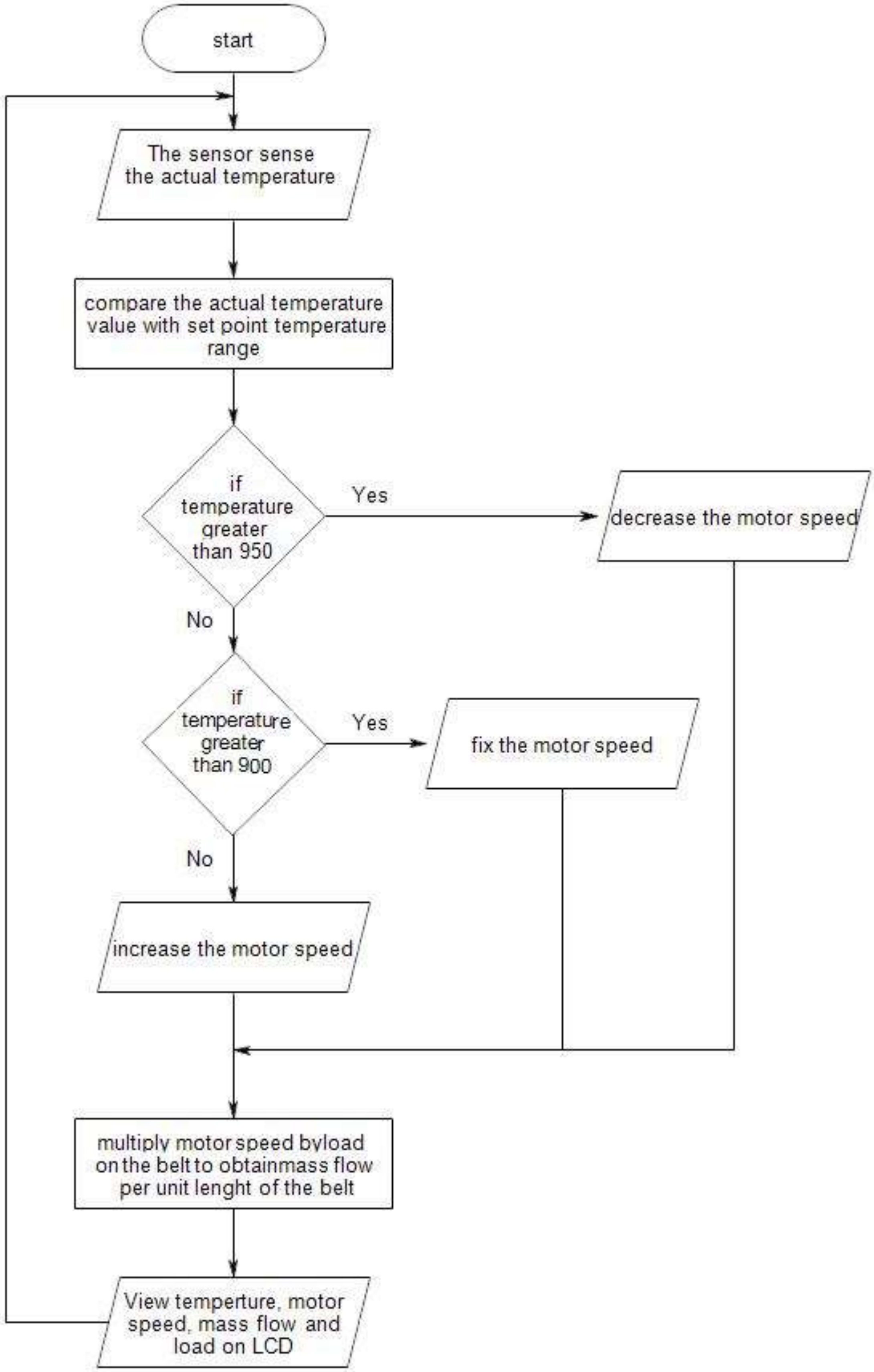


Figure 4.3: Flow chart of the three state

4.5 Results

The simulation results at the three states of sensed temperature are shown in Table 4.1.

Table 4.1: Simulation results at three states

Temperature Range in C°	Speed of Motor Situation in RPM	Mass Flow Rate in kg/s .m
-55-890	Increase	Increase
900-950	Constant	Constant
950-1500	Decrease	Decrease

table 4.2 shows the RPM and M.F values when the temperature varied by constant step from 800˚C until 1045˚C.

Table 4.2: Simulation results

T	RPM	M.F
800	10	90
815	20	180
825	30	270
835	40	360
845	50	450
855	60	540
865	70	630
875	80	720
885	90	810
895	100	900
905	110	990
915	110	990
925	110	990
935	110	990

945	110	990
955	100	900
965	90	810
975	80	720
985	70	630
995	60	540
1005	50	450
1015	40	360
1025	30	270
1035	20	180
1045	10	90

Figure 4.4 shows the plot of the results obtained from three state of temperature in Table 4.2.

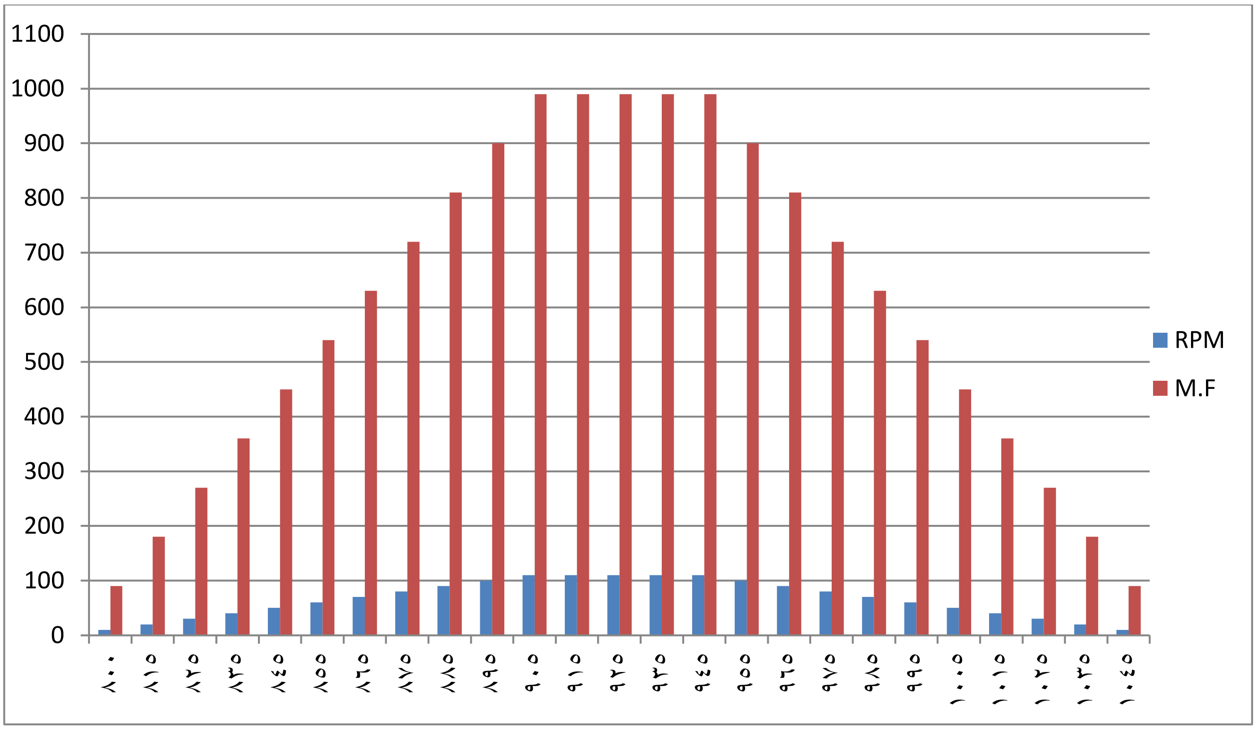


Figure 4.4: The results obtained from three states of temperature

4.6 Discussion

The result as shown in Tables 4.1 obtained at three states of temperature where the mass flow rate of sponge coke is either increase/decrease/fix according to temperatures comparison result. When the sensed temperature is less than 900˚C the microcontroller send order to increase the motor speed which increases the mass flow rate of sponge coke. When the sensed temperature is greater than 950˚C the microcontroller send order to decrease the motor speed which decreases the mass flow rate of sponge coke. When the sensed temperature is in the range of set point temperature range (900-950˚C) the microcontroller sends order to fix the motor speeds which fix the mass flow rate of sponge coke. From Figure 4.4 it can be see that the speed of motor continuous in increasing/decreasing until the temperature reach the range, and when the temperature reach the range the motor speed is constant which the operating range of the boiler.

CHAPTER FIVE

CONCULUSION AND RECOMMENDATIONS

CHAPTER FIVE

CONCULUSION AND RECOMMENDATIONS

5.1 Conclusion

Control the coke feeding to boiler is very important to enhance the boiler efficiency, decrease the cost of fuel consumption and extends the life of boiler parts. Control the coke feeding to boiler was modeled in proteus software and examines how system responds due to change in boiler temperature degree. The microcontroller ATmega32 AVR it is used to carrying out all the required computations and control speed of motor according to boiler temperature. The mass flow rate of sponge coke it is found by multiplying the speed of motor by load sensed on conveyor belt and displayed on LCD.

5.2 Recommendations

- Take the derivative of the weight (change in weight over a time period), to get the feed rate.
- Use a PID controller algorithm to adjust the speed of the feeding device so that the feed rate.
- Tracking switches should always be included with a weight feeder for misalignment alarming or shut down.

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APPENDIX

APPENDIX

BASCOM CODE FOR MICROCONTROLLER TO CONTROL COKE FEED RATE ACCORDING TO BOILER TEMPERATURE

```
$regfile = "m32def.dat"

$crystal = 8000000

Config Lcd = 16 * 2

Config Lcdpin = Pin , Db4 = Portb.4 , Db5 = Portb.5 , Db6 = Portb.6
, Db7 = Portb.7 , E = Portb.3 , Rs = Portb.2

Config Timer1 = Pwm , Pwm = 8 , Compare A Pwm = Clear Down ,
Compare B Pwm = Clear Down , Prescale = 64

Config Adc = Single , Prescaler = Auto , Reference = Avcc

Config Timer0 = Counter , Edge = Falling

Dim T1 As Word

Dim Temp1 As Single

Dim X As Single

Dim Y As Word

Dim V As Byte

 Dim R As Byte
```

```
Dim M As Word
Config Portd.6 = Output
Config Portd.7 = Output
Cls
Cursor Off
Locate 1 , 4
Lcd "Wellcome"
Wait 1
Cls
Compare1a = 0
Compare1b = 0
Main:
Do
    T1 = Getadc(0)
    Temp1 = T1
    Temp1 = Temp1 / 2
    Temp1 = Temp1 - 2
    Temp1 = Temp1 * 10
```

```
R = 10
Waitms 100
Locate 1 , 1
Lcd "T:" ; Temp1
Waitms 100
Y = Getadc(1)
X = Y
X = X / 200
X = X + 8
X = Round(x)
V = V * 1.05
V = V
M = X * V
Waitms 100
Locate 2 , 1
Lcd "M.F:"
Locate 2 , 5
Lcd ; M
```

```
If V < 100 And V > 98 Then
Locate 2 , 5
Lcd "     "
End If
If V < 10 And V > 8 Then
Locate 2 , 5
Lcd "     "
End If
Waitms 100
Compare1a = 0
Compare1b = V
Portd.6 = 0
Portd.7 = 1
Goto Math
Loop
Math:
Do
If Temp1 < 900 Then
```

```
If V < 255 Then

Incr V

Elseif V = 255 Then

V = 255

End If

End If

If V < 100 And V > 98 Then

Locate 1 , 14

Lcd "     "

End If

If V < 10 And V > 8 Then

Locate 1 , 14

Lcd "     "

End If

If Temp1 > 950 Then

If V > 0 Then

Decr V

Elseif V = 0 Then
```

```
V = 0
End If
End If
Locate 1 , 10
Lcd "RPM:"
Locate 1 , 14
    Lcd ; V
Locate 2 , 10
Lcd "X:"
Locate 2 , 14
    Lcd ; X
    Waitms 100
Goto Main
Loop
```