Process Line Balancing by Cellular Machining Process

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Abstract

The more the operator's cost, the more advantageous it will be to have one operator run two or more machines. The more each machine's cost, the less advantageous it will be to have one operator run two or more machines.

In many companies I've visited, a manager can point out every penny that goes into what an operator costs (again, wages plus benefits). One company I visited even includes the cost of the parking space the operator uses to park his or her car. However, when it comes to machine costs, they are not nearly so knowledgeable and diligent. Again, having an accurate value for both operator and machine cost is of paramount importance to making wise operator-utilization decisions. Inflated operator costs and/or devalued machine costs lead to poor operator-utilization decisions. It will appear that using one operator for two or more machines is more cost-effective than it really is.

Keyword — *Process Line Balancing, Machining Process, Cellular Machining Process.*

I. INTRODUCTION

To help maintain a competitive advantage in the global economy, manufacturing companies must continuously strive to increase productivity while reducing the manufacturing cost of their products. This can be tackled in a various ways e.g.
Reducing inventory cost, increasing machine utilization and reducing the direct labour cost. If productivity can be improved for instance by reducing the labour content of the process, this should help to reduce the manufacturing cost of their products.

The first step on the road towards a scientifically sound low cost automation method for a cellular manufacturing line is identifying and quantifying the different manual tasks which could potentially be automated. An adequate evaluation system considering reality, detail, and variation and effort levels has been defined in order to assess the results, suitability for evaluating manual work in a cellular manufacturing line, pointing out potentials and limits of the individual approaches. As the final outcome, a ranking of different work measurement concepts for the cellular manufacturing reference line is presented, verifying the applicability of the general approach and serving as a basis for further evaluation of other lines.

One of these lean practices, cellular manufacturing, is based on a group of different processes located in close proximity to manufacture a group of similar products. The primary purpose of cellular manufacturing is to reduce cycle time and inventories to meet market response times.
Some of the other benefits include:

1. Space Reduction
2. Quality Improvement
3. Labour Cost Reduction
4. Improved Machine Utilization.

Cellular manufacturing is an application of the group technology concepts for factory reconfiguration and shop floor layout design. A part family can be parts similar in size or parts created using similar manufacturing steps. Typically, a cell is dedicated to a single part family.

Cellular manufacturing does have some important human resource issues to consider:

1) Operators must be trained properly to perform tasks including inspection and simple maintenance
2) Cross functional training is critical since operators perform a variety of tasks and move between workstations and cells as the need arises
3) Operators should be trained on team building
4) Supervisors become coaches. Cell teams require only guidance. Supervisors facilitate, assist and guide the overall effort.
5) Compensation issues: Cell employees usually receive the higher pay because they are better qualified to do multiple tasks. We recommend implementation of an incentive program that provides incentives on the basis of results and incremental improvements.
6) Management may be concerned that there will be resistance from employees when the result is actually opposite. Typically, any initial resistance disappears once employees understand the win-win situation at hand.
7) Cells need support from several functions including product engineering, material management, manufacturing engineering, QC/QA, maintenance and management. It is vital

to implementation success that this support is committed, visible and consistent.

II. REVIEW ON LITERATURE

Brief about the work done so far:

Campain (2014) in his research paper titled "Technological growth and unemployment: A global scenario analysis." Explored the possible features generated by the development of the artificial intelligence. He focused on social consequences of automation and robotization, with special attention being paid to the problem of unemployment.

Hughes (2014) investigated about technological unemployment. In his paper "Are technological unemployment and basic income guarantee inevitable or desirable" he questioned, if in the future robots take most people's jobs, how will human beings eat? The answer that has been more or less obvious to most of those who have taken the prospect seriously has been that society's wealth would need to be re-distributed to support everyone as a citizen's right.

Metternich et. al. (2013)in their research work starts with investigating existing analytical Methods for measuring work. The different measuring concepts have been applied to the cellular manufacturing reference line at the process learning factory at TU Darmstadt. An adequate evaluation system considering reality, detail, and variation and effort levels has been defined in order to assess the results' suitability for evaluating manual work in a cellular manufacturing line, pointing out potentials and limits of the individual approaches. As the final outcome, a ranking of different work measurement concepts for the cellular manufacturing reference line is presented, verifying the applicability of the general approach and serving as a basis for further evaluation of other lines.

Apostol set. al. (2013)have presented critical review on the energy efficiency of important manufacturing processes Relevant conventional and non-conventional processes, utilized in the three major industrial sectors of aeronautics, automotive and white goods are briefly discussed. Information related to their energy efficiency is provided. The conclusions of both the analysis and the discussion comprise some practical aspects and recommendations for the energy efficient use of selected processes.

Yadavet. al. (2013) have explained about several techniques like Cellular manufacturing, Group technology are widely used in manufacturing industries to improve the productivity. The proper alignment or load balancing of machines is an important factor for improving the productivity. So In his work, he tried to improve the productivity of an industry by the proper alignment or load balancing of machines.

Park et. al. (2012) did the development of the intelligent operation planning system considering machining safety. In this paper, an intelligent operation planning system considering machining safety has been introduced to model the process of selecting cutting conditions and subsequently to arrive at effective and safe cutting. INOPS (Intelligent Operation Planning System) based on such a proposal has been developed for milling processes. INOPS is composed of two main components: (1) the artificial neural network to learn cutting conditions, and (2) rules and equations to modify the cutting conditions for safe machining. The main functions of INOPS for prismatic components are briefly described and then discussed.

Semipermanent. al.(2012) have stated about cellular manufacturing (CM).Cellular manufacturing have been proven to be an economic, efficient and lean approach bringing flexibility into machining areas. Corresponding solutions use several basic machines that are adapted to the machining task in a right-sized equipment approach. However, these of basic, low cost machinery providing just necessary functions results in a relatively high manual operation effort. The preferred approach in order to reduce manual work in production is automation. Traditional automation of man-machine systems – especially in western countries tends to be comprehensive and thus often complex and expensive. A low cost, lean automation intelligently being adapted to the individual Task, as well as a decision method for choosing the tasks worth being automated, is required.

Maher (2010) has worked on design and development of automated programmable orientation tools for vibratory bowl feeder. This project attempts to make progress in the development of a flexible VBF, the main problems being the inflexible nature of the orientation tools as currently employed. The project tackles the design, development and manufacture of a range of automated programmable orientation tools which in combination make up a typical orientation system for the VBF. Three prototypes tools were developed: the Wiper Blade, Narrow ledge and Edge riser tools. These tools were focused for the purpose of the project on the feeding of a specific target component. Seven further orientation tools were designed with the intension of future development and implementation/inclusion into the feeding research process at a later stage.

Lópezet. al. (2007) have proposed a method for introducing cellular manufacturing in an operating job shop. By applying cellular manufacturing to produce part families with similar manufacturing processes and stable demand, plants expect to reduce costs and lead-times and improve quality and delivery performance. This work outlines a method for assessing, designing, and implementing cellular manufacturing, and illustrates this process with an example. A manufacturing cell that produces aluminium parts for commercial customers is implemented at Boeing's defence and space group machining centre. The conclusions of the work highlight the key lessons learned from this process.

Silversides et. al. (2005) have investigated the vibratory bowl feeder for automatic assembly, presented a geometric model of the feeder, and developed force analysis, leading to dynamical modelling of the vibratory feeder. Based on the leaf-spring modelling of the three legs of the symmetrically arranged bowl of the feeder, and equating the vibratory feeder to a three-legged parallel mechanism, the paper reveals the geometric property of the feeder. The effects of the leaf-spring legs are transformed to forces and moments acting on the base and bowl of the feeder. Resultant forces are obtained based upon the coordinate transformation, and the moment analysis is produced based upon the orthogonally of the orientation matrix. This reveals the characteristics of the feeder, that the resultant force is along the z-axis and the resultant moment is about the z direction and further generates the closed-form motion equation. The analysis presents a dynamic model that integrates the angular displacement of the bowl with the displacement of the eaf-spring legs. Silversides approaches are used to verify the model, and an industrial case-based simulation is used to demonstrate the results.

III. EXPERIMENTAL RESEARCH ETHODOLOGIES

Experimental research is a collection of research work which use manipulation and controlled testing to understand causal processes. Generally one or more variables are manipulated to determine their effect on dependent variable. The experimental method in industrial research is the application and adaptation of the classical method of experimentation. It is a scientifically sophisticated method. It provides a method of investigation to derive basic relationships among phenomena under controlled condition or, more simply, to identify the conditions underlying the occurrence of a given phenomenon. Experimental research is the description and analysis of what will be, or what will occur, under carefully controlled conditions. Experimenters manipulate certain stimuli, treatments, or environmental conditions and observe how the condition or behaviour of the involved processes are affected or changed. Such manipulations are deliberate and systematic. The researchers must be aware of other factors that could influence the outcome and remove or control them in such a way that it will establish a logical association between manipulated factors and observed factors. Experimental research provides a method of hypothesis testing. Hypothesis is the heart of experimental research. After the experimenter defines a problem he has to propose a tentative answer to the problem or hypothesis. Further, he has to test the hypothesis and confirm or disconfirm it. Thus the experimental method has greatest utility in the manufacturing field. The immediate purpose of experimentation is to predict events in the experimental setting.

A. Characteristics of experimental method

There are four essential characteristics of experimental research

1) Control

Variables that are not of direct interest to the researcher, called unrelated variables, need to be controlled. Control refers to removing or minimizing the influence of such variables by several methods such as: randomization or random assignment of subjects to groups; matching subjects on inappropriate variables and then assigning subjects randomly to groups; making groups that are as homogenous as possible on extraneous variables, application of statistical technique of analysis of covariance, balancing means and standard deviations of the groups.

2) Manipulation

Manipulation refers to a deliberate operation of the conditions by the researcher. In this process, a pre-determined set of conditions, called independent variable or experimental variable. It is also called treatment variable. Such variables are imposed on the subjects of experiment. In specific terms manipulation refers to deliberate operation of independent variable on the subjects of experimental group by the researcher to observe its effect.

3) Observation

In experimental research, the experimenter observes the effect of the manipulation of the independent variable on dependent variable. The dependent variable, for example, may be performance or achievement in a task.

4) Replication

It is a matter of conducting a number of sub-experiments, instead of one experiment only, within the framework of the same experimental design. The researcher may make a multiple comparison of a number of cases of the control group and a number of cases of the experimental group. In some experimental situations, a number of control and experimental groups, each consisting of equivalent subjects, are combined within a single experiment.

B. Importance of research

Research is important both in scientific and non-scientific fields. In our life new problems, events, phenomena and processes occur every day. Practically, implementable solutions and suggestions are required for tackling new problems that arise. Scientists have to undertake research on them and find their causes, solutions, explanations and applications. Precisely, research assists us to understand nature and natural phenomena.

Some important avenues of research are:

(1) A research problem refers to a difficulty which a researcher or a scientific community or an industry or a government organization or a society experiences. It may be a theoretical or a practical situation. It calls for a thorough understanding and possible solution.

(2) Research on existing theories and concepts help us identify the range and applications of them.

(3) It is the fountain of knowledge and provides guidelines for solving problems.

(4) Research provides basis for many government policies. For example, research on the needs and desires of the people and on the availability of revenues to meet the needs helps a government to prepare a budget.

(5) It is important in industry and business for higher gain and productivity and to improve the quality of products.

(6) Mathematical and logical research on business and industry optimizes the problems in them.

(7) It leads to the identification and characterization of new materials, new techniques, in short automation.

(8) Only through research inventions can be made; for example, new phenomena and robotizinghave been developed only through research.

(9) Social research helps find answers to social problems. They explain social phenomena and seek solution to social problems.

(10) Research leads to a new style of life and makes it delightful and glorious. Emphasizing the importance of research Louis Pasteur said: I beseech you to take interest in these sacred domains called laboratories. Ask that there be more and that they be adorned for these are the temples of the future, wealth and well-being. It is here that humanity will learn to read progress and individual harmony in the works of nature, while humanity's own works are all too often those of barbarism, fanaticism and destruction.

C. Research methods and research methodology

Research methods are the various procedures, schemes and algorithms used in research. All the methods used by a researcher during a research study are termed as research methods. They are essentially planned, scientific and value-neutral. They include theoretical procedures, experimental studies, numerical schemes, statistical approaches, etc. Research methods help us collect samples, data and find a solution to a problem. Particularly, scientific research methods call for explanations based on collected facts, measurements and observations and not on reasoning alone. They accept only those explanations which can be verified by experiments. Research methodology is a systematic way to solve a problem. It is a science of studying how research is to be carried out. Essentially, the procedures by which researchers go about their work of describing, explaining and predicting phenomena are called research methodology. It is also defined as the study of methods by which knowledge is gained. Its aim is to give the work plan of research.

IV. PROBLEM DEFINITION AND IDENTIFICATION

In many companies I've visited, a manager can point out every penny that goes into what an operator costs (again, wages plus benefits). One company I visited even includes the cost of the parking space the operator uses to park his or her car. However, when it comes to machine costs, they are not nearly so knowledgeable and diligent. Again, having an accurate value for both operator and machine cost is of paramount importance to making wise operator-utilization decisions. Inflated operator costs and devalued machine costs lead to poor operator-utilization decisions. It will appear that using one operator for two or more machines is more cost-effective than previous practices.

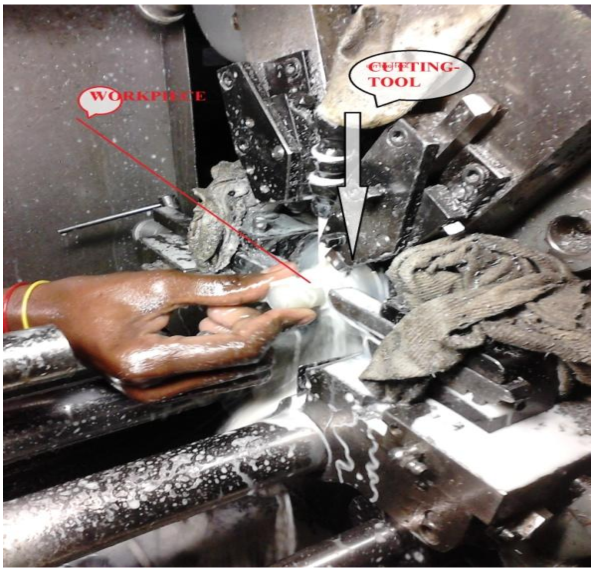

Fig. 4.1Manual loading of work piece

Initially there were 24 machines, which were operated by 24 skilled operators along with 4 unskilled operators or helpers.

Problem in present are,

1. Manual operation hence less accuracy.
2. Skilled worker required.

3. Production time depends upon operator skill.
4. Tool break down problem due to misalignment of part.
5. Machining safety
6. To increase productivity by reducing idle time of the machine by cellular manufacturing approach.

***Objectives*:** After evaluating the machining process at Tuljai Engineering works and literature, following are the objectives decided-

1. To make loading and unloading of the work piece automatically i.e., process automation.
2. To enhance quality product.
3. To reduce labour cost.
4. To minimize worker interference from safety point of view.
5. Utilization of appropriate shop-floor by using line balancing techniques.
6. To increase productivity by reducing idle time of the machine by cellular manufacturing approach.

V. METHODOLOGY

The progress of the developing the project will be smooth and easier with well-defined and proper planning and management. When the proposal submitted, the planning of the project is started in progress. Basically, crucial consideration of time management, resources and fact-finding procedures is carried out and considered at the initial stage, when the project has been approved. Planning is important as only sufficient time and resources are provided.

A. Existing method of manufacturing

Manufacturing is an important commercial activity carried out by companies that sell products to customers. In the modern sense, manufacturing involves interrelated activities that include product design and documentation, material selection, process planning, production, quality assurance, management, and marketing of products. These activities should be integrated to yield viable and competitive products.
In conventional way of manufacturing feeding of the work piece is done manually on turning machine. The operator holds the work piece in his hand to load it on machine collet. As the work piece is loaded on machine and held by collet for grooving and chamfering operation which is done simultaneously it leads to hazards from safety point of view. While the turning operation is done, coolant circulates continuously to carry out machining work smoothly. After the turning operation on work piece is completed the job is ejected or unloaded by the machine automatically, further work piece is stored in a storage bin. Rewinding behind when the work piece is unloaded operator feeds new work piece for turning operation on machine collet which is a part of sequential process. The stored work pieces are soaked in LH3 grade oil for ten minutes, to clean up and remove burr. The work pieces are inspected randomly before shifting to packaging department.
Thus by traditional way of manufacturing the company is facing problems like injury to operators, low productivity, high labour cost, poor quality etc. To overcome with this situation the automation of the whole process is needed. Manufacturing technologies have continually gone through gradual but revolutionary changes. These advancements in manufacturing technologies have brought about a metamorphism in the world industrial scene.
In order to overcome these problems discussed earlier in introduction, I have gone through number of research papers for finding appropriate solution and came to the conclusion i.e. automation by vibrating bowl feeder.

B. Proposed method of automation by vibrating bowl feeder

The vibratory bowl feeder is the most common mechanism for feeding industrial parts. The bowl has a helical track climbing the inside wall. By giving the bowl a circular vibratory motion, parts dumped into the bowl will climb the helical track in single file. As parts climb the track, they encounter a sequence of obstacles which either re-orient the parts, or deflect disoriented parts back into the centre of the bowl. Instead of welded passive orienting devices such as wiper blades and permanently constructed orienting devices on the track, stepper motor controlled wiper blades and adjustable track width are incorporated into the bowl feeder to make it flexible and programmable to suit parts of different sizes. Vibration is applied to the bowl from an electromagnet mounted on the base, and the support system constrains the movement. When component parts are placed in the bowl, the effect of the vibratory motions to cause them to climb up the track to the outlet at the top of the bowl. The schematic figure 5.1of vibrating bowl feeder is shown below.

Fig. 5.1Vibrating Bowl Feeder

When power is supplied to the feeder it starts vibrating with specific amplitude which cause to move work piece gradually in a defined helical path. As the job arrives at wiper blade station, jobs that are stacked on top of one another and also those jobs that are higher than the set height limit of the wiper blade get rejected or wiped off. The wiper blade station is a passive orienting device commonly used in the vibratory bowl feeder to reject or wipe off jobs. After fleeting wiper blade station work piece moves towards deflector station. Here the deflector station deflects the jobs by 90 degree and finally it travels through an inclined rail towards machine collet. Similarly, when number of jobs is in queue inside an inclined rail, at certain position Proximity Switch Sensor is positioned. The sensor provided on inclined rail will complete the close loop. When the jobs exceed its limit, sensor will cut off power supply of the vibrating hopper. In this way by cutting off power supply of vibrating hopper in idle time, we can reduce power consumption of the system. The schematic line diagram of feeding system is as shown in figure 5.2

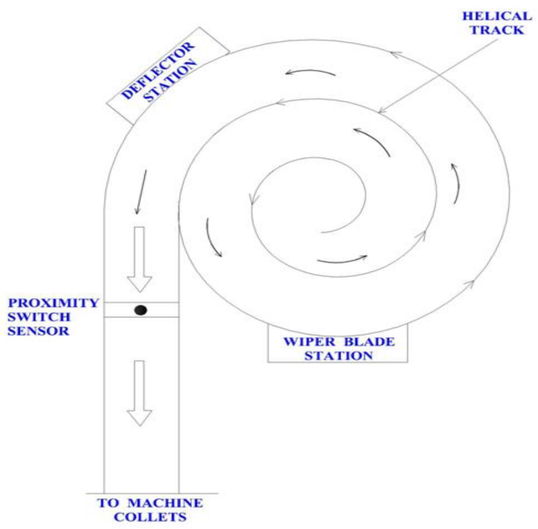

Fig. 5.2Schematic diagram of feeding system

The jobs from the collet (Fig. 5.2) moves to the machine with the help of ram and cam mechanism provided over there. The ram actuated by pneumatic pressure, loads the job on machine for turning operation.

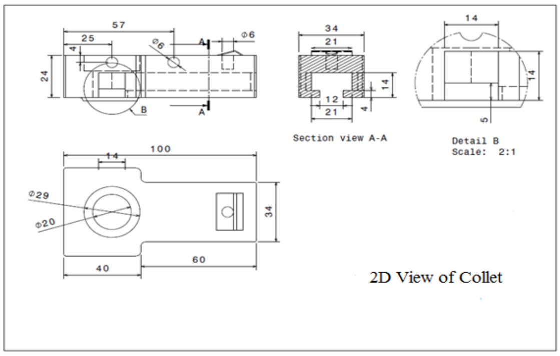

Fig5.3Collet

After loading the work piece, machine performs chamfering and grooving operations simultaneously. Once the turning operation on work piece completes, it get ejected automatically and is stored in a storage bin. This process repeats itself until the work pieces retain in an inclined rail. From above report it can be concluded that process automation with cellular manufacturing, escorts the following advantages,

1. Space Reduction
2. Quality Improvement
3. Labour Cost Reduction
4. Improved Machine Utilization.

C. Specification of cam & follower

Cam and Follower is also called as track follower, which converts one form of motion into another form. It consists of different constraint motions that are rotary, oscillatory and reciprocator. The follower during its stroke that is reciprocating may constitute simple harmonic motion, uniform motion or cyclonical motion as per application.
The cam and follower used in present application have following specifications,

1) FCJS-40 (Sealed, with cage and thrust washer)
2) Boundary dimensions : D = 40, C = 20, d = 18
3) Screw : M18x1.5

Pneumatic Cylinders also known as air cylinders are mechanical devices use the power of compressed gas to produce a force in a reciprocating linear motion. Pneumatic Cylinders forces a piston to move in the desired direction. The piston is a disc or cylinder, and the piston rod transfers the force it develops to the object to be moved. Engineers prefer to use pneumatics sometime because they are quieter, cleaner, and do not require large amounts of space for fluid storage.
Because the operating fluid is a gas, leakage from a pneumatic cylinder will not drip out and contaminate the surroundings, making pneumatics more desirable where cleanliness is a requirement.

1. Media: Air, Oil and inert-gases.
2. Temp. Range: 0° C to +65° C.
3. Pressure Range: Minimum 4bar to Maximum 10bar.
4. Cushions: For 19 and 25 mm bore rubber shock absorbers as optional. Above 25 mm bore adjustable cushions as standard.
5. Consumption: Litters of free air per 100 mm single stroke at 5 Kgf/cm^2.
6. Bore to Stroke: Ø32 - 125 mm.

D. Traditional shop floor layout

In conventional shop floor layout (figure 5.4) 24 machines were controlled by 24 operators which leads too many disadvantages discussed above. Also product cycle time required in present condition was high resulting in low productivity and poor machine utilization. To overcome, by implementing line balancing technique we have designed new or modified shop floor layout

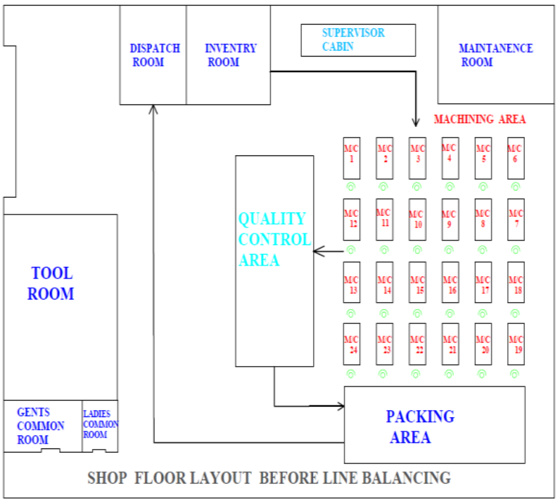

Fig. 5.4 Traditional shop floor layout

E. Proposed shop floor layout

As stated earlier in problem definition, this industry is facing a problem regarding space utilization and line balancing of shop floor. With the help of modified shop floor layout (as shown in figure 5.5.) we have achieved line balancing technique. In this customized layout and automation of vibrating bowl feeder, four machines can be handled by single worker, thus decrease in labour cost. By implementing modified shop floor layout product cycle time has reduced resulting in high productivity, space reduction and better machine utilization.

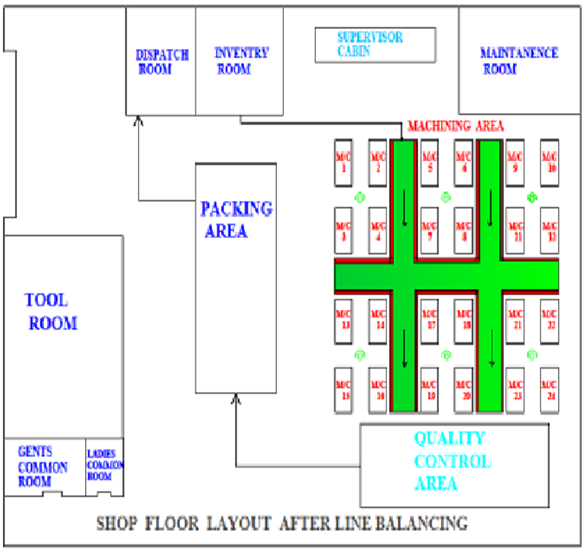

Fig. 5.5 Modified shop floor layout

From above modified layout it is cleared that 6 workers can handle 24 machines, instead of 24 labours on 24 machines in traditional layout. Hence the cost of 18 labours can be saved.

F. Working setup of automated mechanism

To overcome the existing problem automation of machining process was obligatory. Here we have installed vibrating bowl feeder to handle work piece. An inclined rail is attached to the feeder to carry work piece towards collet. The flow of work piece is controlled to the collet by proximity switch sensor, were energy efficiency can be achieved. Pneumatic cylinder which is actuated by cam & follower mechanism feeds the work piece to machine collet by certain interval of time. The turning operation is carried out on work piece, after machining job is automatically ejected and get store in storage bin. Then machined work pieces are soaked in LH3 grade oil for ten minutes to clean and remove burr. Further the work pieces are inspected randomly before shifting to packaging department.

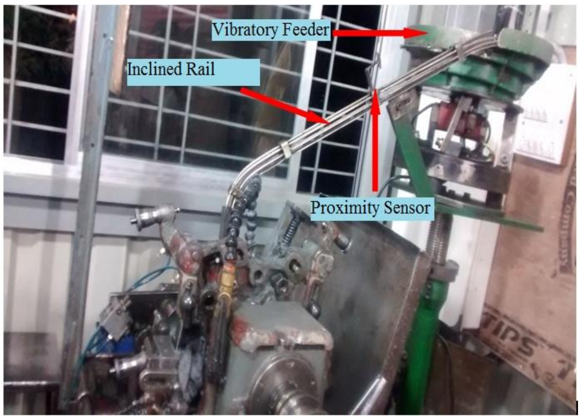

Fig. 5.6Experimental Setup

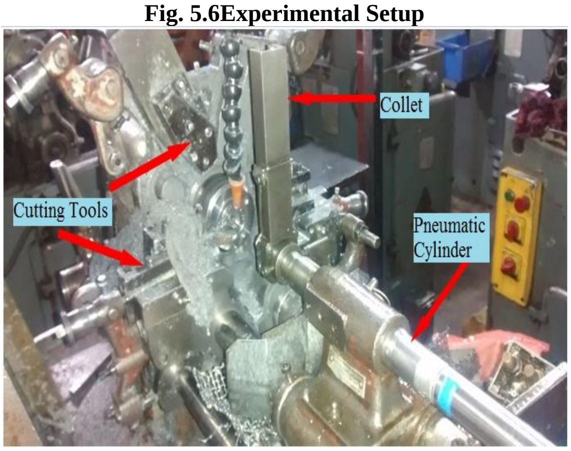

Fig. 5.7Experimental Setup

G. Cost distribution of old process

Cost details of 24 machines for one month are shown in table 7.1. Here the most contributing parameter is labour costing which is 75% of total production expenditure. So, project mainly focus to optimize labour cost.

Table5.1 Old Process Cost Distribution

Sr. No.	Parameter	Unit Cost (Rs)	Unit	Total Cost (Rs)
1	Skilled Operator	12000	24	288000
2	Machine Maintenance	950	24	22800
3	Tool Break Down	840	36	30240
4	Electricity	8.25	2150	17740
5	Material Handling	6000	4	24000
			Total Expenditure	382780

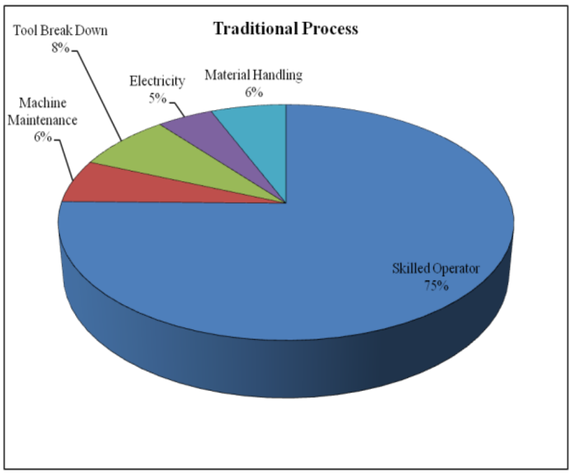

Fig.5.8 Pie Chart – I Cost distribution of revised process

Cost details of 24 machines for one month after automation are shown in table 7.2. After implementing automation system labour cost is 18% of total production expenditure. So, project is able to achieve 56% reduction in labour cost.

Table7.2Revised Process Cost Distribution

Sr. No.	Parameter	Unit Cost (Rs)	Unit	Total Cost (Rs)
1	Skilled Operator	12000	06	72000
2	Machine Maintenance	950	24	22800
3	Tool Break Down	840	21	17640
4	Electricity	8.25	2830	23350
5	Material Handling	6000	4	24000
			Total Expenditure	159790
6	Total Saving Amount	-	-	228600

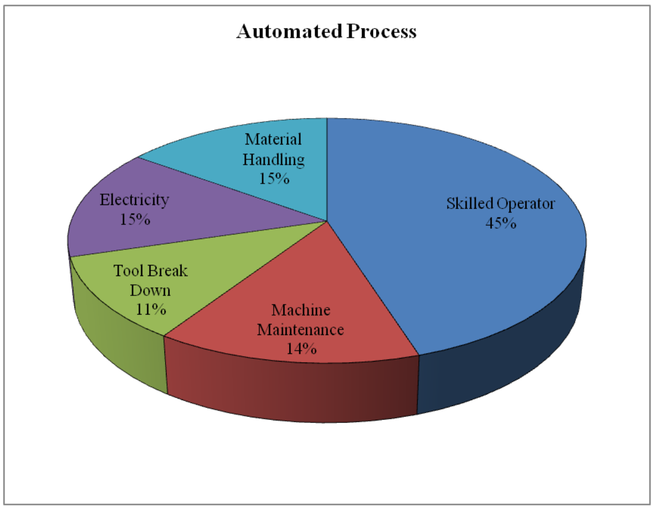

Fig.5.8 Pie Chart– II

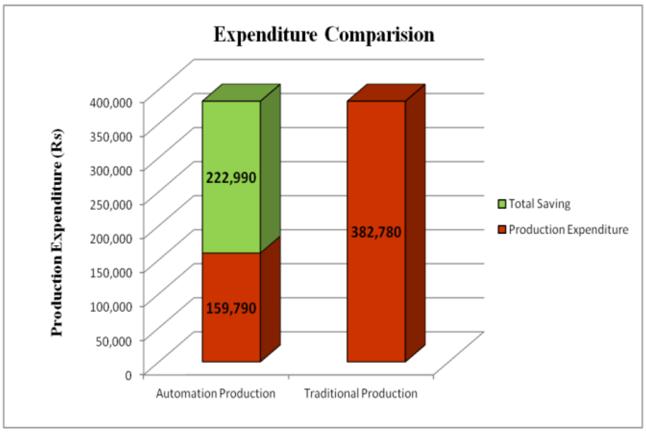

Fig.5.9 Expenditure review

Reviewing fig. 7.3 it is clear that effective cost saving of 58% is achieved by implementing the project.

VI. CONCLUSIONS

The basic foundation for a scientifically sound method for automating a cellular manufacturing and line balancing on a low cost basis is laid as consequences of this project. Project has investigated the effects of time and cost factors on the total cost and the total number of different types of workers assigned to the work stations. The cost factor depends upon the number of the skilled worker and the number of unskilled workers. The decrease in time factor has a greater effect on cost factor for all of the variables analysed.

The manual feeding of work piece was replaced by automatic system, as a result the idle time of machine is reduced which led in productivity improvement. Implementing process automation system has a better accuracy and precision over the traditional system enhanced product quality. Partial effect of tool breakdown and part rejection which was at peak position in conventional system is minimized through this automation.

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