Role of Industrial Engineering Principles and Automation in the Productivity Improvement of Manufacturing Firms

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Abstract: **In today's technologically competent world industries are playing vital role in development of the country. These industries pioneer the economy of the country hence continuous improvement in their processes is necessary for development. Especially in developing countries, even though they have man power and natural resource available abundantly, industries are facing issue in their productivity. For that, Industrial engineering is one such way which ensures that industries achieve desired outcomes. This is achieved by utilizing specialized knowledge and skill in the mathematical, physical and the social science together with the principles and methods of engineering analysis and design to specify, predict, and evaluate the results to be obtained from such systems. This research deals with the case study of implementation of various industrial engineering tools and principles in the automotive part manufacturing firm. Main objectives of this research include improvements in material handling system, implementation of 5S within the organization and using time study for reduction of operational time. Along with that this research also includes implementation of Value stream mapping and Zero-defect principle during manufacturing of floor cleaner.**

Keywords: **Industrial Engineering, Time study, Operations Research, Value Engineering, Zero defect principle**

1. INTRODUCTION

Today's market has become much more competent than before and to survive in this cut throat environment companies need to bring their operational cost and resource consumption down. This research on implementation of Industrial Engineering principles in manufacturing firm deals with optimization of resource consumption and reduction of waste occurred during production. The research explains how time study, material handling improvements and automation can bring drastic results in increasing overall productivity of firm under consideration. Details of the concepts used in research paper are as below

1.1 Time study:

Time study is defined as "a work measurement technique which involves time measurement of an operation with the help of a time measuring instrument, set to pre-determined variation from normal performance or rate and to include allowances for various reasons such as adverse environmental conditions, rest time required to overcome fatigue and personal needs and machine breakdowns or unavoidable delays." Time study is a reliable method of work measurement for setting basic times and hence standard times for carrying out specified work. The main objective of time study is to set up a time for a skilled worker to carry out a specified work under given conditions and at a specified rate of working. Time study plays an important role in any business for determining its production rate. Many other factors such as raw material, operation cost, work force and others affect the production rate, but time is the most dominating factor.

1.2 Material handling system:

Material Handling basically consists of movement of materials from one point to another for processing or storing. According to American Material Handling society,' Material Handling is an art and science of involving the movement, packing and storing of subsystems in any form. Hence material handling operation involves movements in all directions namely - vertical, horizontal or combination of both and materials in all forms, such as fluid, semi fluid and discrete items. It plays a vital role in any production function as most of the time is spent on handling of materials from machine to machine and from one place to other. Material handling equipments are adaptable, interchangeable and multi-functional. AGV-based material handling systems involves accurate design and operational planning to achieve full potential of system. Material handling equipments are manually controlled vehicles required to transfer light and heavy loads from one location of plant to other location. Automated guided vehicle systems are operated by computers which are typically used for routine tasks between two container terminals, storage and warehouses, production stations and assembly lines.

1.3 Value analysis and Value Engineering (VAVE):

VAVE is organised process focused at determining the functions of various factors in design, process, product and service in order to achieve the desired outputs at the minimal cycle cost with required quality, availability, performance, reliability and safety. This

process is implemented in the development stage for reduction of costs. It offers right alternatives after studying various materials, processes and products. The output results should benefit the end users with savings in the cost without compromising the performance and quality of the product. Projects which implement Value Engineering in the development stage get many advantages, due to proper understanding of the aim, outputs, and requirements. Value engineering when applied with flexibility and creativity, is limitless in its ability to point out areas of major savings. The ability of Value engineering to counter with timeliness, pliability and creativity plays an important role in projects. It can be implemented for already existing or new programs, in any phase of project and processes. Value Engineering can be employed to enhance quality, achieve minimum costs, increase acceptance, build teamwork, maximise efficiency, and reduce risks.

1.4 Zero Defect Manufacturing (ZDM):

Zero defect Manufacturing aims to reduce failures in the manufacturing processes by eliminating the defected parts in the early stage of manufacturing. Defected parts refer to anything that does not add value to the product, e.g. defective machines, tools and inefficient employees. ZDM is an innovative concept that completely transforms the manufacturing ideology. The major objective of ZDM is to minimize the defective products to zero. However, zero defects mean zero failures during operation, but not necessarily zero imperfections, faults, or non-acceptances. The four strategies of ZDM are: detection, repair, prediction, and prevention. There are two different approaches of implementing ZDM - The product-oriented ZDM and the process-oriented ZDM. The major divergence between these two is that a product-oriented ZDM analyses the defects on the actual parts and finds a solution, while the process-oriented ZDM analyses the defects of the manufacturing equipment, and evaluates whether the manufactured products are up-to-mark or not. Remarkable reduction of scrap and hence cost reduction can be realized with ZDM.

2. IMPLEMENTATION OF TIME STUDY:

In any industry time required to manufacture a single product on a particular machine is an important factor to decide the overall production in a day. This time defines the work output, worker efficiency, and various operating conditions of machines. The work output is determined by number of products produced per day. This gives the minimum time required to complete the production. To increase the overall production the time required to manufacture single product should be reduced. It also shows whether the delivery is on time or it may delay due to some reasons. If it is delayed, then industries require more time to complete the work which results in overtime of workers. This results in fatigue of workers and overall a disturbing environment in the industry. To avoid all this, we require to set a standard time for all processes to produce manufacture a finished product within time.

There are lot of operation processed on various machine and for each machine there was specific operation time or Cycle time which include all the necessary process such as loading & unloading operation, Clamping& decamping operation, Actual process time on machine and so on. There are some operations on specific machine which consume more time and have scope for improvement. So such operation needs to be focused and the time required for each process should be measured and recorded using stopwatch. Standard time can be calculated by utilizing measured time and adding allowances to them.

For analysis of time study drilling operation on VMC machine can be taken into consideration. The observations to be taken for time study are as follows:

Sr No	Element	Rating	Observed Cycle Time (In second)					
			1	2	3	4	5	6
1	Job loading operation	90%	20	18	22	17	22	20
2	Clamping operation	110%	90	88	93	95	92	91
3	Changing the drill bit as per the size requirement	100%	55	61	65	58	59	61
4	Selecting the required program and switching on the button	80%	32	35	31	38	36	35
5	Drilling operation	105%	120	120	120	120	120	120
6	De-clamping operation	112%	72	75	71	78	74	78
7	Job unloading process	95%	18	20	22	17	19	22
8	Job cleaning operation	102%	10	8	11	9	10	11

From observed time we calculate the standard time by taking average time for each activity and adding the allowance in it. This is shown in following table. From observed time average time needs to be calculated, which when multiplied by rating gives us normal time. Allowances when added to the normal time give standard time of operation. The following table shows the sample calculation

Sr. No	Element	Rating	Average Observed time	Normal Time *(Avg. Observed Time x Rating)*	Relaxation Allowance	Standard Time *(Normal time + Normal time × Allowance)*
1	Job loading operation	90%	19.83	17.847	10%	19.82
2	Clamping operation	110%	91.5	100.65	12%	112.728
3	Changing the drill bit as per the size requirement	100%	64.83	64.83	11%	71.97
4	Selecting the required program and switching on the button	80%	34.5	20.7	10%	22.14
5	Drilling operation	105%	120	128.4	12%	143.48
6	De-clamping operation	112%	74.66	73.54	11%	81.93
7	Job unloading process	95%	19.66	18.67	10%	20.54
8	Job cleaning operation	102%	9.83	10.02	11%	11.12
	Total Standard time					**483.73 sec (8 min 06 sec)**

In the above table it can be observed that time required for clamping and de clamping is more due to manual operation. This in turn adds up to the standard time. As a result standard time required for the operation is more. To overcome this manual clamping system can be replaced by semi- automatic hydraulic clamping system which reduces the clamping and de-clamping time. This is seen in below table.

Sr No	Element	Rating	Observed Cycle Time (In second)					
			1	2	3	4	5	6
1	Job loading operation	90%	20	18	22	17	22	20
2	Clamping operation	110%	10	11	11	9	11	10
3	Changing the drill bit as per the size requirement	100%	55	61	65	58	59	61
4	Selecting the required program and switching on the button	80%	32	35	31	38	36	35
5	Drilling operation	105%	120	120	120	120	120	120
6	De-clamping operation	112%	8	9	9	8	9	8
7	Job unloading process	95%	18	20	22	17	19	22
8	Job cleaning operation	102%	10	8	11	9	10	11

Sr. No	Element	Rating	Average Observed time	Normal Time *(Avg. Observed Time x Rating)*	Relaxation Allowance	Standard Time *(Normal time + Normal time × Allowance)*
1	Job loading operation	90%	19.83	17.847	10%	19.82
2	Clamping operation	95%	10.33	9.81	12%	10.99
3	Changing the drill bit as per the size requirement	100%	64.83	64.83	11%	71.97
4	Selecting the required program and switching on the button	80%	34.5	20.7	10%	22.14
5	Drilling operation	105%	120	128.4	12%	143.48
6	De-clamping operation	95%	8.3	7.86	11%	8.73
7	Job unloading process	95%	19.66	18.67	10%	20.54
8	Job cleaning operation	102%	9.83	10.02	11%	11.12
	Total Standard time					**308.80 sec (5 min 15 sec)**

Due to the implementation of semiautomatic clamping and declamping system it can be evidently observed that standard time required for operation is considerably reduced. Assuming that manufacturing firm operates for 18 hours in a day excluding all the allowances

provided for lunch breaks, personal needs and relaxation. Within this stipulated time the difference in number of products manufactured by the company utilizing manual and semi-automatic clamping and declamping is shown below:

$$\text{Total operating time in a day} = 18 \times 60 = 1080 \text{ minutes}$$

For manual clamping and de-clamping,

$$\text{No. of products produced per day} = \frac{1080}{8} = 134 \text{ products (approx)}$$

For semi-automatic clamping and de-clamping,

$$\text{No. of products produced per day} = \frac{1080}{5} = 216 \text{ products (approx)}$$

From these calculations we can see that as the standard time for operation is decreased by three minutes per product, the number of products produced remarkably I creased from 134 products per day to 216 products. Hence by application of time study, the processes in which unproductive time can be reduced are found out and solutions for the same can be developed and implemented to increase the production of manufacturing firm.

3. IMPLEMENTATION OF IMPROVED MATERIAL HANDLING METHODS:

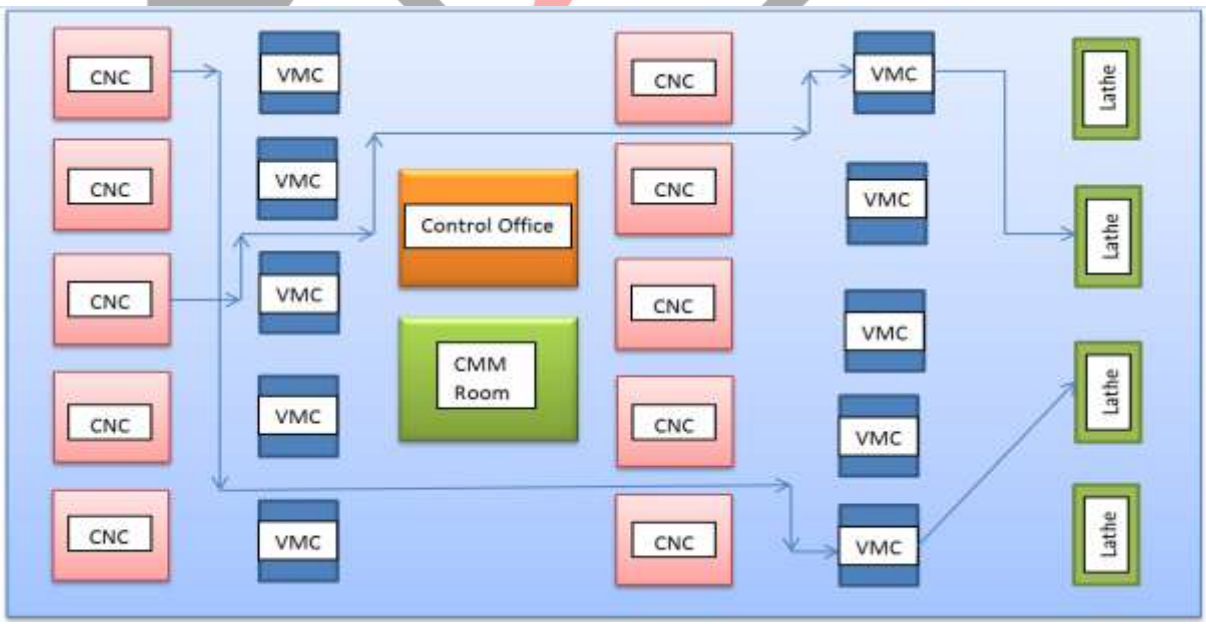
3.1. Installation of Hydraulic scissor lift:

The manufacturing firm under research study has difference in elevation within the floors of production shop and inspection shop. For the material flow within these shops, manual hand pallet trucks are used. The main drawbacks of this method are – the load carrying capacity from higher to lower elevation is less and manpower required is comparatively more. Hence 2 to 3 workers are involved in this operation. Along with these, more number of cycles are required to transfer the finished products from one shop to other. Eventually it resulted in more time consumption. To overcome these drawbacks, hydraulic scissor lift can be used. The details are as follows:

The primary components of lift consist of base frame, top frame, connecting links and hydraulic power pack. The base frame and top frame are connected with the help of links similar to scissor mechanism. It consists of a platform which can be raised and lowered through the actuation of hydraulic cylinders. The hydraulic lift can be so designed that it can easily raise or lower material upto two ton. As the total operation can be now performed by using only two switches, the manpower required is significantly reduced. Due to higher load carrying of lift less number of cycles are required. Hence noteworthy reduction in time consumption will be achieved.

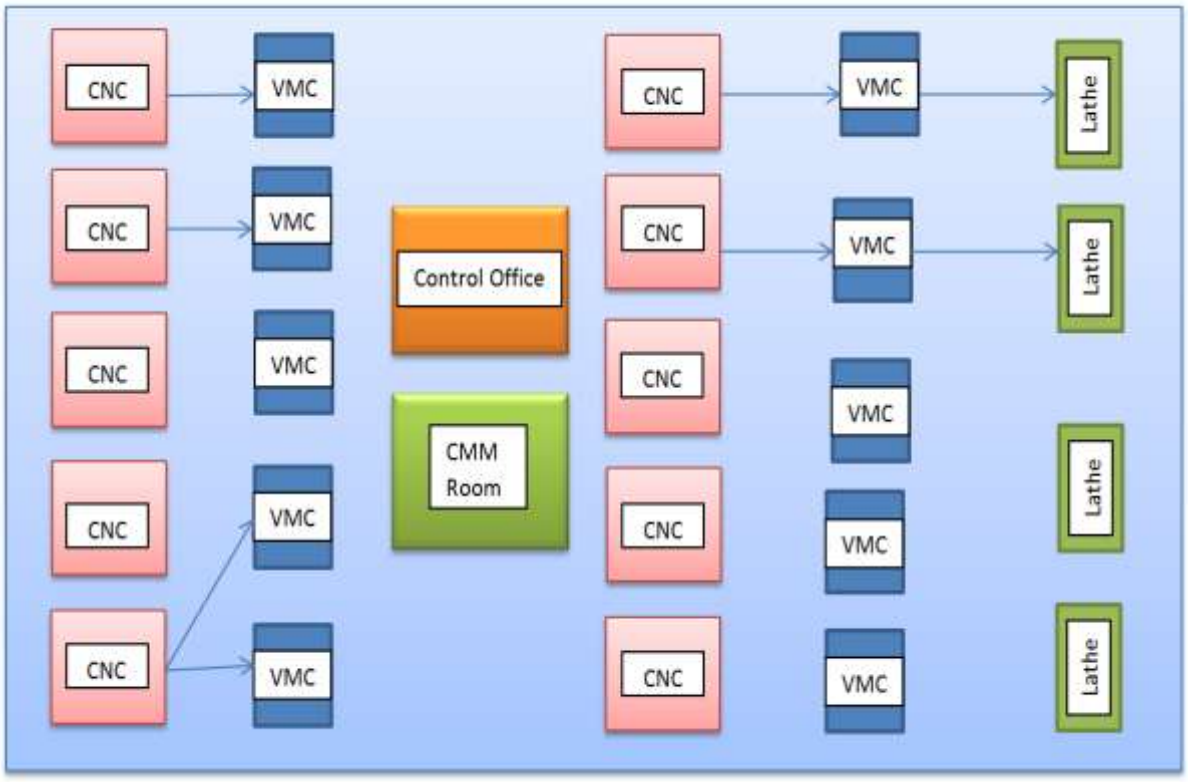
3.2. Re-routing the path of product being manufactured:

Many times material flow within the production shop is not properly organized. Due to this the ideal scenarios such as minimum material handling and traveling time are not achieved. This results in increase in manufacturing cycle time of the product. Hence overall productivity gets decreased. So there is a need of complete re-routing the path of material flow and sequencing of machines. The following is the representation of layout before improvement:



From the layout the arrangement of CNC and VMC machines can be observed. The path of flow of workpiece is as shown in the layout. After completion of first operation on CNC machine, the workpiece is carried to the farthest VMC machine. This resulted in

increase in manufacturing cycle time of the product as the time required for material handling has also increased. This also leads to increase in manpower required and cost of material handling. To overcome this problem rerouting the path of product flow was essential, which is accomplished as follows:



The above layout represents the improvements in the path of product flow. In the previous layout, the CNC and VMC machines allotted for sequential operation of single product had considerable distance. This is avoided by re-allocating the VMC machines. The nearest VMC machine was allotted to the CNC machines as per the sequence of operations. While doing so it is ensured that material flow is kept minimum resulting in reduction of manpower, cost of material handling and time consumption.

3.3. Development of cages for transport of in-process products:

Each product being manufactured has specific cost associated with it whether it is finished, semi-finished or at raw stage. When such product gets damaged due to transportation mishaps, the result is overall economic loss of the company. Especially when the product being manufactured is of high economical value then it is must to implement strategies to reduce this kind of defects. One such problem was the products were stacked on a carrying pallet without any side supports. When there was sudden impact of pallet the jobs used to fall out and totally get rejected. These losses were quite significant, on which following measures were taken to prevent the job from falling out of the pallet. The figure shows the before and after images of implementation of cages for transport of in-process products.

4. IMPROVEMENT IN 5S IMPLEMENTATION PROCESS BY EMPLOYING COST EFFICIENT FLOOR CLEANING MACHINE:

The organizations working on implementation of 5S emphasize extensively on cleaning of the workplace for tidy and clean environment. This emphasize either demands for more number of workers diligently involved in cleaning activity or automatic floor cleaning machines which are already available in market. Both of these things come with high financial investments. To overcome these issues a semi-automatic and cost efficient floor cleaning machine can be employed in any manufacturing firm. Hence efficient design and manufacturing process should be carried out to develop floor cleaning machine at low cost. VAVE (Value analysis and Value Engineering) and ZDM (Zero defect manufacturing) are the two most effective tools which can be implemented to reduce the cost during design and manufacturing stage of machine.

4.1 Implementation of Value Analysis and Value Engineering (VAVE)

Implementation of VAVE can be carried out in three stages as follows

1. Pre workshop phase
2. Workshop phase
3. Post workshop phase

Pre workshop phase-

In the pre workshop phase, the core team strategically determines the whole procedure required for implementation of VAVE. This core team can take decisions regarding the subdivision of team members into various departments. Considering the implementation of Value analysis principles in the manufacturing process, overall team size can be subdivided into various departments such as design department, Manufacturing Department and Quality department etc. Team members in each department will be concerned with their aspects in manufacturing of floor cleaning machine. After this division, core team can form road map indicating the step by step procedure to implement the VAVE in manufacturing process. Pre-workshop stage also involves arrangement of the various resources required to carry out the workshop phase which are as follows-

- Creating PowerPoint presentation to effectively convey the information about VAVE
- Preparing VAVE sheet format required during Idea generation process in workshop phase
- Ensuring all the documents are available during workshop phase, such as CAD models and Design Sheets of floor cleaning machine.
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Workshop Phase –

In the workshop phase, the core team explains what VAVE is and how to implement it to the team members. At first functional analysis of floor cleaning machine is carried out by analysing design sheets and 3D CAD models. Once the function of each part is defined, various cost reduction ideas can be generated by team members through elimination of non-value adding parts or processes. The members can effectively present their ideas on the VAVE sheet as shown below

Name	Pronit Diwale			
Part Name		Idea Description		
Batery		Instead of battery we can use a transformer for operating the D.C. Vacuum Pump so that we can directly operate through AC Supply and the overall cost of the machine can be reduced.		
Current Status		Proposed Change		
Currently we are using two 12V lead acid batteries for vacuum pump.		Instead of battery we can use a transformer for operating the D.C. Vacuum Pump on single phase AC Supply.		
Manufacturing	Quality	Purchase	Design	TS
OK. Easy to manufacture.	OK. Quality will remain same.	OK. will reduce the cost.	OK. can be implemented.	OK. Nice suggestion. Can be implemented

Post workshop phase-

In this stage, all the team members take the final decision about the ideas. They analyse all the remarks given by various departments on VAVE sheet and take the final decision for the proposed idea by looking at overall scenario given by various departments. The ideas which are being finally approved need to be developed further so that its implementation can be carried out.

Implementation of Zero defect manufacturing (ZDM) –

For the implementation of zero defect principles in the floor cleaner manufacturing process, various documents need to be created and detailed evaluation of them needs to be done. Following are the main documents which need to be created.

- Control Plan
- Process Failure Mode And Effect Analysis (PFMEA)
- Work Instruction Sheet.

These documents are assessed and a link between them is formed. This link is useful to find out the possible defects at the early stage of manufacturing which helps to prevent these defects. Following are the details of the document:

Control Plan-

If the defects occur or the manufacturing process deviates then the control plan should contain instructions for the operator. This document can also be used in conjunction with work station check sheet. Control plan also ensures that if defect occurs due to manufacturing team members fault, it can be easily inspected and monitored. But the Control Plan needs to be updated periodically so that latest set of instruction is available. Example of control plan is as shown below:

Op. No	Operation Name, Description	Name of Machine, Jig fixture, Tool	Product and process specification	Gauges used	Error prediction	Control Method	Reaction Plan
1.	Manufacturing of Tanks	Shearing Machine, Bending Machine, Arc welding	Tank should be manufactured as per design dimensions and there should not be any leakage.	L angle, Measuring tape, Spirit level Gauge	Leakage of water from tanks	Spot-welding The leakage points and hammering for distortion in dimension	Tanks should be tested with the help of leakage testing machine
2.	Mounting of motor assembly	Arc welding, Bending machine, drilling machine	Bracket should be welded at exact position and welding should not damage the tanks.	Measuring tape,. Angle dekkor	Fractures in weld or distortion in tank shape due to welding	Welding should be precisely done with no distortion of tanks during operation	Proper adjustment of position of bracket and re welding for correct mounting if necessary.

Process Failure Mode and Effect Analysis (PFMEA)

PFMEA is an effective tool which is widely used by manufacturing industries for the detection of potential failures within the process. PFMEA gives us a proper idea about effects of failures with the help of which we can identify and prioritise the necessary actions required to reduce the risk of defects. Example of PFMEA is as shown below:

Op No.	Operation Description	Requirement	Potential Failure Mode	Potential effects of failure	Potential causes of failure	Process control prevention
1	Cutting and bending of square pipes as per dimension	The bending curvature and length of pipes as per design specifications	1. Required bending curvature and length of pipes not obtained 2. Excessive stresses resulting in cracks while bending.	1. Strength of structure reduced. 2. Problems in further manufacturing processes due to inaccurate dimensions.	1. Application of inaccurate load during bending. 2. Human errors while setting the dimensions.	1. Use of accurate measuring instruments and work procedure. 2. Application of accurate load while bending.
2	Sheet metal cutting, bending and welding for tanks.	1. The length of sheets and bending curvature as per dimensions 2. The tanks should be leak proof and should not have sharp edges.	1. Small holes at the edges of tank. 2. Holes in sheet metal while welding. 3. Distortion of tank.	1. Leakage of water from tanks at the edges. 2. No use of sheet metal due to damage.	1. Improper current rating used for welding. 2. Excessive grinding done at the edges.	1. Use of optimum current rating during welding. 2. Proper grinding depth maintained at all edges.
3	Welding of bolts for mounting vacuum pump.	The bolts should be welded according to slots provided on vacuum pump.	1. Bolts deviated from original place. 2. Required strength not achieved.	1. Vacuum pump not correctly mounted. 2. Leakage of air through gaps generated.	1. Proper weld thickness not given to the bolt. 2. Improper selection of bolt size.	1. The bolt should be welded evenly. 2. Selection of optimum bolt size.
4	Welding of motor mounting bracket to base plate	1. The position of bracket should be such that brush is mounted eccentrically. 2. The run weld should have sufficient strength.	1. Distortion of bracket 2. Shear failure of bracket	1. Improper position of brush. 2. The force required for cleaning not achieved.	1. Insufficient thickness of weld. 2. Spot welding of bracket.	1. The bracket should be mounted by run welding. 2. The position of bracket should be correct.

Work Instruction Sheet.

One of the vital documents required for implementation of ZDM is work instruction sheet. This document gives operational sequence and specifies the inspection method of the each operation, which helps to achieve the goal of ZDM. The safety precautions specified in work instruction sheet help largely to safeguard the workers in all the ways.

Sr. No	Operation Sequence	Method of Inspection	Safety key point	Quality Key Point	Safety Precautions	Quality	Reaction plan
1.	Cutting and bending of square pipes as per dimension	Measuring tape and vernier to be used before cutting as per dimension	Bending curvature and pipe cutting should not cause cracks or excessive stresses in them	Bending curvature and length of pipe should be as per required dimension	Care should be taken while bending and cutting of pipe that there is no intervention of hand in moving parts during process	Use proper fixtures to secure pipe during cutting. Also lubricate the rollers threading and make sure accurate pressure is applied during bending	Readjustment of dimension of cutting pipe if possible otherwise New pipes should be taken for further use
2.	Sheet metal cutting, bending and welding for tanks.	1. Welds to be inspected visually for proper thickness. 2. Measuring tape and vernier to be used before cutting as per dimension.	No any Excessive stresses or damage to sheet metal caused during bending or welding	Dimension of tank should be strictly as per design requirement. Proper care should be taken that holes are not formed on sheet metal due to excessive welding	Safety gloves and personnel protective equipment used while welding and bending of sheet metal	1. Marking by permanent marker using measuring scale should be done. 2. Make sure that no leakage is present in the tank.	Re-welding of the tank edges where leakage is present.
3.	Welding of bolts for mounting vacuum pump.	1. Welding should be inspected visually. 2. Position of the bolts should be checked. 3. Alignment of bolts to be inspected by right angle.	Ensure that while welding the bolts no damage is caused to the tank surface.	1. The bolts should be perfectly perpendicular to the tank surface. 2. The position of bolt should be exact.	Make sure all the PPE (Personal protective equipments) are used while welding.	1. Use right angle to align the bolts perpendicular to surface of tank. 2. The position of bolts should be marked prior to welding.	Adjust the alignment of bolts as per requirement. Re-weld if necessary.
4.	Welding of motor mounting bracket to base plate	1. The position of the bracket should be checked. 2. The welding should be inspected visually.	While mounting the bracket no damage should be caused to the base plate.	1. The position of bracket should be perfect for proper functioning of brush. 2. Run weld should be done to mount the bracket rigidly.	Use of safety precautions and equipments is compulsory while welding.	The position of bracket should be marked on the base plate for accurate mounting.	Proper adjustment of position and re-welding for correct mounting.

4. CONCLUSION-

Implementation of the Industrial engineering principles such as Time study, Re-routing, Rescheduling, Value Engineering and Zero defect along with process automation in the manufacturing firm, leads to remarkable improvements in overall productivity of the firm. These management based tools have potential to bring the much needed positive change in any production system with complex production lines in their manufacturing stages. Hence it is plausible to posit that these core industrial engineering concepts have the potential to bring extraordinary results in design and manufacturing process of any product manufacturing firm

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