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DESIGNING OF A MATERIAL HANDLING SYSTEM WITH AUTO-SYNCHRONIZING TECHNIQUE FOR FLEXIBLE PRODUCTIVITY CONTROL

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ABSTRACT

A project work was done within the time frame of January to December 2004 in Islamic University of Technology, Gazipur, Bangladesh. The main objective of this work is to design a Flexible Material Handling System (FMS) that can automatically synchronize its speed as per requirement. The system is designed for two types of conveyor system where the speed of the horizontal conveyor belt will be related to the production rate and the speed of the vertical Bucket elevator will be synchronized. A very cheap electrical controller has been designed to synchronize the speed of the bucket elevator with the help of a stepper motor.

Key words: Conveyor belt, Bucket elevator, Synchronization and Bulk material.

INTRODUCTION

Material handling is becoming an extremely crucial issue within the industry. Technological improvement has made it possible to employ a great deal of material handling equipments. In industries like Urea fertilizer Plant or Coal mines the main product is in the form of bulk. Some times it requires depositing these products to some places away from the production areas, as for an example urea is frequently stored after the production in the silo. These are transported within the industries with the help of conveyor belts. Some times more than one type of conveyors are required to pickup the bulk from the ground level to some higher place. So, synchronization between these conveyors is an important issue. The production rate is not constant all the time. And it is a very hazardous and time-consuming job to adjust the belts speed manually all the time. It also requires shutting down the entire production system. So it will cause a huge loss in terms of money also. This can be eliminated if the belts speed can be adjusted automatically with the help of a controlling system without shutting down the production line. Many research works (Mousavi et al., 2005, Vaziri et al., 2005, Wong et al., 2006, Kulak et al., 2005 and Babiceanu et al., 2005) are going on for the development of flexibility of materials handling systems.

Objective of this paper is to design and manufacture such a system, which can automatically sense the alteration of production rate and synchronize the speed of the belt with out hampering the flow rate of the bulk. The system consists of a horizontal belt and a bucket elevator. Conveyor belt is the horizontal belt, which speed will be related to the production rate and the speed of the bucket elevator will be changed according to the flow rate of bulk through the conveyor belt. In the bucket elevator there is a belt with some buckets attached with it. The bulk comes through a passage from the conveyor belt and fell in the buckets and is delivered to a higher place. If the bulk flow increased then the buckets cannot take up all the materials as their capacity is limited at a certain speed and the bulk material will deposit below the bucket elevator in a place called elevator boot. This elevator boot acts as an automatic controller, which with the help of an electrical controller controls the speed of the bucket elevator. In the elevator boot, there are sensors, which can sense the level of deposit in the boot. The signals go to the controller circuit, which operates a stepper motor and the stepper motor controls the speed of the bucket elevator thus synchronizing the conveying system.

Synchronization

One way of defining synchronization is to obtain a desired fixed relationship among corresponding significant instants of two or more signals or a state of simultaneous occurrences of significant instants among two or more signals. Synchronization may be done of high-speed production equipment. Some times it needs to integrate and synchronize equipment supplied by a variety of foreign and domestic vendors into a single handling, preparation and painting line. The equipment may include boilers, chemical tanks, spray washer applicator, gas-fired ovens, dryers, infrared, paint applicators, ventilation, and conveyors. If this is done then Installation went smoothly with minimal supervision. The end

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result of these automation projects was a reduction in manufacturing labor. Production hours may be reduced from two shifts to one.

Multi-axis synchronization
In many machine control and automation problems, there are two or more axes of motion, which must be coordinated. The term "multi-axis synchronization" refers to the motion, which requires coordination, and the techniques used to achieve control of the motion. With today's increasing automation and machine sophistication, the control applications have become more demanding, and the control techniques have improved.

Motion coordination is required in many industrial processes, and can take many forms. The accuracy of motion synchronization in a machine directly affects the quality of the products made by that machine. In the past, the speed and accuracy of synchronization has been limited by the use of mechanical components. The development of programmable electronic motion control, however, has made great improvements in multi-axis synchronization possible, replacing mechanical components such as gears, clutches, and brakes. The flexibility of programmable electronic motion control has significant economic benefits as well, because it allows short production runs and custom product requests. The downtime associated with these short runs is minimized when the setup is programmable.

The mechanical approach to synchronization
By definition, synchronization of two or more axes requires a definite relationship between one axis and the others. Before electronic motion control was available, the traditional approach to this had been largely mechanical, using a central motion source. Individual axes were driven from this source with gears and drive trains. The gears determine the speed relationship, and the drive trains deliver the motion to the appropriate place. Such an approach works well if the desired gear ratio is constant and the drive train is short and direct. More complex arrangements require more costly mechanics, and the problems of backlash and mechanical wear become more pronounced.

If the relationship desired between axes was not constant, but needed to follow a pattern, mechanical cams were used. The shape of the cam determines the motion pattern of the cam follower with respect to the motion of the cam driver. If the required shape is very complex, the cam can be quite difficult to design, and expensive to machine and produce. Cams are also subject to wear, which directly affects the accuracy and repeatability of the cam follower motion. Individual axes were started and stopped using clutches and brakes. These are required to accelerate and decelerate the load, but as with all mechanics, they suffer the problem of wear. They also do not allow for precise control of the position relationship between axes, because the amount of slip during starting and stopping can not be precisely controlled. Clutches and brakes tend to be rough on the rest of the machinery, because of the sudden jerk when they are engaged.

Stepper and Servo Motion Control Systems
The availability of electronic motion control has brought solutions to the problems inherent with the mechanical approach to synchronization. To understand how these solutions are achieved, it is helpful to review basic electronic motion control systems. One axis of electronic motion control consists of the motor, the motor drive, and the controller. The controller accepts motion commands from a host computer or an internally stored program. These command are interpreted by the controller to generate continuously updated position commands (motion profiles) to the drive. The motor drive controls the current to the motor, which will result in the commanded position. In a multi-axis system, one controller can control several motors and drive combinations. The motion control system may be a stepper or servo system. Stepper systems tend to be less expensive than servo systems, but have less speed and power for a given size of motor.

MATERIALS AND METHOD

The whole system was designed and constructed to handle bulk type materials like Urea, Food grains like wheat, rice, paddy etc. For this purpose many belts may be used but the synchronization would also be difficult then. To make it simpler two belts have been selected here to construct the system. The speed of one belt would be fixed and the other belt, which was a vertical one, would be synchronized.

The flow of bulk comes from the conveyor belt, which is horizontal belt, and is delivered to the bucket elevator, which is the vertical belt. Buckets of the vertical belt lift the bulk material from the input path. This bulk material may then be delivered to some other belt or place. If the flow of grain is not accurate, if it is more than the desired rate then the bucket will not be able to pull all the material. The overflow of the material will then deposit on the elevator boot and after some time it hampers the elevator system. So some kind of controller is required to avoid this kind of situation.

The controller will control the speed of the bucket elevator. When the flow rate of the material will be high the controller will increase the speed of the bucket elevator automatically and when requires it can also reduce the speed. The elevator boot of the bucket elevator act as a mechanical controller. There is another electrical controller to support it. When the buckets of the vertical belt cannot take up all the bulk materials, those will deposit in the elevator boot. The construction of the designed flexible manufacturing systems are shown in Figure:1.

In the elevator there are two LDR. They are placed according to the capacity. LDR-1 positioned above, indicates the upped level and LDR-2 indicates the lower limit. When the bulk crossed the upper limit, LDR-1 will not get any light and it gives a 5-voltage signal to the controller circuit, which will increase the speed of the vertical belt. This action of the bucket elevator will begin to clear the elevator boot and at one stage the level of bulk goes below the upper level. This time the LDR-1 will give another 5-voltage signal. But the speed of the elevator will not change until it goes below the lower limit. When the bulk material goes below the lower level the LDR-2 will get light and it will give a 5-voltage signal to the controller circuit. When this signal comes the controller circuit will reduce the speed of the D.C motor. So the whole process continues with out any interruption. No matter what the flow of the bulk material is the system can switch according to the desired rate.

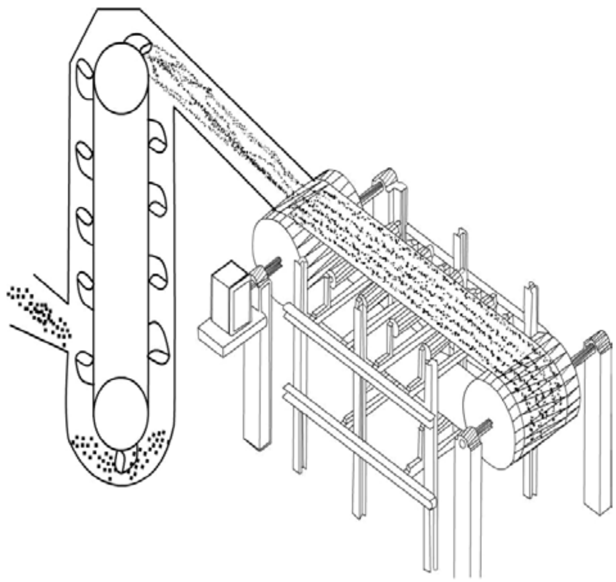

Figure: 1: Construction of the designed flexible manufacturing systems.

Portrayal Of The Constructed System: A brief description of the manufactured system for the work has been given below. It will give an apparent idea about the whole process also.

Conveyor belt: The conveyor belt is the horizontal belt of the system. A small experimental conveyor belt was designed and constructed for the purpose. A schematic diagram of the conveyor belt is shown in Fig.2.

Specifications of the manufactured conveyor belt

Most of the components were constructed in the university workshop though a few of the components were bought from the local market according to the specifications. Some important specifications of the components have been given below:

Capacity	: 1.5 tons per hour	Driven pulley	
Belt Length	: 1.1 meter	Shaft diameter	: 25 mm
Pulling member		Bore Bearing Diameter	: 25 mm
Belt-Width	: 200 mm	**Framing**	
Belt-length	: 1100mm	Length	: 1400 mm
Belt-thickness	: 7.3mm	Height	: 600 mm
Flat Rollers		Width	: 410 mm
Roller Diameter	: 78 mm	Drive Units	
Roller Face (Length)	: 400 mm	A three-phase motor	
Driving and driven pulleys		Motor power	: 0.5HP (0.372 kW)
Diameter	: 205 mm	Motor RPM	: 56
Face or Length	:250 mm		
Driving pulley			
Shaft diameter	: 30 mm		
Bore Bearing Diameter	: 30 mm		

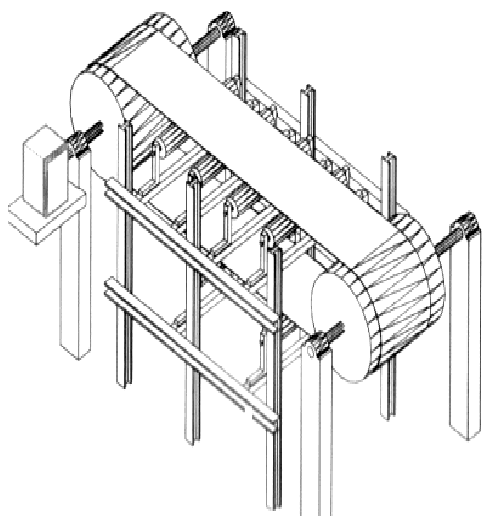

Figure2. Construction of a Conveyor Belt

Bucket Elevator

Elevators serve to raise bulk and unit loads vertically or at step inclined from horizontal. The nature of the material to be elevated has an important bearing on the elevator design. A bucket elevator has shown in Figure 3. Bucket elevators are specified for the conveyance of various powdered, granular and lumpy materials. Transverse compactness, ability to, raises loads to considerable height (up to 50 m) and capacities ranging from 5 to 160 m3/hr are the main merits of bucket elevators. The fact that they are sensitive to over loads and must be loaded at a uniform rate is their main disadvantage.

Bucket elevator may employ a belt or I or 2 strands of chain. According to the method of feed and discharge they are related to the high speed centrifugal or the low speed gravity discharge type.

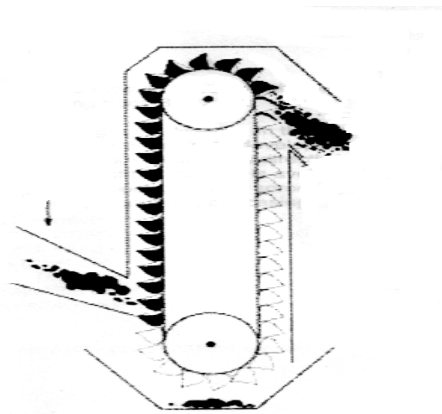

Figure 3. Construction of a Bucket Elevator

Specifications of the manufactured bucket elevator

Specifications of some important components of the Bucket Elevator have been given below:

Pulling Member (Belt):

Width (b)	:152.4 mm	Ball bearing (For lower shaft):	
Length (L)	: 3.33 mm	Inner diameter	: 30 mm
Bucket (Deep):		Outer diameter	: 60 mm
Width of the Bucket (B)	: 127 mm	Power transmission Pulley:	
Height of the Bucket (h)	: 120.65 mm	Inner diameter	: 25 mm
Bucket spacing (a)	: 301.62 mm	Outer diameter	: 120 mm
Drum pulley:		Motor pulley:	
Inner diameter	: 38 mm	Inner diameter	: 12 mm
Outer diameter	: 254 mm	Outer diameter	: 92 mm
Ball bearing (For upper shaft):		Drive unit:	
Inner diameter	: 25 mm	Motor	: D.C Motor
Outer diameter	: 50 mm	Motor power	: 1.0 HP

Drive Unit Arrangement

The motor used for the vertical belt is a D.C motor. It is possible to Change the speed of the D.C motor by energizing its magnetic field. Varying the resistance of the motor do this and the stepper motor can change the resistance by giving the steps according to the signal. The motor used for the horizontal belt is a geared type speed reduction motor. The rpm of the motor can be adjusted according to the requirement. This is required because the rpm of the motor is usually very but in this work motor with less rpm is required so that this type of motor is selected. The bucket elevator motor is attached to the system with the help of belt pulley assembly. The conveyor belt motor is joined to the belt shaft by direct coupling. A rubber gasket has been used in between them. This is used mainly to avoid the vibration. Because the motor is placed above the ground and if the vibration is more it may break the motor carrier stage.

Controller Required For Speed Synchronization

The synchronization of the system is done mainly with the help of an electrical controller. But to understand the controller it is better know the problem before and also the logic to solve the problem.

Logic of the controller circuit

During the operation two types of LDR conditions arise. Dark condition of the LDR when bulk material is on the LDR and Light condition when bulk is not on the LDR. Let us consider darkness of the LDR as 1 (5Volt) and light condition of the LDR as 0 (0Volt). As there are two LDR so there should be two variable. Let us consider the variables as x and y. Fig shows the position of the LDR in the elevator boot of the Bucket Elevator. As the bulk material filled the elevator boot three types of condition occurs. The position of the LDR in the bucket elevator boot is shown in the Figure 4.

First condition: When bulk material goes above the

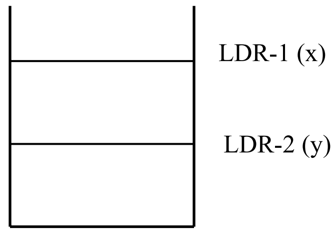

Figure4. Position of the LDR in the Elevator Boot

LDR-1, the signal that is supplied by the LDR is x = 1 and as bulk is above the first LDR then it must be above the second LDR. So the second LDR signal is y = 1.

Second condition: When bulk material is in between the two LDR the signal is
x = 0 and y = 1.

Third condition: When position of the bulk material is below the LDR-2 then the signal is
x = 0, y = 0.

During these three conditions the speed of the D.C motor should be different for proper synchronization. To control the speed of the D.C motor one stepper motor has been used. The stepped motor has two types of rotation. According to the signal of the LDR the controller circuit gives signal to the stepper motor and the stepper motor gives the rotation. One rotation is positive and the other is negative rotation. These rotations energies the magnetic field of the D.C motor and so the speed of the D.C motor change. Let think about the positive revolution of the stepper motor as P and negative revolution as Q. According to the requirement for the system to be synchronized the logic equation is given below

$$P = \bar{x}.y + \bar{x}.\bar{y} \quad \text{......................(1)}$$

$$Q = x.y \quad \text{.............................(2)}$$

So, according to what is being said the logic table is look like this.

Table: Truth table

x	y	P	Q
1	1	0	1
0	1	1	0
0	0	1	0
1	0	×	×

The fourth condition is not considered as it cannot actually possible.
For the first condition signal from the logic circuit Q gets a 5-volt signal and it increase the speed of the DC motor. For the second condition according to the truth table P gets the 5 volt signal and it reduce the revolution of the motor. For the third condition P gets the signal and it remains in the reduce condition.

Function of the controller circuit
From the logic circuit the signal goes either at P or at Q. There is a Timer (555) in between counter and the logic circuit. The timer is always giving clock pulse to the counter. Amid the timer and counter a PNP transistor has been place, which acts as switch. When the signal (5 volt) goes either to P or Q the respective transistor is switched on and the 5 volt signal passed to the respected counter. Each counter has six pins. First two pins are usually grounded. The other four pins are

connected to the stepper motor. For positive pulse that is to reduce the speed the counter reaction is ABD ABD. So these three pins are connected to the stepper motor as shown in the fig.4.

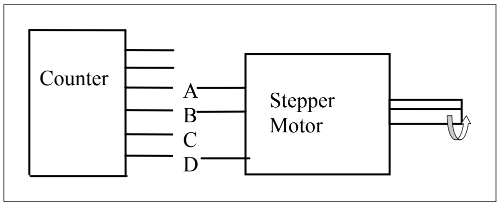

Figure4. Connection between the Counter and Stepper Motor

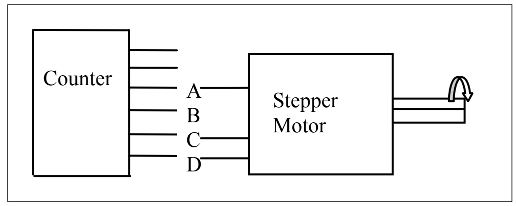

Figure 5. Connection between the Counter and Stepper Motor

When Q is activated, that means the speed of the motor needs to be increased. So the rotation of the stepper motor should be on the reverse direction. To rotate the stepper motor in the reverse direction the response of the counter is DCA DCA. For this the connection of the stepper motor with the counter is also different which is shown in the fig.5.

The signal from the counter is 5 volt which is not enough to run the stepper motor. For this an additional source is needed. A 7 volt source is used with the help of three PNP transistors. When 5volt signal comes the transistor becomes short and 7 volt signal goes to the stepper motor as shown in the fig.6.

Design of the controller circuit

According to the logic the circuit has constructed and it has been shown below in the fig. Different logic gates have been used to acquire the preferred signal for the rationale. Two counters and a Timer (555) have also been inserted here. The timer always gives a clock pulse to both the counter. Two PNP transistors have been utilized which will act like a switch for the clock pulse. As the transistor gets the signal from the logic gate it allows the clock pulse to pass through it to the preferred counter. Thus the selected counter is activated and in turn it energizes the stepper motor to synchronize the speed of the D.C motor. A diagram of the circuit is shown in the fig. 7.

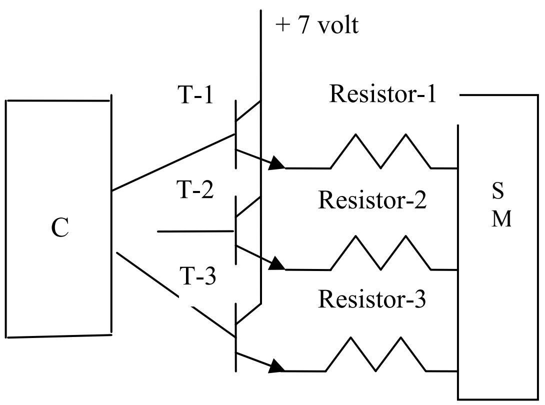

Figure 6. Connection between the Counter and the Stepper Motor to contribute 7volt Signal to the Stepper Motor

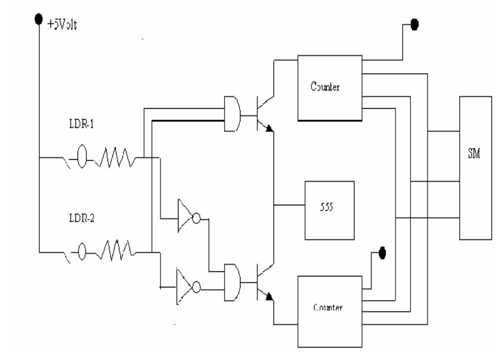

Figure 7. Circuit Diagram of the Controller

RESULTS AND DISCUSSION

A few experiments had been done to examine the performance of the system. The experiment shows the response time of the system to synchronize its speed according to the requirement. It gives a clear conception about how much time the system takes to adjust the speed of the vertical belt and to make the system stable. Wheat and Paddy was taken as raw material to investigate the performance of the system..

The improvement of the system efficiency with the implementation of the controller has shown in figure:8. It has been observed that the efficiency of the system with the controller has remarkably increased compared to a non-controller system. The implementation of the designed controller converted a manual controlled material handling system into a flexible material handling system.

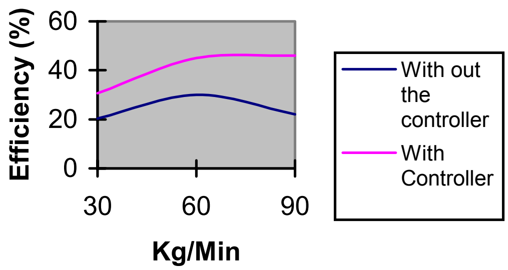

Fig:8 Comparison of the two System depending on the implementation of the Controller

The response time of the flexible manufacturing system for different loading conditions are shown in figure: 9. It has been observed that with the increase of load the response time decreases. The response time for the paddy is higher than that of wheat.

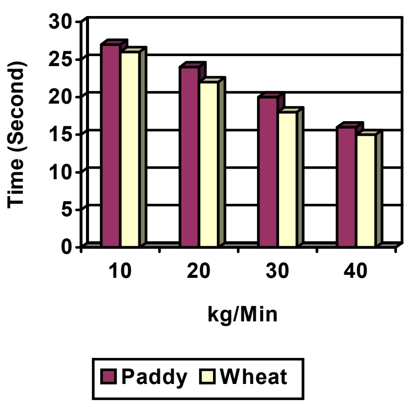

Figure 9.Response time of the system depending on the different load conditions

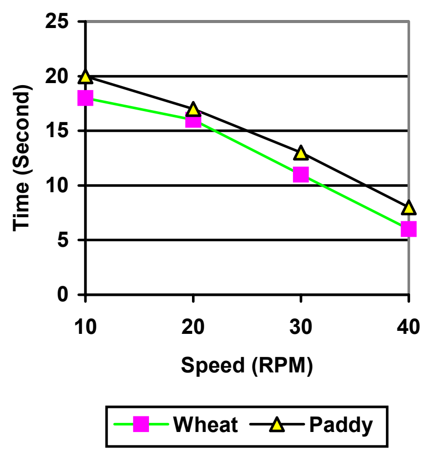

Figure 10. Response time of the system depending on the speed of the system

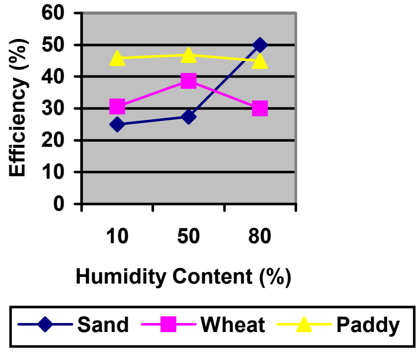

Fig:11 Depending on Humidity Content of the Bulk the Variation of Efficiency

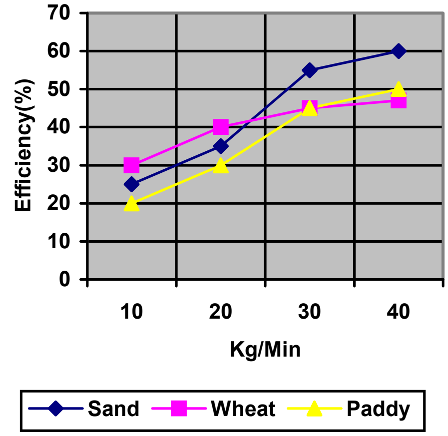

Figure:12 Variation of Efficiency Depending on Granular Size of the Bulk

The response time variations of the system of different speeds of the Bucket Elevator are represented in Fig. 10. It shows as the speed of the elevator increased the response time also decreased. For both the raw materials the variation behavior of the materials is same but the response time for the wheat is less than that of paddy.

Figure 11 shows the variation of efficiency of the system depending on the humidity content of the bulk for different types of raw materials. The observations were made for three raw materials as Sand, Wheat and Paddy.

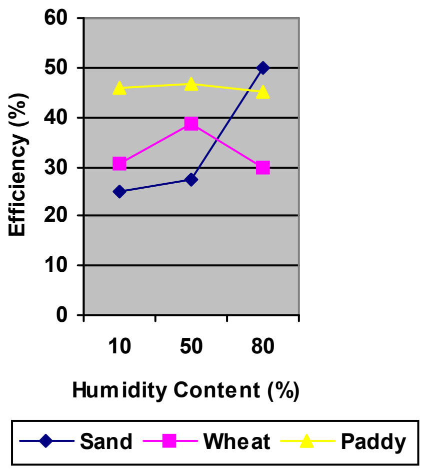

Fig:11 Depending on Humidity Content of the Bulk the Variation of Efficiency

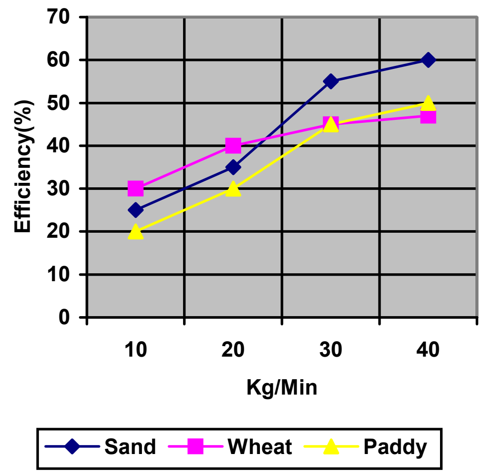

Figure:12 Variation of Efficiency Depending on Granular Size of the Bulk

As the humidity increased it also increase the bonding capacity of the bulk material and hence the efficiency also increased. The variation of the efficiency for paddy is not significant compare to sand and wheat.

Figure 12 shows the variation of efficiency of the system depending on the different loading conditions for different types of raw materials. The observations were made for three raw materials as Sand, Wheat and Paddy. As the load is increased the efficiency of the system is also increased. The pattern variation of the efficiency for different raw materials is similar but efficiency variation for sand is significant compare to wheat and paddy.

CONCLUSION

The advantage offered by the work is to offer an improved automatic material handling arrangement. The operator intervention associated to the transportation of bulk material can be abridged drastically or eliminated. The users benefit includes reduction of operator fatigue, fewer mistakes caused by human error, and consistent and predictable hauling time for the material. The controller circuit controls the system. So once it is set the requirement of skilled operator is also reduced as compared to a manual system. The system is not free from a few drawbacks because of cost. There are a few sectors where improvement can be done. However, certain options are left intentionally in the system for future feasibility study. The horizontal belt can also be controlled with the assist of a central processing unit. If it can be implemented then the speed synchronization of the entire system will be smoother.

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