Waste management by application of quality control tools in the manufacturing industry – a case study

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Abstract: Waste management (WM) is a multi-disciplinary activity involving engineering principles, economics, urban and regional planning, management techniques and social sciences, to minimise the different types of wastes in the processes in the manufacturing industry. This study attempts to improve the performance of magnetic particle inspection machines, remove fire hazardous and reduce the use of kerosene oil using application of root cause analysis through quality control tools in manufacturing Industry. With implementation of tools modified action resources are improved which leads to continuous improvement in productivity and product quality in the organisation.

Keywords: waste management; magnetic particle inspection machines; quality control tools.

Reference to this paper should be made as follows: Singh, J., Singh, H., Singh, D. and Kumar, V. (2020) 'Waste management by application of quality control tools in the manufacturing industry – a case study', *Int. J. Services and Operations Management*, Vol. 35, No. 1, pp.12–35.

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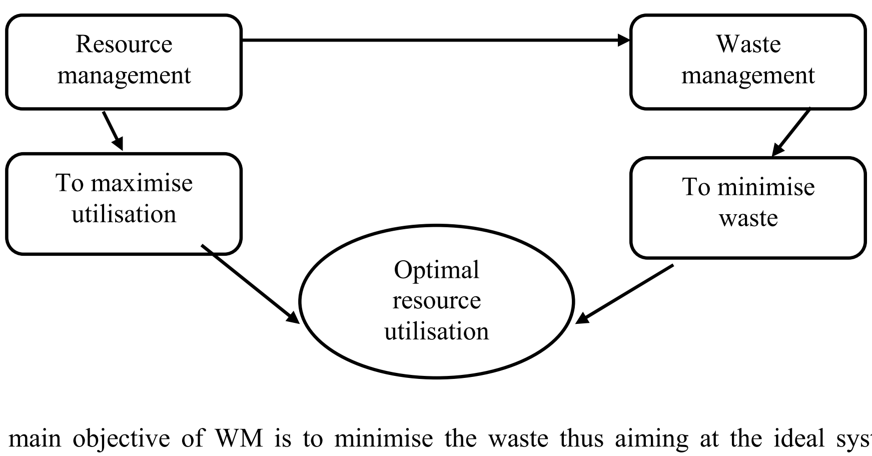
1 Introduction

Waste management (WM) includes the formation, treatment, and disposal of wastes and their resulting materials. The root cause of the problem can be solved by analysing the entire flow of materials and human activities. It is a science that involves logistics, environmental impact, social responsibility, and an organisation's waste disposal costs. It is also a process related to human resources, vehicles, governmental regulating bodies, and natural resources (Lemann, 2008).

Figure 1 Complementary relationships of waste and resource management



The main objective of WM is to minimise the waste thus aiming at the ideal system. Management of waste is an integral part of responsible oil and gas exploration and production activities throughout the world. Good WM can be especially challenging in areas where supporting infrastructure or regulatory frameworks are not well developed or absent. While the resource of management aims to maximise the utilisation, and productivity of the resources (man, machine, material and plant layout). WM is a manual, labour-intensive and hazardous occupation that has been and remains a means of survival for millions of people living in developing and globalising economies (Ziaee et al., 2012). The main objective of WM is to produce ideal system aiming at maximum utilisation of available resources and reducing waste arising in the processes (Jereme et al., 2015). WM has always been a serious problem for cities throughout the world (Maity et al., 2012). The impact of WM is inherently linked to other indicators of environmental health and sustainability, particularly water, land and air quality and human health (Praditya, 2012). The current emphasis in WM is on preventing pollution and minimising waste at source (Mavropoulos, 2013). This study has been carried out in the manufacturing Industry of Northern India to reduce the cost of kerosene oil and improve the performance of magnetic particle inspection machine through root cause analysis by using quality control (QC) technique in a systematic manner. The article is presented in ten different section including introduction, introduction to the industry under study and problem formulation, literature review, research methodology and objectives, research framework and root cause analysis, data collection before implementing qc tools, modifications done, data collection after implementing qc tools, validation of reduction in kerosene oil consumption, and conclusions, limitations, managerial implications and scope of future work.

2 Introduction to the industry and problem formulation

XYZ Ltd. (famous to manufacturing rear axles, shafts and spindles over worldwide), company used the kerosene oil as a medium to generate the magnetic field in components, so the company mixed the magna flux powder in the kerosene oil to done this process. These days, use of kerosene oil for this process was too much approximate 228 litres per day. Which was the basically need for poor people for their home needs such as used in stove for made their meals. This company have total 17 magnetic particle inspection machines, 100% components are inspected on Magnetic Particle Inspection machines. Generally, the M.P.I. process is characterised by:

- higher productivity
- quality of product increased by sort-out the defective product
- improve rust preventive method.

XYZ Ltd. manufacture large variety of Axle Shafts ranging from 1.5 kg to 150 kg, producing more than two million Axle Shafts annually. Their wide application range is given below:

- light and heavy commercial vehicles
- off-highway vehicles
- rear axle shafts are manufactured with flanges up to 425 mm
- large ranges of splined shafts are manufactured to meet a variety of transmission shaft requirements
- hollow spindles are the choice of heavy commercial vehicles like Volvo, Renault and specialty vehicles in Europe and North America.

The company is producing 1.8–2.0 lacs components in a month. Monthly consumption of kerosene oil in magnetic particle inspection procedure is around 6,500–7,000 litres. The company is facing wastage of kerosene oil of about 45%–50% of the total kerosene oil, in which 35% waste oil collected from the oil tank and the remaining 10%–15% of kerosene oil collected from the tray which was placed below the demagnetiser. Other 50% kerosene oil is used to wet the components during the process and placed on their surfaces for protecting the components from the rust. But this rust preventive method is not valid for a long time means it works only for 24 hours and after that, the magna-flux powder is used to remove the causes of rust. Total cost of kerosene oil is Rs. 310,000/- to 325,000 per month @ Rs 48 per litre, and the total amount of wastage of kerosene oil around Rupees.150,000/-. Present process of monthly waste disposal saves 100% of kerosene oil. By applying QC tool, it is expected to reduce the cost of scrap and trained the unskilled operators for better productivity and reducing oil wastage for saving the environment.

3 Literature review

Jewarski and Heinzle (2000) studied that biological processes are usually most efficient for degrading pollutants occurring in wastewater. Refractory and toxic compounds contained limit their applicability. In such cases combinations with chemical oxidation processes may improve the overall efficiency and efficacy. Most suitable oxidation processes for combination with biological treatment are wet air oxidation, ozonation, hydrogen peroxide treatment and other advanced oxidation processes. Some refractory compounds may be eliminated from the wastewater by the combined processes such as control of combined processes, elaboration of design parameters. Combined chemical-biological oxidation processes can provide effective and economic solutions. Al-Khalifa and Aspinwall, (2000) described 7,690 tons of municipal solid waste (MSW) generated daily at the six major cities of Bangladesh namely Dhaka, Sylhet Chittagong, Barisal, Khulna and Rajshahi, as estimated in 2005. Sampling was done in different seasons, at different waste generation sources such as residential, commercial institutional and open areas. The composition of the entire waste stream was about 74.4% organic matter, 9.1% paper, 3.5% plastic, 1.9% textile and wood, 1.5% metal, 0.8% leather and rubber, 0.8% glass and 8% other waste. The per capita generation of MSW as measured in six major cities was ranged from 0.325 kg/cap/day to 0.485 kg/cap/day while the average rate was 0.387 kg/cap/day. The potential for waste recovery and reduction based on the waste characteristics are evaluated and it is predicted that 21.64 million US dollar per year can be earned from recycling and composting of MSW. Foster (2006) investigated group performance, focusing on consistency between plant quality improvement approaches within a firm. In each of five automotive original equipment manufacturing plants, employees were surveyed regarding quality practices. Results showed that out of five plants, plants one and four both emphasised process and design over external approaches, but plant four also emphasised reward-based incentives. Plants two and three have emphasised external approaches while discouraging reward based incentives. Rawabdeh (2011) presented a model that utilises quality function deployment (QFD) for identification, prioritisation and determination of sources of shop floor waste, so as to eliminate them. The approach used in developing the model identified the importance of recognising signs of waste or the 'whats' in the waste HOQ. The high priority areas of waste are taken as inputs in the causes HOQ. Analysis of the HOQ highlighted the wastes with high priorities. The developed QFD-waste elimination model proved to be a powerful tool for identifying, prioritising and finding the most practical methods for getting rid of major waste in a shop floor environment. Rajalingam et al. (2012) presented a case study for identifying critical factors and its Level affecting a plastic injection mouldings process of a plastic cell phone shell call front Cover by deployed some of seven QC tools. The highest defect 30% contributed due to shrinkage which causes the length and width below the specification limit. Three Experimental factors mould temperature, injection pressure and screw rotation speed is to be studied at two levels and 16 results were found within the required limit. The shrinkage defect has reduced from 30% to 0%. Hassan (2013) suggested a set of criteria based on the yield of incinerator ash (Φ) to study the ash recycle and reuse potential. The Taiwan Environmental Protection Administration (TEPA) has studied the treatment and reuse of municipal solid waste incinerators (MSWI) ashes for many years and collected references on international experience accumulated by developed nations for establishing policies on treatment and reuse of MSWI ashes. Feasible applications included utilisation of ashes, which after sieving and separation of metal particles, produce granular materials. When granular materials complied with TCLP limitations, they could be utilised as cement additives or road base. The procedures of evaluation have been proposed in the performance criteria to be included in the proposed decision-making process of ash utilisation. The amount of ash generated is now 1.05 million tons per year, including 90% bottom ash and 10% fly ash. The average yield is 0.192 tons of ash per ton of waste. Niutanen and Korhonen (2013) discussed the possibilities for a regional network management system with a case study of WM scenarios of the Satakunta Region, located in Southern Finland. Results of this study indicated that, perhaps, the regional systems approach to many different municipalities and many different firms can better prevent problem displacement or problem shifting than more fragmented and isolated management efforts, e.g., of an individual firm or of an individual municipality. Ilangkumaran et al. (2014) described an application of hybrid multi-criteria decision-making (MCDM) technique for the selection of waste water treatment (WWT) technology for treating wastewater. The proposed approach is based on fuzzy analytical hierarchy process (FAHP) and hierarchy grey relation analysis (GRA) technique. The FAHP is used to determine the weights of criteria and then ranking of the WWT technology alternatives is determined by GRA. Chvatal and Smit (2015) examine policy prohibiting landfill salvaging and the intended and unintended consequences of such a decision on landfill waste salvagers. The author development of an integrated WM model that is in concert with the policy directives but more importantly, ensures that the now destitute waste salvagers regain some form of income security and human dignity. Jereme et al. (2015) conducted semi-structured interviews with WM related dealers operating at Kuala Langat and Sepang districts in Selangor State, it was found that inconsistency in policy formation by local authorities on waste disposal regulations and as well bureaucracy in business registration for waste dealers has indirectly encouraged illegal dumping of waste in the districts.

4 Methodology adopted and research objectives

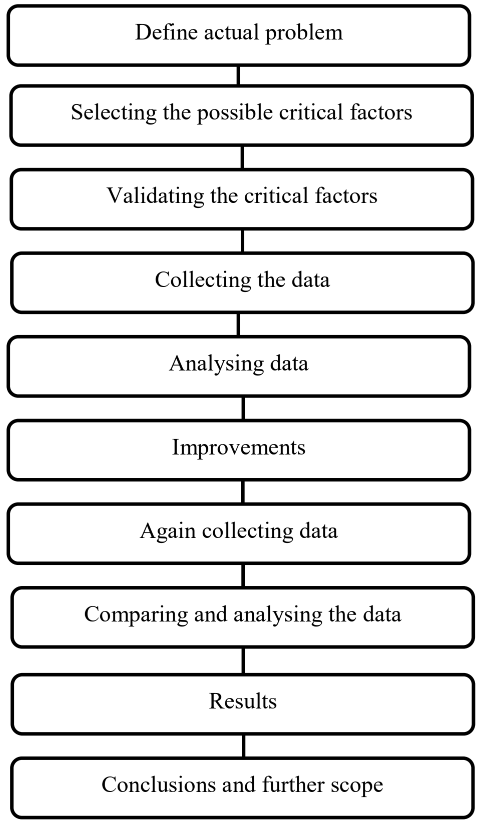
The methodology used for this study is root cause analysis through QC tool, which is very effectual tool in all industries, where we necessitate more productivity, at slighter cost. This tool is being used by various companies to optimise its resources like man, machine, material and method systems through the implementation of QC tools as this concept has already been tested and used in many developed countries and proved to be very effective. The majority of the companies could be benefited from upgrading their quality management tools in improving productivity, as well as enhancing competitiveness in national and international markets. Implementation of QC tools is a management decision that requires many considerations such as company's operations, strategy, staff and customers. It has been identified from the literature that a commitment of implementing QC tools is essential for industry's top management to floor level employees to compete against competitors. QC tools has been a popular business strategy in many leading manufacturing industries over the past few years. A large number of companies that have implemented QC tools are large multinational companies (MNCs) such as NOKIA, Hawlett-Packard (HP) and International Business Machine (IBM). The practical use of QC methods today is still limited in SME's. In this era of global competition, there is a need for application of new quality techniques in form of strategic management, quality assurance, quality systems, QC, etc. In other words, organisation has to implement the concept of QC tools. This concept provides the approach to realise the manufacturing strategy leading to fulfilment of organisation's corporate strategy. The principle of QC tools philosophy is to increase a firm's commitment to quality and once they applied it correctly to enhance the firm's competitiveness positions in market, it effectively support their business practices, e.g., cost reduction, improve product quality, and safety for environment and human being. The methodology adopted is shown in Figure 2.

The objectives of the present study are as follow:

- Reduce the use of kerosene oil using application of QC tools.
- Make eco- friendly environment and remove fire hazardous.
- Improving the performance of M.P.I. machines.

The present study is an attempt to assess the performance of QC tools in the case company. Theoretical framework including quality circles that involves team of senior managers and senior engineers has been established to improve the performance of M.P.I. machines and reduce the consumption of kerosene oil and results are highly encouraging. Data collection before and after implementing QC tools has been analysed and results are obtained.

Figure 2 Use of methodology



5 Root cause analysis and research framework

To reduce wastage of oil in M.P.I. procedure exhaustive study was carried out and it was decided to go for brainstorming session. In brainstorming session, different ideas had been taken from different department's officers and workers about the excessive wastage of kerosene oil generation in the company. This helps in generating ideas of a group. Brainstorming session provides the platform for person to person interaction, so entire team is involved. It is not platforms for debate for criticising the ideas of other people but it only helps in building of ideas that leads to fantastic ideas. Once ideas are generated then it is displayed by using effective tool that allows people to easily see the relationship between factors to study processes, situations and for effective planning.

- Brainstorming related to wastage of oil (man)
  1. overtime
  2. unskilled
  3. wages problem
  4. unsatisfactory job profile

5 over work
6 carelessness
7 inadequate working environment
8 absenteeism.

- Brainstorming related to wastage of oil (material)
  1 improper production planning
  2 poor plant layout
  3 material (kerosene oil) quality
  4 inadequate ventilation in the shop
  5 improper material handling
  6 poor condition of waste collection drum
  7 over production
  8 improper location of standing fan.
- Brainstorming related to wastage of oil (machine)
  1 defective machines
  2 improper machine lighting
  3 outdated machines
  4 without preventive maintenance
  5 improper foundation
  6 less trained machine operator
  7 design problem
  8 bad condition of ASTM standards.
- Brainstorming related to wastage of oil (method)
  1 inadequate space for storage
  2 improper material handling of oil
  3 improper method of M.P.I. procedure
  4 improper method of induction hardening and tempering process
  5 inappropriate machine tray
  6 improper material handling of produced components
  7 poor plant layout
  8 improper method of induction hardening process.

The wastage of oil due to 4M's has been identified through brainstorming among the members of quality circles and M.P.I process is standardised using QC tools. From all brainstorming points, critical points have been selected from several meetings with the employees (managers level and workers.) of the different departments (Induction Departments, Lab Department, Production Department and Store Department). The action is further taken on those critical points to improve the process of M.P.I Machine.

6 Data collection before implementing QC tools

The data regarding the wastage of lubricating oil by various critical factors has been shown in Table 1.

After data collection against all the valid points, it has made calculations very easier. All the valid critical factors were divided into groups according to the percentage loss of wastage oil and it was divided into four categories which are shown in Table 2.

It is clear from Table 2 that the group 1 has the maximum waste oil percentage about more than 80%, so if we assume the group 1 for removing its critical factors. These three factors under group 1 can solve problem up to 80%. That's why we had selected the group 1 for modified action. We have also taken some steps which resolves the factors of group 1 and as well as group 2. In fact, our main motive is to reduce the wastage of oil without any extra expenditure.

In Table 3, we can see that almost all critical factors have more than 50% generation of waste oil, these critical factors are the root cause of the problem.

Table 1 Waste oil collected by various critical factors

Reasons	*WEEK-1st (April 2015)*	*WEEK-2nd (April 2015)*	*WEEK-3rd (April 2015)*	*WEEK-4th (April 2015)*
Improper method of M.P.I. process	16.25	15.75	15.50	15.75
Less training to operator (unawareness)	15.00	15.50	15.50	16.00
Design of parts of machine	685.00	680.00	670.00	675.00
Design of work pieces	90.00	98.00	95.50	98.50
Unskilled	10.50	12.50	14.00	13.50
Evaporation and improper location of standing fan	7.00	7.00	7.00	7.00
Carelessness	2.50	2.00	1.75	1.75
Loading/unloading of components	3.50	3.25	2.75	2.75
Transportation of work pieces	20.00	30.00	20.00	40.00
Lack of interaction between employees	3.50	3.00	3.50	3.50
Absenteeism	1.50	1.00	1.50	1.00
Inadequate machine settlement	1.00	1.00	1.00	1.00
Improper method of induction hardening and tempering process	2.50	2.75	2.25	2.50
Poor material handling	15.00	15.00	15.00	15.00

Table 2 Percentage wise grouping of critical factors

Sr. no.	*Group frequency*	*Observed critical factors*	*Group wise oil wastage in a week (in litres)*
1	> 50%	Improper method of M.P.I. process/less training to operator (unawareness)/design of parts of machine	708.81
2	20%–30%	Design of work pieces/unskilled/evaporation and improper location of standing fan	115.13
3	10%–20%	Loading/unloading of components/transportation of work pieces/lack of interaction between employees/carelessness	35.94
4	< 10%	absenteeism/inadequate machine settlement/improper method of induction hardening and tempering process/poor material handling	19.75

Table 3 Total average scrap of group 1

Reasons	*WEEK-1st (April 2015)*	*WEEK-2nd (April 2015)*	*WEEK-3rd (April 2015)*	*WEEK-4th (April 2015)*	*Average*
Improper method of M.P.I. process	16.25	15.75	15.50	15.75	15.81
Less training to operator (unawareness)	15.00	15.50	15.50	16.00	15.50
Design of parts of machine	685.00	680.00	670.00	675.00	677.50
Total					708.81

Table 4 Total average scrap of group 2

Reasons	*WEEK-1st (April 2015)*	*WEEK-2nd (April 2015)*	*WEEK-3rd (April 2015)*	*WEEK-4th (April 2015)*	*Average*
Design of work pieces	90.00	98.00	95.50	98.50	95.50
Unskilled	10.50	12.50	14.00	13.50	12.63
Evaporation and improper location of standing fan	7.00	7.00	7.00	7.00	7.00
Total					115.13

In Table 4, it could be seen that one of the factor, i.e., design of work pieces is generating more waste oil, but we cannot do anything on this reason, because this change depends on the customers.

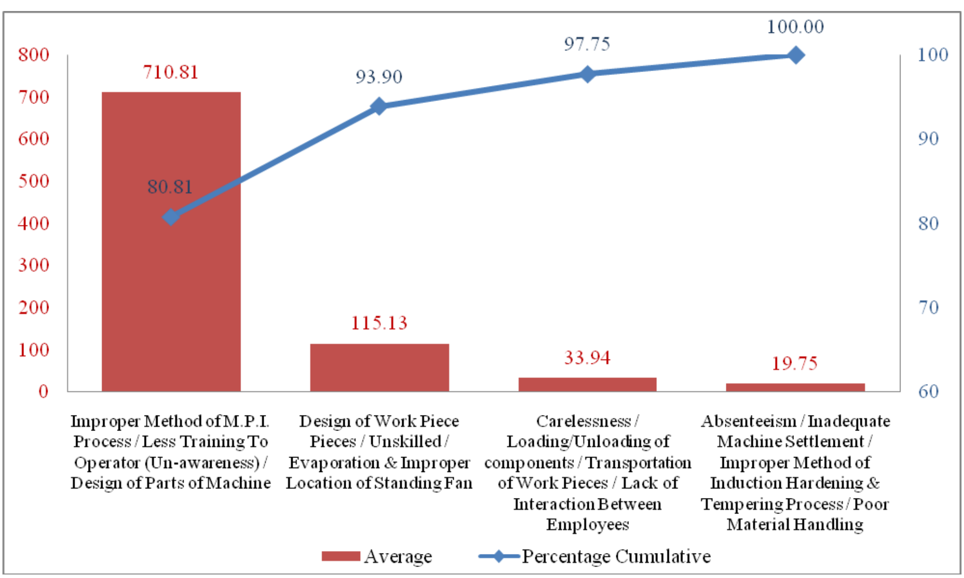
Table 5 Total average scrap of group 3

Reasons	*WEEK-1st (April 2015)*	*WEEK-2nd (April 2015)*	*WEEK-3rd (April 2015)*	*WEEK-4th (April 2015)*	*Average*
Carelessness	2.50	2.00	1.75	1.75	2.00
Loading/unloading of components	3.50	3.25	2.75	2.75	3.06
Transportation of work pieces	20.00	30.00	20.00	40.00	27.50
Lack of interaction between employees	3.50	3.00	3.50	3.50	3.38
Total					35.94

Table 6 Total average scrap of group 4

Reasons	*WEEK-1st (April 2015)*	*WEEK-2nd (April 2015)*	*WEEK-3rd (April 2015)*	*WEEK-4th (April 2015)*	*Average*
Absenteeism	1.50	1.00	1.50	1.00	1.25
Inadequate machine settlement	1.00	1.00	1.00	1.00	1.00
Improper method of induction hardening and tempering process	2.50	2.75	2.25	2.50	2.50
Poor material handling	15.00	15.00	15.00	15.00	15.00
Total					19.75

Figure 3 Perato chart (see online version for colours)



After forming the groups of the critical factors than it was analysed with help of Pareto Chart which was named after Wilfred Pareto's, 80:20 rule was used in the study to analyse the main causes of waste in organisation.

Now Pareto tool helped to find the causes of wastage and all the main causes were listed and identified. After identification of critical factors, modified actions were taken to remove all these factors and reducing the kerosene oil wastage from the organisation.

7 Modifications done

To optimise the suitable and best result for saving the kerosene oil from their wastage, we have taken the following actions.

7.1 Awareness

First of all, we found that our operators, who worked on M.P.I. machines does not knows the actual drawbacks of the wastage of kerosene oil. So we organised some meeting and seminars to teach them. These awareness steps are most important to save the oil and reduced the risk of fire because sometime operator can do mistake due to their negligence which can cause the reason of dangerous accident such as risk or blast. These steps were also helpful for us to shrink the distances between operator and employees of the department. We aware the operator to decrease their absenteeism so that we could provide proper information to them, which will be very helpful for them in their future work. We also enlighten them to concentrate on work to reduce the carelessness of work. Awareness of workers regarding their role in implementation of QC Tools plays a significant role in reducing wastage.

7.2 Training to operators

We have organised some lectures to the new and old operators to remind and teach them the procedure of reducing wastage. In this lectures, we give some information to the operators that how to operate the machine in best way by which we can save the oil at maximum by wetting the component in a systematic manner The proper training is provided to load and upload the component with minimum wastage of oil. We taught to machine operator and transportation operators (who works on fork lifter to move the components from one stage to others) that how to place the components on stand and what are ways, at where, they can easily move the material from one place to another and how to protect the material from the dust and other particles respectively, so that we can save the kerosene oil from the dust particles. We arranged the seminars to the workers twice in a month, so that, we can easily convey the message to the workers. Moreover the training regarding proper implementing of QC tools is necessary if there is still some wastage of oil.

7.3 Change in the collection drum of waste oil

Another one main constraint of waste oil was the collecting drum, in which the used oil of M.P.I. procedure was collected. In fact, the placement and condition of waste collecting drum was poor. Then we arranged the spare drums and wrote the 'used M.P.I. oil' on the drum as shown in Figure 6. Moreover, the drums are placed nearer to the M.P.I machines which results in time saving of the operator.

Figure 4 Waste oil collecting drum before the implementation (see online version for colours)

Figure 5 Waste oil collecting drum after the implementation (see online version for colours)

7.4 Re-design of the parts of machine

There are some obstructions related with the parts of the M.P.I. machines which are causing wastage of oil. In order to obtain the optimised results, some changes in the design of parts of machines and system of distributions of oil have been done, which are discussed below:

7.4.1 Change in the design of de-mug trolley

The first preference was to change the design of de-mug trolley, which is helpful to demagnetise the components after the procedure. We placed the components on this trolley after M.P.I. procedure and passed it through the de-magnetiser transformer, so that we can remove the magnetic property from the components. But the design of trolley was very older, and the major fault was the base of the trolley which was made with wood. Actually when we placed the components on it for de-magnetising, then oil which was placed on the groove of axles that falls on the wooden base which was not collected in tray of de-magnetiser, and some oil was evaporated in the environment by the hot temperature of production shop. So we did some changes in the design of trolley so that we can collect maximum waste oil from the machine and can improve the quality of the product. The more changes related to design are given below:

7.4.1.1 Initial design of trolley

Initially, the design and condition of de-magnetiser trolley was poor and it does not fulfil actual requirement. So the changes in the material of base and the design of trolley have been done. The main problem was the quantity of kerosene oil that was available on the wooden base, which was the reason of oil evaporation and falls on the floor.

Figure 6 Initial design of de-magnetiser’s trolley (see online version for colours)

7.4.1.2 Changes in trolley of de-magnetiser

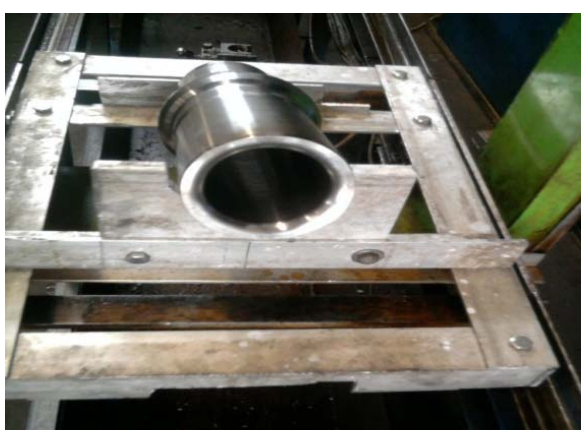
First change in the trolley was to reduce the quantity of wood as a base as we are getting maximum wastage oil in the tray of de-magnetiser. By this activity, it had made possible to save the oil from the evaporation and try to use that oil in other processes also. So we placed the two wooden blocks on the trolley so that we easily kept the components on.

Figure 7 First change in trolley those wooden blocks (see online version for colours)

The main problem of the wooden blocks is that sometime our components were fallen through the gap between these blocks, which made the reasons of high scraped material.

In second change in the trolley, the wooden blocks were replaced by the with aluminium plates having 0.5–0.8 cm thickness. By using this material, the base plates were totally removed and we collected the maximum kerosene oil in the de-magnetiser tray because of providing some inclination in the design which spell out whole oil from the grooves of splines.

Figure 8 Second improvement in trolley (see online version for colours)



But the main constraint with this technique was the scratches on the surface of components. In actual fact, the surface of components which was hardened through the process of induction hardening process was saved from scratches but the material which was only machined on the CNC and no hardening process was done on it, surface of those components were scratched with this aluminium structure.

Figure 9 Final improvement in trolley (see online version for colours)

In the last change in trolley, the aluminium plates were replaced with the Teflon sheet having the same thickness as that of aluminium plates use in previous improvements (0.8 cm–1.0 cm).

This technique was very helpful, because it provides the maximum oil in the tray and the major problem of scratches on the surface of soft material components was totally eliminated.

7.4.2 Change in the height of pump

When the kerosene oil needed to be changed then we got more than 7 litres oil in the tank of M.P.I. machine, and this oil in pumped with the help of rotary pump which is fixed in the tank. This pump also helps to maintain the proper concentration of magna-flux powder in the oil. Due to this, there is a need to change the height of pump in the tank, so that we could use the maximum quantity of oil for M.P.I. procedure. By this change, we can use the 3–4 litres extra in the procedure and for the recycling we got 3–4 litres instead of 7 litres.

7.4.3 Increase in the length of de-magnetiser tray

To get more oil for the recycling, increase in the length of de-magnetiser tray was done, because those components whose length is too much and the extra oil cannot fall in this tray. This improvement was very helpful for us, since the oil which falls on the floor is then collected in the tray and the risk of fire accidents is reduced.

7.4.4 Change in the oil distribution system

Another problem of system was the improper distribution system of all the using oil in the stores. This is very important to save the oil all over the company. Actually, there was no proper distribution system and most of the time, over quantity oil was spread on the floor during its pouring in the flask container, which called the fire hazardous accidents. So improvement in the storage system of oil in the drums and pouring system in the flask have been done as shown in Figures 11 and 12.

Figure 10 Initial picture of distributing system of oils (see online version for colours)

These new improvements increased the storage capacity up to twice. Moreover level indicator showing the level of quantity of oil in the drum is provided. The tap to each drum and two different trays having different section related with different oil have been provided. These changes reduces fire risk and save the maximum oil at higher level.

Figure 11 Storage drums of different oils and new pouring systems of oils (see online version for colours)

Figure 12 Clean storage areas (floor) of oils and provide note for the workers (see online version for colours)

Figure 13 Centri-gravitational equipment under construction (see online version for colours)

7.4.5 Design of centri-gravitational equipment

The main project was to reuse the used kerosene oil after M.P.I. procedure. So the idea of centrifugal gauge has been introduced. In this gauge the oil sediments settled down in the tube, so from this idea, equipment same as that centrifugal gauge has been prepared. In this equipment, we welded the drum with four rods as pillars below the drum; and attached the conical shaped container which helps in collecting the heavy particles, mixed in the oil. This conical shaped is attached with a pipe and rotating valve. A tap is also attached with lower side of the drum which helps us to separate the used oil as shown in Figures 13 and 14.

Figure 14 Centri-gravitational equipment in working and recycled M.P.T. oil drum (see online version for colours)

This equipment is very helpful to recycle the M.P.I. oil and without any extra expenditure. We made a proper system to apply it and no other workforce is needed to follow this recycling system. All this recycled system undergone in the sight of LAB Department.

7.5 Replacement of the kerosene oil with Redi-Bath

Now, de-mineralised water is used in the place of kerosene oil. This process is same as like the process which was done with kerosene oil but the components having a risk of rust, which is very dangerous for our original equipment (OE) components. So, to prevent them from the rust we add new product named Redi-Bath in the water. It helps to prevent the OE components from the rust and the one another process is saved, when we use the water for the M.P.I. procedure. Actually, that other process was taking the extra workforce, time and labour cost. So this product is very helpful for us to save the money and time. This product has the main function to maintain the better visibility of Magna-flux powder in the de-mineralised water. We use the concentration of 2.1 ml of Redi-Bath oil in one litre of de-mineralised water. So the one machine takes 20 litters of de-mineralised water and 42 millilitres of Redi-Bath. The capacity of single Redi-Bath bottle is 5.0 litres

Figure 15 Redi-Bath oil (14A) (see online version for colours)

The price of one Redi-Bath bottle is Rupees 11,300/- and it is used for 115–120 times on M.P.I. machine. If we compare this cost with kerosene oil then the price of kerosene oil used for many times, i.e., Rupees 92,000/- (Rs. 40/- per litres of kerosene oil), which saves about Rupees. 80,700/-.

In order to optimise the best results, training and awareness of operator working on M.P.I machine, change in the collection drum of waste oil, re-design of the parts of machine, and replacement of the kerosene oil with Redi-Bath has been done to ascertain the important benefits occurred in the form of reduced consumption of kerosene oil. As these improvements reduces the wastage of kerosene oil, so this improvements covers all conditions such as eco-friendly environment, fire resist, cost savings and many others.

8 Data collection after implementing QC tools

The data regarding consumption of oil has been collected after root cause analysis and results were highly encouraging.

Table 7 Data collection after taken modification action

Reasons	*WEEK-1st (Aug. 2015)*	*WEEK-2nd (Aug. 2015)*	*WEEK-3rd (Aug. 2015)*	*WEEK-4th (Aug. 2015)*
Improper method of M.P.I. process	4.50	4.00	3.00	2.50
Less training to operator (unawareness)	2.50	3.00	2.50	2.00
Design of parts of machine	405.00	395.00	385.00	390.00
Total wastage oil from these three factors	412.00	401.50	390.50	394.50

Table 8 Monthly use of kerosene oil in 1st section improvements

Sr. no.	*Name of shops*	*Initial*	*Awareness*		*Change de-mug trolley and tray*		
		Apr-15	*May-15*	*Jun-15*	*Jul-15*	*Aug-15*	*Sep-15*
1	Axle tech line	120	100	90	85	80	75
2	Escorts line	80	70	70	75	70	75
3	Graziano line	210	200	195	185	185	170
4	Induction hardening	2,010	1,975	1,905	1,925	1,905	1,850
5	LAB	1,680	1,730	1,620	1,675	1,655	1,630
6	Mahindra line	675	680	620	595	570	550
7	MNC line	435	430	425	435	380	365
8	PTL line	495	435	430	430	395	380
9	Shaft line	310	305	295	285	270	265
10	Spindle line	550	540	520	530	525	495
11	TMA line	585	580	560	570	550	550
	Total	7,150	7,045	6,730	6,790	6,585	6,405

In Table 8, it is seen that the 1st section improvements in which we provide some seminars and training lectures to the machine operators, change the design of de-mug trolley and de-magnetiser tray, which helped us in collecting the maximum used oil for the reused process. The consumption of kerosene oil in different shops for April-15 was 7,150 litres which was reduced to 6,730 litres in June-15 by proper awareness aspects. Further, the consumption of oil was reduced from 6,730 to 6,405 litres by changing de-mug trolley and tray.

Table 9 Monthly use of kerosene Oil in 2nd section improvements

Sr. no.	*Name of shops*	*Change location of pump*		*Sedimentation*	
		Oct-15	*Nov-15*	*Dec-15*	*Jan-15*
1	Axle tech line	65	60	65	60
2	Escorts line	60	55	55	50
3	Graziano line	150	125	140	130
4	Induction hardening	1,710	1,665	1,570	1,495
5	LAB	1,525	1,450	1,465	1,450
6	Mahindra line	535	520	485	450
7	MNC line	355	340	325	315
8	PTL line	350	335	305	290
9	Shaft line	255	240	230	210
10	Spindle line	450	430	435	410
11	TMA line	490	470	475	460
	Total	5,945	5,690	5,550	5,320

Table 10 Monthly use of kerosene oil in 3rd section improvements

Sr. no.	*Name of shops*	*Re-use of kerosene oil (15 litres fresh + 5 litres sediment oil)*						
		Feb-15	*Mar-15*	*Apr-15*	*May-15*	*Jun-15*	*Jul-15*	*Aug-15*
1	Axle tech line	50	65	60	65	65	70	75
2	Escorts line	35	30	30	30	25	25	20
3	Graziano line	90	105	90	100	95	95	90
4	Induction hardening	905	950	850	835	755	705	645
5	LAB	1,380	1,425	1,370	1,395	1,330	1,350	1,295
6	Mahindra line	290	270	235	255	240	235	220
7	MNC line	275	305	310	300	295	290	290
8	PTL line	165	140	130	135	120	115	100
9	Shaft line	125	155	140	145	145	130	130
10	Spindle line	330	350	310	295	280	275	270
11	TMA line	310	315	275	270	220	250	240
	Total	3,955	4,110	3,800	3,825	3,570	3,540	3,375

In Table 9, we can see the 2nd improvements, in which we change the location of pump of M.P.I. machine that is used to pump the kerosene oil from the oil tank to machine bed. The improvement is sedimentation, in which there is a use of centrifugal equipment to separate the carbon and dust particles from the oil.

In Table 10, we can see the third section improvements that the separated oil reused in M.P.I. procedure in addition to fresh kerosene oil. With this improvements decrease in the consumption of kerosene oil from 141 litres to 109 litres per day have been achieved during the months of Feb-2015 to Aug-2015.

9 Validation of reduction in kerosene oil consumption

The data of overall improvement in consumption of oil has been taken from Feb-15 to August-15 and this improvement is validated by using paired sample t test.

Null hypothesis

HO There is no significant difference in the overall improvement before and after implementing QC tools.

Alternate hypothesis

Ha There is a significant difference in the overall improvement before and after implementing QC tools.

- Average of deviation = 62.48
- Standard Deviation = 0.639

- t value = 6.765
- p value (two tailed) = 0.007.

The table value for 9° of freedom at 5% significance is 2.432, which is less than 6.210902 and p-value is less than 0.05. Hence, the null hypothesis is rejected. The result signifies that there is a significance difference in the overall improvement before and after implementing QC tools. Hence, it is concluded that QC tools brings significant positive impact on processes in the case company.

10 Conclusions, limitations, managerial implications and scope of future work

The main significance of this study is to reduce the kerosene oil quantity of WM is a challenge for efficient and cost-effective operation at plant under study, because the actual waste generation is more than any other plant in India and abroad as well. Considering the oil wastage of last year is 80,550 litres, which is on higher side and the rejection is 45%, which is on the higher side than any other organisation. The main objective was to reduce the wastage of kerosene oil used in M.P.I machine. At present, there was no system for monitoring the WM; this is leading to lesser the productivity and mismanagement of resources during the M.P.I. process. Reducing the wastage helped the case company to enhance productivity and reduce the cost of wastage. The selection of manufacturing Industry has been done on snowball sampling. There are chances of variation in views of various members of quality circles formed for root cause analysis. It will be useful for researchers and academicians to study the practical significance of QC tools in the manufacturing industry. The study can also be extended to other machines that are used in the industry. The wastage of kerosene oil was reduced to 100%. The wastage of other consumable items is also on higher side and one can extent this work by taking other critical factors which cause the wastage. Moreover, the research can be done on application other advances QC tools like tree diagram and affinity diagram and integrated tools involving QC tools and process control tools.

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