The Role of Total Productive Maintenance (TPM) In Safety Improvement and Decreasing Incidents in Steel Industry

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Abstract—Incident occurrence probability and hazards, which usually occur in repairing operations for repairmen, industrial cleaning and production personnel, are increasing along with the improvement of technology and applying equipment’s in production. Human faults are of the most significance in incident occurrence which are dependent to the kind of human activity and are categorized into three classes; production, industrial cleaning and repairs. Total Productive Maintenance (TPM) is one of the very important and strategic plans in maintenance department of the productive industries which is seeking maximization of equipment efficiency and reliability. The objective of this paper is identification and introduction of parameters affecting directly or indirectly the industrial safety with continuous utilization of TPM plan and eventually presenting its advantages such as; incident reduction and equipment safety increase and resulting in improvement of industrial safety conditions.

Keywords—Equipment’s; Erosion; Incidents; Safety; Total Productive Maintenance; 5s.

Abbreviations—Total Productive Maintenance (TPM).

I. INTRODUCTION

Industrial cleaning and repairs are dependent to equipment’s failure. The older are the equipment’s, the more probable are failures and incidents. Most of the incidents occur because of the unsafe conditions such as; incorrect design of workplace, inappropriate design of equipments and tooling, existence of technical and physical faults in equipments, damaged instruments and tools like rotted isolating coating, electricity wires, cracking or rusting of ladder bases, lack of sealing around the gas pipes and etc [Haley, 1992; Brah & Chong 2004; Pomorski, 2004]. Lack of effective protection shields for the equipments, insufficient protecting gears, equipments risky and inappropriate position, lack of fire and explosion preventive system, unfavorable working conditions such as; air pollution, disturbance in automatic machines mechanisms, and etc [Chan et al., 2005; Dossenbach, 2006]. Generally, workplace is made up of three elements; human, materials, and equipments and environment. For succeeding in safety plans, all the three elements must be noticed and it may be inferred that the most important noted element is human in workplace [Borris, 2005; Waeyenbergh & Pintelon, 2009; McBride, 2010]. As human is a complicated creature and environmental, mental, and physical factors are directly affecting his behavior, it can be briefly said that the equipments and materials can be made safe to a favorable extent but the human factor in workplace must be conducted to the more interest in incident prevention. Emphasizing the safety and preventing incident occurrence is a very vital and important affair. Operational trainings must be done simultaneously with the training for incident prevention and near miss analysis in order to be efficient. Safety is an important part of TPM and must be, like other activities, accomplished stage by stage [Nakajima, 1988; Tokutaro Suzuki, 1994]. Some issues in process environment are of special importance. For instance, it’s very important to
utilize the instruments which have safe and non-failure systems. It means the tooling must be designed in a way that even if they’re not maintained, they continue working safely [Venkatesh, 2005]. Ensuring the plant safety condition over stoppage and maintenance are also very important. One of the TPM objectives, beside delivery of sound product, is protecting and preserving organization resources such as human resources. In the other hand, human and equipment safety in industrial and production environments is one of the most important issues which will bring about irreparable damages and sometimes financial and human risks for the operators and organization if safety principles and standards are not regarded [Wakjira & Pal Singh, 2012; Werkema, 2012]. In this paper, in addition to the applications of safety in maintenance, TPM plan and its components and results of its systematic deployment are discussed. Then, the safety principles in work place while operating the equipment’s and tooling is discussed and after that, the functions of TPM in improving the level of human-equipment safety are mentioned.

While implementing maintenance, it’s maybe necessary to use the services of other companies and contractors, too. So it’s very essential to make the safe and non-risky condition for such tasks. TPM is one of the instruments applied in production industries for increasing equipment reliability, maximizing tooling efficiency, and their longevity. Safety and its indicators are always of the most important organization indexes.

In this paper, the role of TPM in production lines of Iranian Steel CO. in terms of safety improvement and incident reduction, is investigated.

II. THE HISTORY OF MAINTENANCE

Maintenance, since its manifestation in 1930 till now, can be classified into three successive periods [Singh et al., 2013].

First period: this period is before the Second World War. During that era, industry wasn’t mechanized like now and then the equipments stoppage time wasn’t so important.

Second period: during world war, many changes happened in the world. The war pressures and conditions made a great demand for goods, while the power for producing these goods was severely reduced.

Third period: after the second period, industrial mutation in maintenance technology, increase in organizations extension and complication and their resources, and increase in physical resources maintenance expenses lead to inquiry methods for increasing equipments and tooling longevity.

III. TPM HISTORY

After the Second World War, Japanese industries concluded that in order for successful competition in global market, it’s necessary to improve their products quality. In this regard, Japanese imported management, production and manufacturing techniques from the US and adapted them to their condition. As a result of these works, Japanese products got well-known all over the world due to their high quality and global attention was drawn to the Japanese management techniques.

3.1. From Preventive Maintenance (PM) to Total Productive Maintenance (TPM)

More than thirty years ago, in order to improve equipment maintenance system, Japan imported maintenance hypothesis and patents from the US. The next imports included productive maintenance, repair-less products, reliable engineering and etc. The thing which is called TPM nowadays is actually the same as American productive maintenance system that has been enhanced to adapt with the Japan industrial condition [Dossenbach, 2006]. In most American companies net groups are responsible for all the maintenance works in the plant and a kind of worker separation is imposed to the industry by the motto “I produce and you maintain.” Adversely, many Japanese companies have put all the workers in company plan with changing and optimizing the American preventive maintenance [Dossenbach, 2006; Rodrigues & Hatakeyama, 2006]. Total productive maintenance which is defined as “productive maintenance which is applied by all the workers”, is based on the principle that in optimizing equipments, all organization people, from production operators to top level managers must be involved [Dossenbach, 2006].

The basic initiative in TPM principles is that the operators themselves do the main and primary equipment maintenance. They keep the machines in proper condition for production and increase their knowledge and abilities for achieving the potential problems in equipments before these equipments are damaged and inactive.

In most American companies, it’s more than thirty years since the first TPM documents were presented. TPM was developed first in Japan. This system was first deployed by Nippon Enson CO., a car spare parts manufacturer, in 1971. The first version of TPM is known as Nakajima’s model (of TPM founders) [Brah & Chong, 2004]. Some changes were made to the fifth principles of his model up to 1989. With attitude change in TPM macro-policies, the second and third versions of mentioned system were presented by Mr. T. Suzuki (during 1989 to 1994) [Borris, 2005; Chan et al., 2005]. One of the important characteristics of the third version is increasing the system principles to eight pillars as below:

1. Increase Overall Equipment Effectiveness (OEE)
2. Self-control maintenance by production line personnel
3. Planned maintenance by PM department
4. Theoretical and practical trainings for all the personnel
5. Early management on equipments
6. Establishing qualitative maintenance system with the relationship between PM and QC departments
7. Establishing TPM in support and staff departments
8. Safety and environment management (HSE management)
IV. Surveying the Eight Pillars

First Pillar (5S)
TPM is started by 5S. When the workplace isn’t clean, the problems aren’t finely determined. Workplace cleanliness and arrangement helps the teams to view the problems and seeing the problems is the first step.

Second Pillar (Self-Control Maintenance)
This pillar prepares the operators to be able to do the simple maintenance works.

Third Pillar (Kaizen)
Kaizen is a Japanese term compound of two words “kai” which means change and “zen” which is good (for better). Kaizen is basically for small but continuous improvements with partnership of all the organization personnel.

Fourth Pillar (Planned Maintenance)
This pillar seeks sound equipments with fault-free production to satisfy the customer. Here, maintenance works are classified to three groups: predicted maintenance, emergency maintenance, and corrective maintenance.

Fifth Pillar (Maintain Quality)
The objective of this pillar is to satisfy the customer with delivery of the most quality product meanwhile keeping a sound and fault-free plant.

Sixth Pillar (Training)
The objective is to have multi-skilled personnel who do their responsibilities well and interestingly.

Seventh Pillar (Official TPM)
The objective is increasing productivity and efficiency in managerial and staff works. Tasks analysis and increasing the level of official automation are of the most important tasks in this pillar.

Eighth Pillar (HSE)
Objectives: incident omission, physical harm omission, and fire prevention.

V. TPM Objectives
- Maintaining the buildings
- Optimization of equipments and stoppage time reduction
- Human resource better conduct and control
- Increasing the equipments longevity and depreciation control
- Safe workplace
- Reliable equipment installing and running
- Optimization of maintenance costs and keeping records
- Material, spare and tooling waste reduction
- Enhancing Technical information system
- Making maintenance costs archive for budgeting
- Equipment operation assessment in order for future purchasing policies
- Maintaining systems in favorable condition for rising motivation

VI. TPM and its Components

TPM is a total maintenance plan. Scientists compare TPM with Total Quality Management (TPM) in several aspects such as; the general objective is enhancing the quality level. The personnel must be able to improve their efficiency. It’s also probable to take a year or more to be deployed for equipments and process. Changing personnel thoughts and putting them in the direction of their job responsibilities must be done as well. The word TOTAL in TPM includes three basic concepts in accordance with three specifications of TPM:

Total Effectiveness
Financial efficiency improvement and development

Total Prevention
Designing repair need-less equipments and comprehensive preventive maintenance as well

Total Cooperation and Collaboration
Self-oriented and independent maintenance by the production operators in small groups in each of the industry departments and by other personnel as well

5S is known as the Foundation for TPM Structure
Seiri (sort)
Set in order (Seitoin)
Shinetsu (shine)
Seiketsu (standardize)
Shitsuke (sustain)

Is the brief definition of 5S terms. 5S is used in Japan and has had very good results for industrial plants. The results which are usually achieved by this method can be briefly mentioned as incident prevention, work delay reduction, production operation control, and production increase. Generally, 5S objective is waste prevention. Although 5S seems very simple, understandable, and easy to deploy, organizations have many problems for its deployment. It’s because of its simple appearance. In fact, 5S achievement is difficult because managers and personnel are not aware of its goals and missions correctly. Consequently, deploying 5S and preparing proper condition for it is so hard till its principles are not known well.

VII. 5S Advantages

5S causes efficiency, production, and standardization increase, safety improvement, work cycle reduction, customer satisfaction, and personnel flexibility, high spirit and motivation. These results bring about a clean and vain-free workplace and leads to proper thought and continuous improvement.

- Quality improvement
- Relationships improvement
- Determine criteria for unnecessary items omission
- Discipline in workplace
- Replacement acceleration
- Fast and simple access to items and equipments
- Creating more effective condition
• Increasing equipments longevity
• Making the workplace safe and healthy
• All people are automatically disciplined

7.1. Seiri (Sort)
From 5S view sort means determining necessary from unnecessary. Adopting conclusive decisions and priority management for getting rid of unnecessary. Some examples of implementing this S are:
• Troubleshooting (office supplies, technical equipments and cars repair)
• Fighting pollutions (using air conditioning, smoking prohibition in workplace, food proper transport, healthy use of water supply)
• Workplace cleaning (frequent washing with detergents, warehouse cleanliness, removing used oils)
• Preventing pollution on the floor (regulate workshop washing, reticulating polluting stations such as painting and oil changing)

7.2. Seiton (Set in Order)
Set in order means setting the things in suitable places so that they can be used in the best way. Discipline is a way to find and use needed items without vain searching. Some examples of implementing this S are:
• The things which are used frequently must be in workplace or carried (installing the tools on specific boards in workshops, equipping tables with office supplies, …)
• Putting the things which are rarely used far from access (using proper archiving system so that the past work records are in farther places, …)
• Bringing and returning everything in the minimum possible time (finding records archive, ease of tools access)
• Putting parts in shelves and putting the tools and equipments in order (separating damaged parts from the others in warehouse, putting parts in pallets according to housekeeping principles, using FIFO system)

7.3. Seiso (Shine)
In 5S view shine is disposing frills and cleaning the things from the pollution and external material. In the other word, shining is a kind of inspection. Its reviewing and cleaning workplace to omit pollution. Some accessories, equipments and places must be necessarily clean and pollution-free.
Some examples of implementing this S are:
• Simplification, cleanliness and reviewing (management inspection and reviewing the subsets)
• All people responsibilities for workplace cleanliness
• Continuous reviewing and cleaning in order for eliminating small problems

7.4. Seiketsu (Standardization)
Standardization is permanent control and correction, organization, discipline, and cleanliness. The main emphasis in standardization is on management who controls the workplace in a way that all the factors are always used fast and accurately using the check lists and regulations. Some examples of implementing this S are:
• Using signs and symbols (in workshop salon, warehouses and offices)
• Signing risk limitations (in chemicals store and high pressure equipments)
• Signs showing directions and guide (for cars movement in workshops and using light signals in buildings entrances)
• Stickers showing main parts (using special stickers such as holograms and barcodes)
• Fire distinguishers signs (signs related to warning bells, safety equipments and guide to use firefighting system)
• Arrangements to prevent fault and error (training personnel about risks, preparing work instructions for using instruments and equipments)
• Putting the things in a way that they can be used fast and control them

7.5. Shitsuke (Sustain)
Sustain is training behavior and abilities for doing a special responsibility. The main point here is to make good behavior instead of bad one. This must be done through training methods and practicing.
Some examples of implementing this S are:
• Punctuality practice (training optimal use of time specially in meetings and workshops)
• Wearing safety shoes
• Emergency performance practice (using safety equipments)
• Noticing the beauty and appearance (using proper overalls in workshops and plant)
In this stage 5S culture must be institutionalized. This can’t be done without management commitment.

VIII. SAFETY AND TPM
One of the TPM objectives is involvement of the whole engineering, designing, planning, production, and maintenance departments and all the personnel from top management to workshop level workers. One of the TPM policy bases is safety increase in production lines. The question is how to find a proper relationship between safety and TPM implementation to achieve this important goal in maintenance [Wireman, 2002, 2004; Borris, 2005].
In OHSAS18001, health and safety are explicitly mentioned and a system called safety risk assessment is used to determine safety risks for all jobs. In this system, safety risks are controlled through periodic visits and inspections and safety committee and safety officers reports. In the other
hand, TPM system has some check lists for daily visits and process related SOS which can be modified by adding safety issues. This way a suitable relationship between these two systems is established and reworking is prevented.

Some cases for determining safety risks in production lines:
1. Incidents records
2. Personnel complaints
3. Engineering surveys
4. Standards and regulations
5. Equipments catalogues
6. List of equipments related to the machinery
7. List of places in which human existence must be limited (such as high voltage electricity boards)
8. Brainstorming (using experts and supervisors experiences)
9. Periodic Inspection and audit reports

**IX. SAFETY RISKS ANALYSIS**

This analysis is used for finding safety risks by group work techniques and meetings and some aware and creative people must be in the group to identify the risks and suggest the best solutions. These people are normally selected among the safety committee members and maintenance engineering experts. One of the solutions is surveying the equipments periodic visit. The group can produce proper check lists and add them to the daily TPM visit list to control safety issues. Some of these issues are as below:
1. Visiting wires and electrical connections
2. Sweeping dust from the electrical circuits
3. Equipments rotating parts cleanliness and lubrication
4. Correct operation of couplings

**9.1. Safety in Preparing SOS**

The other important point is preparing equipments visit instruction. The cases that must be controlled and inspected are determined but the how to do the SOS is not mentioned. SOS preparation team must consider safety experts views and invite them to prepare this form. The simple example in this case is wires and electrical connections visit which in SOS preparation; the first safety point is disconnecting the electricity current before the visit. This must be surely mentioned and if not done, wires and sockets visit can increase the incident risk.

**9.2. System Safety Criteria**

Risk severity: risk severity shows extent and scope of losses and harms which occur if the risk happens.

Risk likelihood: likelihood factor shows the possibility of a risk occurrence in a specific time period

Reliability: is the certainty limit which a product or system can maintain its specific work under predetermined operational and environmental condition for a specific time period

Risk: is the possibility of incident occurrence in term of its likelihood and severity

**X. FINDINGS**

5S system implementation as one of the main foundations of Total Productive Maintenance (TPM) causes workplace adornment and discipline and it direct result is work-related accidents reduction which happen because of disorderliness and workplace polluted with lubricants. Wear (corrosion) in equipments can also have safety and environmental consequences. Wear in equipments parts can cause vibration, noise and loose fitting bolts. In this condition the possibility of pieces throw to the people is high. Material and gas transfer pipes lose sealing and the materials are leaked out. The environment becomes dusty because of material dispersion and it has environmental problems. The objective of equipments improvement by TPM is maintenance operations reduction and equipments efficiency increase.

The amount of industrial housekeeping and cleaning has a direct relationship with material leakage in process and lubricants. For example if seals and washers are damaged, the oil is leaked out and the equipment needs cleaning or the fault of dust filter system causes environment and equipment pollution and cleaning becomes necessary. As mentioned above, the main necessity for cleaning is related to the equipments failure. The more equipments longevity is reduced, the higher amount of maintenance operation is needed and the incident likelihood is increased, and vice versa.

**XI. CONCLUSION**

Incident occurrence likelihood and hazards in workplaces are increasing along with the improvement of technology and applying equipments in production. Maintenance is one of the important pillars in technical management in industry. Losses and harms due to lack of a suitable maintenance system, in addition to production reduction which is caused by the equipments failure, are early parts change and human and financial risks for the personnel. In implementing TPM, it’s necessary to consider the needed safety predictions in every stage. So involved personnel in this area must be trained and understand that TPM isn’t a monthly plan but an organizational approach which must be permanently considered. If all the personnel always use TPM with safety standards and points in their activities, the organization will achieve development and improvement in production and safety.

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