

TPM and FMEA in Maintenance Management Technical Analysis

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Seiichi Nakajima was a Japanese citizen born in the year 1919 and died on April 11, 2015. He is known as the core founder of Total Productive Maintenance (TPM). He is also the founder of the Productive Management Awards, which are currently known as the Total Productive Maintenance Awards (Joyce, 2014). Due to his continued dedication to improving the sector of production industry through the introduction of TPM, the emperor then awarded him with Ranju Ho-sho. Nakajima, for about fifty years, worked as a teacher and a consultant in the sector of productive maintenance (Joyce, 2014). His idea of TPM reached the United States in the year 1986, in an article published in Plant Engineering Magazine (John, 1998).

Nakajima labored a lot in the creation of TPM to ensure significant improvement in the manufacturing plants (Bill, 1994). His ideas on Total Productive Maintenance have wrought a lot of changes and improvements in the production plants (John, 1998). It has ensured the effective production of machines with fewer or zero defects (Bill, 1994). This is aimed at ensuring the customer is satisfied, and the company avoids replacement and wearing out of machine components (Bill 1994).

This technique, as employed by Nakajima, has three major features that are closely and effectively related to Total Quality (Bill, 1994). Nakajima did intensive work on the TPM, which has three major features. These features are closely related to Total Quality, which is an orderly approach towards realizing an improvement that unites products with the service specifications and the performance of the customer (Wienclaw, 2008). The aim of this Total Quality management is to produce these specifications with no defects or limitations. These major features of the work of Mr. Nakajima include a system that maximizes the needful life of the equipment. This is a core feature of TPM, which is important if the producer wants to fully meet and satisfy the needs of the customer (Wienclaw, 2008). Equipment with the longest useful lifespan is the most needful in the market. TPM ensures that such equipment is realized, which, when achieved, directly forms part of the Total Quality. When the lifespan of a given machine element is long, then it implies that the Total Quality is achieved (Wienclaw, 2008). Total Quality is the aspect which aims at producing an element with little or no defect at all. The other feature of TPM is that its main goal is to maximize the use of equipment together with its effectiveness! Mr. Nakajima labored in coming up with the TPM in which he ensured that the materials produced were exploited in usage to the maximum and that the effectiveness of the equipment was realized. This typically shows that the material was produced with little or no defect at all hence Total Quality met. The final feature of TPM is that it operates through role-sharing in routine check-ups, daily maintenance, cleaning and other repairs. This will ensure effectiveness in usage as well long life of the equipment and increased production (Wienclaw, 2008).

Definition of Terms

Total Productive Maintenance is a wholesome or all-around technique of equipment maintenance with the aim of producing a perfect end product of equipment. It ensures zero breakdowns of equipment, low, poor operations and zero defects. Its major advantage is that it ensures the equipment has zero accident cases. TPM focuses on preventive measures and maintenance that aim at maximizing the functional efficiency of that equipment (Houston, Rochester, December 1988). It diminishes the line of distinction between production and maintenance by emphasizing on supporting the operators to assist in maintaining their equipment. It was first developed in the late 1960s.

Equipment availability (reliability factor) is the comparison of the available time (total time inclusive of the operating and resting time) of a plant to the overall lasting time (Houston, Archester, December 1988). This time is directly dependent on the quality of the equipment upon the production. Availability is the total time the machine can perform effectively in production as a percentage of the overall intended production period. It is majorly confused with reliability, which, of course, is not available (Houston, Rochester, December 1988). Reliability is obtained as the ratio of the total intended production time to the calendar time.

Process yield (quality factor) is a formula or technique used in the manufacturing process to regulate the overall performance (Houston, Archester, December 1988). It can well be expressed in other words as the overall percentage of the manufactured products passing through the checker, to affirm if the extreme parameters fall within the production tolerances. In other words, these excess units that are not within the tolerance limit will not be counted as waste material to be incurred by the company; rather, the process yield will provide room for further operations on the materials, such as scrapping to ensure the dimension of the units are within the tolerance limits (Hoyle, 2007).

Overall equipment effectiveness is a systematic calculation that identifies the total percentage of the overall intended production time that is effectively used (Hoyle, 2007). When the TPM idea was developed, there were some shortcomings, which eventually led to the development of the OEE, which was developed to accurately monitor the process progress by aiming at the production of perfect equipment (Hoyle, 2007). OEE is classified according to percentages in that an OEE of 100% is considered to be a perfect production with no defects. This is an ideal OEE. The most common OEE is 85%, and this is referred to as a world-class limit or percentage.

Performance (speed factor) is the level of the efficiency of the equipment. It is the extent to which equipment can operate under normal circumstances without straining (Martínez, Angel, Dewhurst, Frank; Dale, Barrie, 1998). The performance of equipment will largely depend on the conditions of manufacturing. It can be obtained by getting the ultimate product against the total cost of the input. When the input is greater than the output, then the overall performance of the equipment is low. The performance also depends on the condition of the workplace (Martínez, Angel, Dewhurst, Frank; Dale, Barrie, 1998). The better the condition of the working environment, the higher the performance and

vice versa. For an effective machine, the performance or the speed factor must be elevated to realize maximum production (Martínez, Angel, Dewhurst, Frank; Dale, Barrie, 1998).

The determination of OEE is generally beneficial to the process of manufacturing quality. The main purpose why OEE was developed was to support TPM by accurately monitoring the progress of production towards achieving perfect equipment. Tracking or measuring OEE will enable the producers or the operators to know and identify the level of effectiveness of the equipment produced (Martínez, Angel, Dewhurst, Frank; Dale, Barrie, 1998). By measuring the OEE, one can tell if the material produced is “perfect” or poor design. For effective manufacturing, the manufacturers must know the OEE of their production and try to maintain it at high levels.

OEE is a mathematical expression regarding the percentage of the effectiveness of an element. In the various production plants and automobile plants all over the world, the value of the OEE varies depending on the level of technology (Nelson, Robert, 1991). OEE depends on three major factors such as availability, quality, and performance. The current value of OEE in the European automobile industry is slightly below 55%. However, attempts are made to improve this figure to about 75%. 75%, therefore, becomes the current benchmark value of OEE in the automobile industries in Europe (Nelson, Robert, 1991). Availability, performance, and quality must first be improved.

- Station 1: 99.3%
- Station 2: 92.0%
- Station 3: 96.1%
- Station 4: 92.5%
- Station 5: 85.0%

The probability that, at any point in time, the whole line will stop is indicated by the following;

For station 1; the probability is $(100-99.3) = 0.7\%$

For station 2; the probability is $(100-92.08) = 8.0\%$

For station 3; the probability is $(100-96.1) = 3.9\%$

For station 4; the probability is $(100-92.5) = 7.5\%$

For station 5; the probability is $(100-85.0) = 15.0\%$

Hence, the overall probability that the whole line will stop is given by;

$(0.7+8.0+3.9+7.5+15.0)/5 = 7.02\%$

=7.02%

This is the probability that at any particular point, the whole line will fail and will not run (Nelson, Robert, 1991).

From the above cell, given that the maximum available working time is 5.5 days per week for 16 hours a day,

The expected output average is 30 perfect parts in every 1 hour of time.

However, the actual output is one perfect part every 2.5 minutes, out of which 12 perfect parts out of every 8 hours are not usable.

Calculation of the equipment availability for the whole cell:

In calculating the availability, we will assume the maximum available working time of 5.5 days per week for 16 hours a day. This translates to;

$(5.5 \text{ days} * 16 \text{ hours}) = 88 \text{ hours per week.}$

But 12 parts per 8-hour shift are not usable.

Hence, the actual available time is given as $(88-8) \text{ hours} = 80 \text{ hours}$

Hence, the availability is given as $(80/88) = 0.9090$

=90.90%

Thus, the availability is 90.90%.

2. The total actual working time per week.

Given the maximum available working time per week is 88 hours.

If 1 part is 2 minutes and 30 seconds, and the expected perfect parts produced are 30 per hour, then it follows that $(30/2.5) = 12 \text{ parts}$

And $(60/2.5) = 24 \text{ parts per hour. Then, the actual working time is given as } 88-8 = 80 \text{ hours.}$

Translating into hours and minutes, we multiply by 60 and thus,

$80 * 60 = 4800 \text{ minutes.}$

3. The planned output production

The planned or the intended output of production is given by;

$$(60/2.5) = 24 \text{ perfect parts per hour.}$$

But the maximum working time is 88 hours; then the maximum planned output will be given by $(24 * 88) = 2112$ perfect parts.

4. The actual production of the products per week.

To obtain the actual product produced per week (Nelson, Robert, 1991). We find the maximum available working time per week. Given that the maximum available time per week is 80 hours and that 24 parts are produced per hour, but out of which 12 parts are not produced for every 8 hours.

The total number of parts, thereby not produced because of the defects, will be $(12*10)$ which will give 120 parts per week (Nelson, Robert, 1991). But remember, the planned production was 2112 parts per week. It follows then that the actual production of the parts is $(2112-120) = 1992$ perfect parts after every week.

5. Calculation of the cell yield

This will be expressed in percentage form for the items that are manufactured.

For the data above, the produced parts are 1992 while the planned output is 2112 parts. Therefore, the quality factor or the yield cell can be obtained by;

$$(1992/2112) * 100 = 94.32\%$$

Hence, the cell yield is 94.32%.

Calculation of OEE for the whole cell:

The Overall equipment effectiveness is a function of performance, availability, and quality. This value, therefore, increases with the increase in these three parameters. OEE is a very crucial aspect of production as it will point to the effectiveness of an element. These three parameters can be increased by the company depending on the prevailing circumstances, for instance, for the performance to be high then it follows that the output must increase. An increase in output would follow that the maximum available working hours are increased and that the many employees are employed to incur the resting time. Failure to maximize the output, which directly influences the quality, the value of OEE will be reduced.

For this particular cell, the OEE is given by (performance * availability * quality)

Availability = 90.90

Quality = 94.32

To calculate the performance, we need to get the value of the maximum speed of the production and the actual speed of production. The performance will be given by finding the ratio between these two equipment.

For this case, the maximum production rate is 24 products per hour, and the actual production rate is 24.9 products per hour. Thus performance is given by finding the ratio between the normal or ideal speed to the actual speed.

Performance = C/F ; Where C = normal speed

F = actual speed.

But for this case, $c = 24$ and $F = 24.9$

Thus performance = $(24/24.9) * 100$

= 96.39%

This enables us to easily calculate the value of OEE for this cell as

= (Performance * availability * quality.)

= $(96.39 * 90.90 * 94.32) \%$

= 82.64%

Hence, the value of OEE for this cell is 82.64%. This is a world-class value for OEE.

Ways of Improving OEE of A Cell:

The OEE value of a cell should be increased for effective production. For this cell, as calculated above, the value of the OEE is 82.64%. This is a high value, almost close to the world-class value, which is at 85%. However, the ideal value should be 100%, and this will lead to a “perfect product.” As has been highlighted earlier, the value of the OEE entirely depends on the performance, availability and quality (Creech, 1994). To improve this value, the value of the performance as a percentage should tend towards or close to 100%. As it has been calculated and seen above, the value of performance is a factor of the speed factor. That is the maximum production speed to the actual production speed. When the ratio of maximum production speed to the actual production speed is 1, then it follows that

the performance is 1, which, when translated into a percentage, would be 100% (Creech, 1994). It is usually advisable to have the performance at 100% for the value of OEE to increase even if the other two parameters, quality and availability, are kept constant. This ratio can be adjusted to one by increasing the number of employees. When employees are increased, working at a constant available time, then the maximum speed and the actual production speed will be one. This should be given priority to achieve maximum profit at the end (Creech, 1994).

Again, the value of OEE can be increased by considering the availability. The availability will be the total usable time available. This will be obtained by calculating all the lost time due to resting time and the breakdown time (Houston, Archester; Dockstader, Steven, 1997). The availability can only be increased by minimizing all these losses. To minimize these losses, then the company can reduce the maximum available time to some value closer to the actual production time. This can also be achieved by immediately replacing the worn-out parts of a machine element so that the resting time due to breakdown can be minimized (Houston, Archester; Dockstader, Steven, 1997). It is also possible that alternative equipment should be purchased and placed as a stand-by so that in cases of failures for the existing elements, the stand-by components can be installed and used. This, however, is a very expensive alternative which, when employed by the company, will not only lead to a lot of expenditure but also lower the profit. It can, however, be considered as the second alternative in case the first alternative fails (Houston, Archester; Dockstader, Steven, 1997).

The third alternative that can be employed by the company to improve the value of OEE, the company can decide to increase the value of the quality factor, or what is known as the cell yield. This factor is a function of the actual products produced to the maximum allowable products which can be produced at a particular time (Houston, Archester; Dockstader, Steven, 1997). To maximize this value then it implies that the total number of goods produced is equal to the total maximum allowable goods which can be produced at a particular time. For this to be achieved, then all the other remaining two factors, like availability and performance, must be considered. This would be very expensive and will lead to reduced profits realized (Houston, Archester; Dockstader, Steven, 1997).

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