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Kobetsu Kaizen Losses Analysis to Enhance the Overall Plant Effectiveness in Steel Manufacturing Industry–A Case Study at JSPL, Raigarh

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Abstract - *Total Productive Maintenance (TPM) is a tool that increases the efficiency and effectiveness of equipment. In 8 pillars of TPM, Kobetsu Kaizen play a vital role to sustain in present market scenario for an organization. Kobetsu Kaizen pillar is not a simply analysis and indicates the effectiveness of an equipment. Rather, it is a tactical tool to increase availability, performance rate and the quality rate, through kaizen perform by the plants. Overall Plant Effectiveness (OPE), a plant performance evaluation or measurement tool, is introduced by analysis of 16 types of Kobetsu Kaizen losses. By implementing TPM, companies may use it as a Panacea for their continual improvement. In this study it is concluded and emphasized that the why-why analysis and kaizen perform by the plant reduce Kobetsu Kaizen losses and increase the trend of OPE, which ultimately helps to create a profitable culture in an organization.*

***Key Words*: Total Productive Maintenance (TPM), Overall Plant Effectiveness (OPE), Continual Improvement, Why Why analysis, Kaizen, Kobetsu Kaizen Losses.**

1. INTRODUCTION

Total Productive maintenance (TPM) is a maintenance concept which not only reduces various losses (like, downtime, speed loss etc.) but also provides a healthy and safe working conditions for employees. TPM is a maintenance practice which aims at establishing a corporate culture to maximize production, system effectiveness and reduces chronic losses to zero by involvement of all employees and practicing Genba-Genbutsu. It suggests that in order to truly understand a situation, one need to go to Genba i.e., the Place, where work is being done, to prevent losses and achieve such "Reduction-to-zero" targets as "Zero accidents", "Zero defects" and "Zero breakdowns" in the entire production system life-cycle through Kaizen.

Kaizen is a combination of two words as KAI (change) and ZEN (for the better). However, the concept of Continuous improvement needs to be updated with continual improvement. Competition and never-ending demand of customer's requirement for satisfaction raised the bar for manufacturing organizations. Continuous improvement implies that organisations are in a consistent condition of driving process upgrades. This includes an emphasis on direct and incremental change inside existing procedures. A continual improvement implies that organisations experience process enhancements in stages and these stages are isolated by a timeframe. This timeframe may be important to comprehend if the enhancements did really help all that really matters! Now and again, the outcomes may require a significant stretch of time to work out as intended.

Overall Plant Effectiveness (OPE) is performance indicator which can be used to analyse the progress or effectiveness of a Plant's all equipments. The improvement of OPE can be ensured by minimizing Sixteen Kobetsu Kaizen (KK) losses which are directly or indirectly responsible for availability, performance rate, as well as quality rate of equipments.

The JSPL, Raigarh plant, with up to 3.6 million tonnes per annum (MTPA) steel production capacity, is the world's largest coal-based sponge iron manufacturing facility with state-of-the-art machinery. The company is recognised as a leader in manufacturing coal-based sponge iron in India. First commissioned in 1991, JSPL leads the Indian market in this sector and has the world's largest coal-based sponge iron plant, with a capacity of producing 1.32 MTPA DRI. It is the only sponge iron manufacturer in the country with captive raw material resources and power generation. Direct Reduced Iron (DRI) plant - 4 units of 0.72 MTPA capacity producing 500 tonnes/day and 6 units of 0.6 MTPA capacity producing 300 tonnes/day rotary kilns. At present most of the departments of this organization which is under study having already achieved the international standard benchmark OPE of 85 %. TPM has a standard of 90% availability, 95% performance rate and 99% of quality rate. The Organization has about 34 different departments which include both Service and manufacturing Departments. At present, 32 departments have already implemented TPM practices while implementation of TPM in other two departments is in progress. Since, some departments of the organization are present where TPM is not fully implemented. Amongst them DRI Plant is selected for the study and complete TPM implementation. Various tools of TPM are used to analyse and monitor the progress of implementation of maintenance practices.

2. LITERATURE REVIEW

According to Chaneski [1], TPM is a maintenance program with the objective of eliminating equipment downtime. TPM implementation is a major departure from the "you operate, I maintain" philosophy to "I operate and maintain" philosophy. TPM has been accepted as the most promising strategy for improving maintenance performance in order to succeed in a highly demanding market arena [2]. TPM is a unique Japanese system of plant management, developed from preventive maintenance concept. This approach emphasizes the role of team work, small group activities, and the participation of all employees to accomplish equipment improvement objectives [3]. It challenges a sense of joint responsibility between operators and maintenance workers, not only to keep the machines running smoothly, but also to extend and optimize their overall performance [4] TPM is intended to bring both functions (production and maintenance) together by a combination of good working practices, team working and continuous improvement [5]. Marquise and Gupta [6] have said that TPM can help the maintenance department to improve its system by using continuous improvement. According to Simoes et al. [7], continuous improvement is playing a vital role to examine the modern maintenance activities systematically. Many organizations have used continuous improvement as a driver to optimize maintenance performance and improve competitive position [8]. Manufacturing organizations are considering maintenance functions, as a strategic issue for a reliable production system in this competitive environment [9]. The author(Wakjira and Singh [10]) evaluate the contributions of total productive maintenance (TPM) in the process industry it is very much essential to maximize the production effectiveness and the effectiveness of a production depends on the effectiveness with which it uses equipment, materials, people and methods. The wastes generated due to the failure shutdown of facilities which cause waste such as defective products should be absolutely eliminated and reduce huge investment required for maintenance. Focused improvement or Kobetsu Kaizen is characterized by a drive for zero losses meaning continuous improvement effort to eliminate losses [11]. TPM has a standard of 90 per cent availability, 95 per cent performance efficiency and with 99 per cent rate of quality. An overall 85 per cent benchmark OEE is considered as world-class performance [12]. The concept of Kaizen is always trying to improve manufacturing process continuously by actively and repeatedly participation. Shingeo [13] has concluded that the Kaizen for manufacturing process has become necessary to satisfy both external and internal customers. Kaizen is playing a vital role in this competitive era for achieving manufacturing excellence [14]. Manufacturing organizations are widely used Kaizen concept for improving quality, reliability, reducing prices and lead time.

3. METHODOLOGY

For the case study purpose, DRI (Direct Reduced Iron), a production plant is selected. The objectives of this study were:

1. To reduce 16 Kobetsu Kaizen losses in the DRI department
2. To find out the root cause of the above losses
3. To improve the OPE by eliminating above root causes, if any

The above objectives of the plant need to be fulfilled. The below flowchart Fig-1 shows the overall methodology adopted for study.

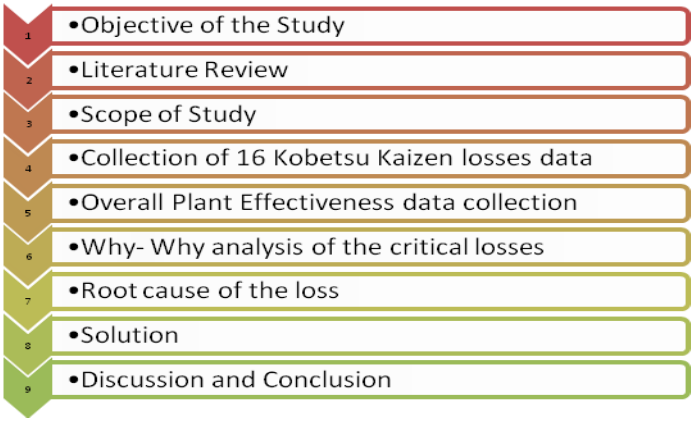

Fig -1: Methodology

4. EIGHT TPM PILLARS

Through TPM plants adopta milieu which increases reliability in safety, quality, cost, delivery, and creativity are encouraged through the involvement of all employees. The eight pillars of TPM are as follows:

Pillar-1: Jishu Hozen (Autonomous Maintenance)

The meaning of pillar is Maintenance by Operators. Maintenance is not the job to be undertaken by personnel not directly linked by those personnel who know maximum about machines or equipments and without any doubt these personnel are not Qualified Engineers or Experienced Fitters but the Operators, who are with machines day in and day out. The aim of this pillar is to avoid forced deterioration of equipment just by maintaining basic conditions of equipments i.e. Cleaning, Lubrication, Inspection, Tightening (CLIT) & maintaining operating condition of equipments.

Pillar-2: Kobetsu Kaizen (Focused Improvement)

Japanese word for Focused Improvement i.e., prioritizing most important losses and eliminate them. These are individual improvement and focuses on Losses, Reduction of quality defects, Cost, Inventory, Accident etc. The aim of this pillar is to maximize overall plant effectiveness, process improvement and plant by eliminating 16 types of Kobetsu Kaizen losses.

Pillar-3: Planned Maintenance

Planned maintenance has to focus on preventive action to eliminate equipment failure / breakdown in order to ensure availability and reliability of equipment. The objective of this pillar is to increase equipment reliability and production up time and minimize maintenance cost by reducing breakdown and development of efficient maintenance monitoring method like MTBF, MTTR etc.

Pillar-4: Quality Maintenance

This pillar states need of making machine incapable of producing defective product. The pillar necessitates putting a control on all condition contributing in generation of defect. Pillar provides guideline to identify those quality components and control strategies. The aim of this pillar is to achieve zero Defects.

Pillar-5: Initial flow Control

Concept of this Pillar is that equipment designing should be reflected with problems or experiences on the same or similar equipment installed in the plant to have an initial control. At the same time concept of Life Cycle Costing (i.e. L.C.C.) should be the base at the time of designing new equipment instead of "Cheaper the better". The aim of this pillar is Maintenance, Prevention & Designing of equipment which is easy to operate, easy to maintain, safe and of high precision.

Pillar-6: Office TPM

The production Plant is required to accomplish a plant constitution to produce product for the sales department within delivery terms, in quality and cost scheduled by top management. The aim of the pillar is to draw up what the sector must be and start aiming at accomplishing it.

Pillar-7: Education and Training

An Education isn't the amount to retain or even the amount to know. It's having the capacity to separate amongst knowing and not knowing. Training implies getting to be noticeably capable through specialised instructions and drills. It likewise implies developing, in this way accomplishing wanted objectives or results. It shows a person to how to abstain from committing similar errors that can without much of a stretch be made. It gives particular skill expected to close the hole amongst present and wanted capacities. The aim of this pillar is to bring up personnel competency in equipment and office work through TPM activities and to bring up personnel for specific purpose for workplace needs from a long-range view.

Pillar-8: Safety, Health & Environment

This Pillar is based on the belief that "Accidents can be prevented, if and only if the same can be predicted". Pillar has a different definition of Accident and as per concept any "Near Miss Case" is an accident and should be analysed as per "Genba –Genbutsu" approach. The aim of this pillar is to achieve Zero Accident, Zero Pollution and Healthy workforce The Pillar also gives guidelines about the occupational health monitoring, Environmental parameter mapping (e.g. dust , noise, heat) to control the emissions.

5. OVERALL PLANT EFFECTIVENESS

The Overall Plant Effectiveness (OPE) is a performance measurement tool for assessing the performance of Total Productive Maintenance (TPM) practices in a plant, which can be computed as the multiplication of Availability, Performance rate and Quality rate. The increment of OPE can be assured by eliminating different factors which are responsible for lower Availability, Performance rate, and also Quality rate .The Availability factor reduces because of Breakdowns, set-up and adjustment stoppages etc. The Plant's aggregate time of operation after any stoppage or delay in planned activities that may have upset production, for cases like scheduled and planned maintenance, official Shut Downs of plant, process improvement activities or testing and so on, is considered as Operating time in the calculation of Availability. Then again, the second OPE component named Performance rate measures the ratio of the actual operating speed of the plant (e.g. the ideal speed minus speed losses, minor stoppages and idling) to the standard operating. The third component of OPE is quality rate indicates the ratio of production which meets the desired Quality to the total production volume. There is a component to be coordinated with the three components of OPE expressed above named Planning factor. It is a measure for the use of the installation in the theoretical production time or measure for the degree of not using the installation. It can be calculated as Planning factor = Available production rate/Theoretical Maximum production rate. The available production rate is the production sum or loading of which production is generally installed it out. The theoretical rate is the most extreme achievable measure of a particular process available in the given period and is a consistent throughout. OPE tool give an exceptionally significant knowledge – a precise picture of how viably you production process is running. Also, it makes it simple to track changes in that process after some time.

OPE = Availability X Performance Rate X Quality Rate.

6. KOBETSU KAIZEN LOSSES

There are total 16 categories of losses are identified under the Kobetsu Kaizen Pillar. These 16 types of losses are:

•**Breakdown loss –** Losses which occurs due to failures of equipments. Different types of failures include sporadic, function-stopping failures, and function-reduction failures in which the functions of equipment do not achieve normal level of performance.

•**Shutdown loss –** These are planned stoppage of equipments. Example: Preventive Maintenance.

•**Set up and Adjustment loss –** Stoppage losses that go with setup changeovers.

•**Start up Loss –** At the start of production process, the losses that occurs until equipment start-up, running-in and production process conditions stabilize.

•**Minor Stop and Idle Loss –** Losses that happen when the machine briefly stops because of some small issues like jamming etc.. The machine will work typically through basic measures like removal of relevant obstacles.

•**Management loss –** In any work situation there are waiting time which are treated as loss due to inability of management for proper line balancing of equipment, waiting of materials, tools, instructions repairs etc. These losses increase if the proper communication fails within the organization. This also results in increased production time compared with normal cycle time. This affects OPE.

•**Cutting Tool replacement loss –** Losses occur due to changing the cutting blade due to breakage. Changing of blade requires time and results in speed loss which reduces the capacity of the equipment and the production time exceeds normal cycle time. This affects OPE.

•**Rejection and Rework loss –** Losses occur due to defects and rework.

•**Speed loss – Losses** occur due to actual operation speed falling below the standard speed of the equipment.

•**Motion loss –** When proper integration of three main resources men, machine and materials are not in the best possible way these losses may increase. These losses further increase from differences in skills involved in setup and adjustment work, cutting blade change work. This also results in increased production time and reduces OPE.

•**Internal Logistics loss –** These man-hours loss are actually due to mismanagement in supply chain such as delay in transport of material, products, equipment, and delay at the vendor end. These losses can be minimized by making an attractive supply chain management with vendor and supplier.

•**Energy loss –** Losses due to ineffective utilization of input energy like electric, gas, fuel, oil etc. This will affect the output of the plant and OPE.

•**Yield loss –** In any organization, several times, it is observed that qualities of weight of the material are different than required. Some time it is found that size & shape of the material received are not as per specification / requirement. In such situation there is loss of time to replacing and getting new materials. Quantity loss is one of the metrics of OPE.

•**Line organisation loss –** This type of loss occurs due to shortage of operators on the line and operators needs to work on more equipment than the original plan.

• **Measurement and Adjustment Loss –** Losses occurs due to frequent measurement and adjustment in order to prevent the occurrence and outflow of quality defects in the process.

• **Tools, jigs and consumables loss –** This types of loss includes the total cost of the physical consumption of the spare parts or maintenance of items that are used in the production process.

6.1 Linkage of Losses with OPE Parameters:

Availability depends on:

- Shutdown loss
- Breakdown loss
- Cutting blade change loss
- Setup and Adjustment loss
- Startup loss

Performance rate depends on:

- Speed loss
- Minor stoppage / Idle loss

Quality rate depends on:

- Rejection and Rework loss

7. CASE STUDY

7.1 Introduction - DRI is a production Department. The main function of Department DRI is to produce direct reduced iron. DRI plant is having 4 units of 0.72 MTPA capacity producing 500 tonnes/day and 6 units of 0.6 MTPA capacity producing 300 tonnes/day rotary kilns. The Department is having huge impact over the profitability of the organization.

7.2 Data Collection - The data collection for the study is started from May 2017. The data was collected for various losses occurred during the period and OPE calculation. The data includes 16 types of Kobetsu Kaizen losses in monetary terms which are shown in Table 1. Also, data required to calculate Overall plant effectiveness i.e., availability, performance rate and quality rate is collected which is shown in Table-2.

7.3 Data Analysis - After collecting the data from May 17 to July 17, it was found that the most critical loss in monetary terms is due to minor stop/ idling loss. This type of loss costs on an average Rs.686.42 Lakhs per month which is shown in Chart-1. It is about 19% of the total loss of the department which is shown in Chart-2. So, it is the most critical loss and necessary to find out the root cause of this problem. Moreover, this loss directly affects the performance rate of the department, so to improve OPE this type of Kobetsu Kaizen loss must be reduced. It was fond that the average availability during the starting three months of study was 81.57%. The average quality rate during this period was 89.92%. Also, the average performance rate during this period was as low as 71.90%. These figures are so far from achieving international standard. As a result the OPE was 52.73% which is shown in table-2. We used Why Why analysis to find out the root cause of the problem.

Table -1: Kobetsu Kaizen losses (Rs in Lakhs)

Kobetsu Kaizen Losses (Rs in Lakhs)																
Month	Shutdown loss	Breakdown loss	Setup and adjustment loss	Cutting tool replacement loss	Startup loss	Rejection and Rework Loss	Minor stop / idling loss	Speed loss	Line organisation loss	Management loss	Motion loss	Internal logistics loss	Measurement and Adjustment loss	Yield loss	Energy loss	Consumable loss
May'17	534.1	418.08	11.42	325.75	0	84.75	878.08	236.83	24.5	238.92	255.16	23.17	9.83	436.08	417.58	0
June'17	432.2	282.16	22.35	325.38	0	104.56	532.35	365.08	54.15	311.83	85.16	18.65	8.56	389.17	248.38	0
July'17	388.9	511.67	18.67	318.52	0.1	124.98	648.83	312.63	48.15	255.08	187.23	35.83	10.49	501.35	196.55	0
Average	451.71	403.97	17.48	323.22	0.03	104.76	686.42	304.85	42.27	268.61	175.85	25.88	9.63	442.20	287.50	0.00

Table -2: OPE data

OPE Data before TPM implementation				
Month	Availability(%)	Performance Rate(%)	Quality Rate(%)	OPE(%)
May'17	79.65	72.61	89.21	51.59
June'17	81.54	74.16	92.59	55.99
July'17	83.51	68.92	87.95	50.61
Average	81.57	71.90	89.92	52.73

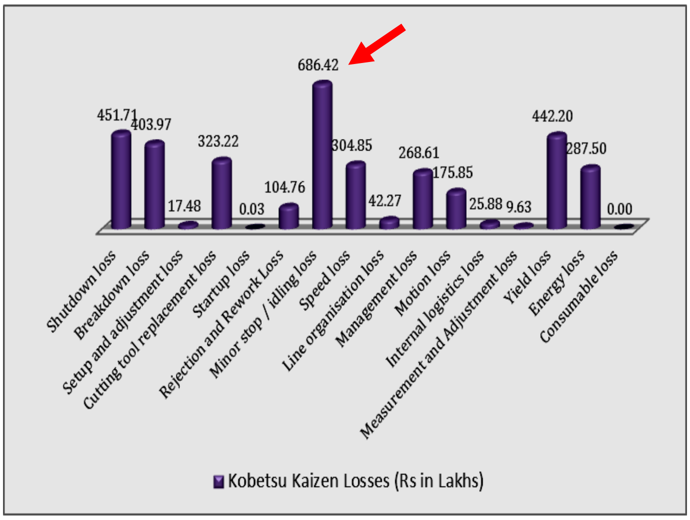

Chart -1: Kobetsu Kaizen losses (Rs in Lakhs)

7.4 Why-Why analysis - A why-why analysis is used to find out the solutions for an issue that address it's root cause(s). Why-Why analysis provide a safe approach to find out the real solution of the issue in place of taking actions that are merely Band-Aids. The table-3 & 4 shows the why why analysis of the problem. The root cause of the problem is the lack of control over the material flow through the discharge chute. So, it's come under the category of Design Weakness. To eliminate the problem a kaizen is recommended which is shown in table -4. The above kaizen was performed in August 2017 to deal with the problem.

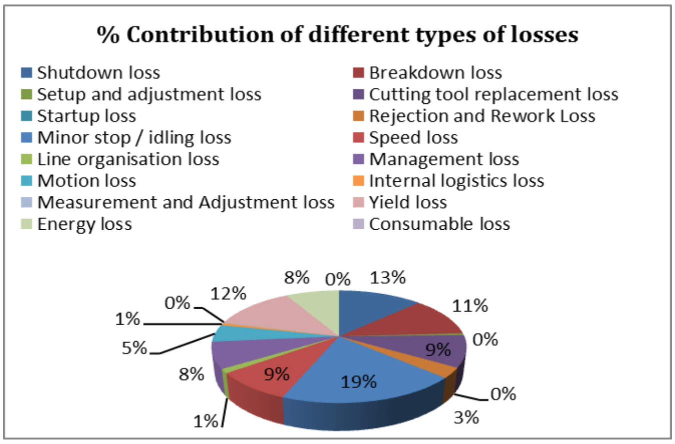

Chart -2: % Contribution of different types of losses

Table -3: Why-Why analysis of the problem

Problem reported: Minor Stoppage/ Idling loss is very high		
Final Action: Kaizen Recommended		
SN	**WHY**	**ANSWER**
1	Why Minor Stoppage/ Idling loss is very high ?	Due to Frequent jamming of discharge chutes at the outlet.
2	Why frequent jamming of the discharge chutes occurs ?	Due to malfunctioning of the dicharge chute.
3	Why there is malfunctioning of discharge chute ?	Due to heavy flow of material from it.
4	Why heavy flow of material from it ?	Due to no control is established at the inlet of chute to control the incoming material flow.
5	Why there is no control established at the inlet of chute to control the incoming material flow ?	ACTION- Corrective action recommended as Kaizen to established the effect ive control to prevent such type of failure.

Table -4: Why wy analysis recommendations

Why-Why analysis must end when any of the following conclusion is reached as a root-cause:
(Please tick the most appropriate option)

- **Natural Deterioration**
- **Forced Deterioration**
- **Planned Maintenance**
- **Design Weakness** ←
- **Operational Malfunction**
- **Lack of Skill**

Suggested countermeasures to prevent repeat failure:

SN	RECOMMENDATION	TARGET DATE	RESPONSIBILITY
1	A periodic hammering system needs to be established at outlet to prevent blockage of material	31st August 2017	Shift Incharge

7. DISCUSSION AND CONCLUSION

After successful implementation of the recommended solution in month of August 2017, all data are collected for month of September 2017. It was found that the performance rate of the department was increased to 87.16 % from 71.90% as a result the Overall plant effectiveness of the department has increased shown in Table-6. After this, It was found that about Rs 530 lakhs per month is saved because it is reduced to Rs 156.84 Lakhs. Now, it is clear that Breakdown loss is highest contributing loss about 19% of total current loss shown in chart -4. The total loss due to breakdown loss was Rs 522.64 Lakhs shown in Chart-3 and Table-5. So again same cycle of steps can be followed to reduce losses and to improve OPE.

Table -5: Kobetsu Kaizen losses (Rs in Lakhs)

Kobetsu Kaizen Losses (Rs in Lakhs)																
Month	Shutdown loss	Breakdown loss	Setup and adjustment loss	Cutting tool replacement loss	Startup loss	Rejection and Rework Loss	Minor stop / idling loss	Speed loss	Line organisation loss	Management loss	Motion loss	Internal logistics loss	Measurement and Adjustment loss	Yield loss	Energy loss	Consumable loss
sep'17	387.2	522.64	19.24	298.76	0	95.35	156.84	378.15	14.62	308.15	115.23	28.95	8.97	378.25	108.15	0

Table -6: OPE Data after TPM implementation

OPE Data before TPM implementation				
Month	Availability(%)	Performance Rate(%)	Quality Rate(%)	OPE(%)
September 17	86.34	87.16	92.64	69.72

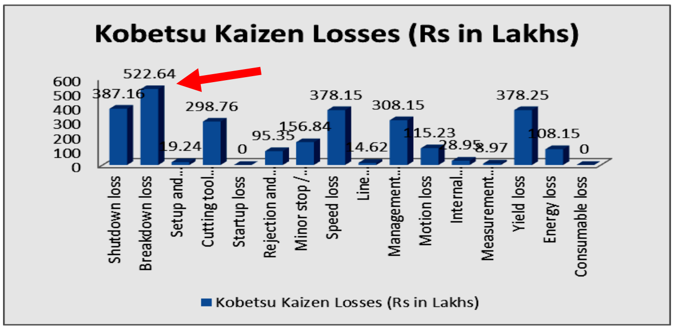

Chart -3: Kobetsu Kaizen losses (Rs in Lakhs)

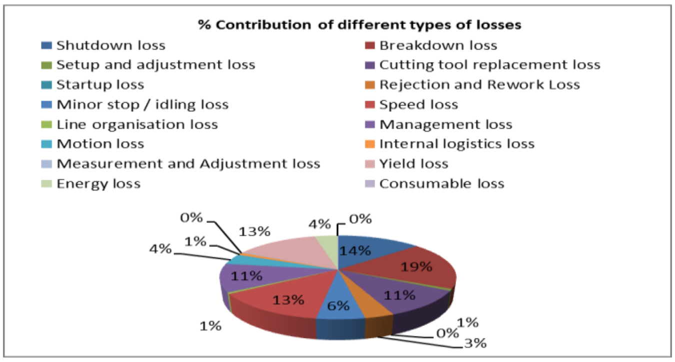

Chart -4 : % Contribution of different types of losses

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BIOGRAPHIES

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