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Determination of the Critical Point Steel Billet Production Unit Plant by using Overall Equipment Effectiveness Method

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Abstract **- Measuring the value of the effectiveness of the production facilities need to be done as an indicator of the critical point of a process. One concept that is commonly used to measure and analyze the effectiveness is Overall Effectivenes Equipment (OEE). Precaution against interruptions of production facilities requires an analysis tool to identify the cause of the ineffectiveness of the production facility occured. For these precautions, the analysis of the causes of ineffectiveness can be done by using a concept that is Fault Tree Analysis (FTA). This study goal is to determine the effectiveness of production machines, determine the dominant cause of the low value of the effectiveness and provide corrective action plan to improve the effectiveness. This study begins with a determination of the value of OEE on all production machines. To the smallest value of OEE, to identify the cause of the low value of the OEE using fishbone diagram. Based on the results of data processing, it can be revealed that the overall value of the OEE for each engine is still below the standard of a world class company while the lowest value was for the Continous Casting Machine (CCM) 2 OEE that is equal to 17.21%. The cause of the low value of OEE is affected by the downtime where busted breakouts are common causes occurs. In the analysis of the FTA, it is known that the less maximum engine effectiveness factor have the highest value probabalility that is equal to 0.3945 so that become the first priority factor in the reduction of fracture breakout.**

Keywords: Critical Point, Effectiveness, OEE, FTA

I. INTRODUCTION

In a production process will probably occur disfluencies production flow that will affect the quality of the product On the other hand the company wants an operational state or the production process can proceed smoothly, stable and controllable

Measuring the value of the effectiveness of the production facilities need to be done as an indicator of the critical point of a process. One concept that is commonly used to measure and analyze the effectiveness is Effectivenes Overall Equipment (OEE). And then for the precaution against interruptions of production facilities can be done by using a concept which is Fault Tree Analysis (FTA).

Several research groups have conducted research related to OEE. Reference [13], conducted research on the implementation of total productive maintenance in the food industry which is used as an indicator of OEE. Based on this study showed an increase in production and product quality improvement. Research on OEE also conducted by [3]. In this study discusses the concept of OEE through case studies of organizations that focus on Cross Functional Team (CFT) within the organization. This case study shows that the CFT approach will significantly increase the successful implementation of OEE which can be done on the machine, production line or factory level and also in the operational measurements. OEE also used to determine the effectivity of production line in garment company. [14]. The usage of FTA has been done such as reference [7] uses FTA to identify caused of defect product. Beside that, reference [15] also uses FTA as a support instrument in six sigma quality control method as an identification instrument of defect product.

This research was conducted at the Company produces steel products where the production activities are still disruption or unsmoothly. In the production of steel, there are six machines were used and are still experiencing unsmoothly production. So far, the company does not yet have a standard parameter in the measurement of the performance of a production machine, but just based on the down time production machine data without any concepts or theoretical methods used

Therefore, the problem to be investigated is to increase the effectiveness of production machines. This can be done by identifying the value of the effectiveness of production machines with the large percentage indicated that in term of aspects of OEE Availability, Performance and Quality. For machines that have been calculated by using OEE value, will be determined one machine that has the smallest value of OEE. The next step will be to identify the cause of ineffectiveness by using Pareto diagrams, fishbone diagrams and FTA.

II. OVERALL EQUIPMENT EFFECTIVENESS

OEE can be considered to combine operations, maintenance, and management of manufacturing equipment and resources. [6].

Percentage OEE can determine the hidden capacity in the manufacturing process and make balanced production flow or current. [11].

OEE measurements can be applied at several different levels in a manufacturing environment. First, it can be used as a benchmark for measuring the performance of initial manufacturing plant as a whole. Second, the value of OEE is calculated for a single manufacturing line, can be used to compare the performance of the line in the factory. Thirdly if the machine worked individually, OEE measurements can identify poor engine performance and indicate sources focus Total Productive Maintenace. [6]

OEE calculation gives three main contributions in the production flow, namely the production, maintenance and quality of the product. [13].

OEE can be determined by equation: [1]

OEE = *Availability x Performance Efficiency x Quality Rate*

= A x PE x QR (1)

Sharma et al (2006), found OEE increases with an increase in equipment availability, performance efficiency and quality rate products

Availability (A) will be affected by the time losses that decrease the availability of production time. [13].

Availability (A) is calculated using the formula: [1]

$$A = \frac{Loading\ Time - Downtime}{Loading\ Time} x100 \qquad (2)$$

Where the loading time is the time available that had been planned for production operations and downtime is the total time the system is not operating due to damage to the equipment, set-up time, turn the workpiece and others. [4].

Increasing Availability can reduce safety stock required to maintain the decline in production due to breakdowns and improve the capacity effectively. The decrease safety stock will also reduce the lead time of workmanship. [12].

Performance Efficiency (PE) will affected by the amount of product produced during a certain period. [13].

Performance Efficiency formulated: [1]

$$PE = \frac{Processed\ Amount\ x\ Theoretical\ Cycle\ Time}{Operating\ Time} x100 \qquad (3)$$

Where the processed amount based on the amount of product produced per period and the operating time is the difference between the loading time with downtime. [4].

Quality Rate (QR) by considering the number of defective products in the production process as a product defect. [13].

Quality Rate (QR) formulated: [1].

$$QR = \frac{Processed\ amount - defect\ amount}{processed\ amount} x100 \qquad (4)$$

Where the defect amount indicates the number of defective products. [4]

References [6], revealed that the ideal value for the measurement of OEE components, namely:

a. *Availability* 90 % or more
b. *Performance Efficiency* 95 % or more
c. *Quality Rate* 99 % or more

OEE value in ideal conditions which is a world-class company standard is 85%.

OEE provide benefits as a monitor production, ie the measurement of improvement. [6].

III. Diagram Pareto

The Pareto diagram is a picture that sort of data classification from left to right according to the rules of the highest to the lowest rank. This can help to find the most important issues to be resolved (the highest ranking) to a problem that does not have to be resolved (the lowest rank). Pareto diagrams can be used to compare the condition of the process. [2].

IV. Fishbone Diagram

To identify the cause of failure / defect can be use the causal diagram (fishbone, ishikawa). Its basic function is to identify the causes that might result from a failure and then separating the root cause. [16].

V. Fault Tree Analysis (FTA)

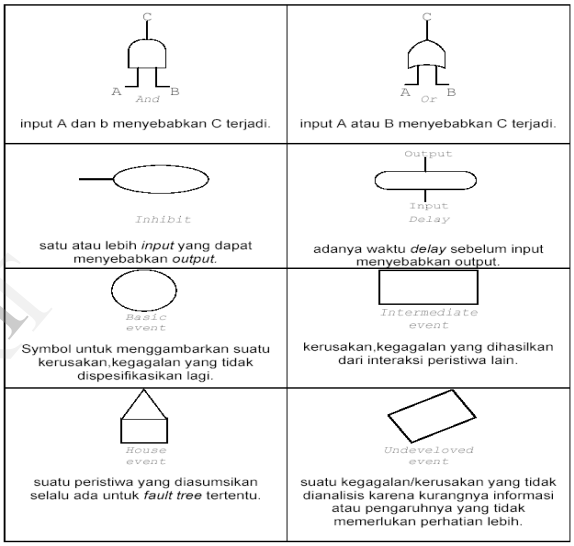

Fig 1. Symbols of fault tree

FTA is an analysis methodology that uses a graphical model to visually demonstrate the analysis process. FTA allows for the identification of failure events based on assessment of the probability of failure. [7].

According to References [5], FTA is a branch of the graph model of a system that can lead to a possibility of undesirable failure. The branches is connecting between the various circumstances and support events by using standard logical symbols.

1. FTA Structure
   Symbols used in the fault tree is a Boolean symbol as shown in the fig 1.
2. Stages Of *Fault Tree*
   Fault Tree Analysis (FTA) consist of 4 (four) stages, which are: [10].

a. System Identification
   This step establishes the system, adverse events (incidence peaks) and restrictions. The first thing to do is to understand how the system works, then the incidence of failure of the peak (top failure) were selected to be the subject of analysis. Any failures will actually be

considered to do with the effects of events that occurred at the peak.

b. *Fault Tree Construction*
This step describes the condition of the system with symbols. At this stage also the identification of the contribution of events that may be the top cause of failure. If all events simultaneously cause failure top, then the construction used is an AND gate. If only one of the events leading up to the top failure, the construction used is an OR gate. If the event is an event that causes the failure of basic (basic event), then this event is symbolized by CIRCLE or circle.

c. Qualitative Analysis
After the construction of a fault tree is created, the next step is to evaluate the qualitative fault tree. The purpose of this analysis is to transform the fault tree into a logical form associated with a combination of events that led to the top failure occurs.

d. Quantitative analysis
This stage produces numerical information related to the fault tree failure peak (top failure). Quantitative analysis of fault tree logical structure transformations that have been made into the form of probability and calculate the probability that the top event occurs based on the probability of events occurring in the basic event.

The probability of occurrence of an event of fault output of AND and OR gates can be calculated based on the following two equations: [8].

AND Gate : $F = f_1 f_2 f_3 \ldots\ldots\ldots f_n$ (5)

OR Gate : $F = 1 - (1 - f_1)(1 - f_2)\ldots(1 - f_n)$ (6)

Remarks: F = The probability of the occurrence of the fails output.

f = The probability of the occurrence of the fails incident input.

n = The number of fails input events.

VI. Research Method

The method used in this study is OEE where as a first step is the determination of the value of Availability, performance, and quality rate as the aspects of OEE, this is where the value will be obtained for the OEE. Next will be determined one machine that has the smallest OEE values for further analysis which identified the cause of the low value of OEE with fishbone diagrams and Pareto charts were continued with a quantitative analysis of the dominant causes by using the concept of FTA. Analysis of the FTA will be able to provide an action plan for improvements to the cause of low OEE based on priority.

VII. Results And Discussion

A. *Data Collection*

Machine which is the object of this research is the engine of Electric Arc Furnace (EAF), Ladle Furnace (LF), and Continuous Casting Machine (CCM). In measuring Overall Equipment Effectiveness requires some data that will be the input for calculations effectiveness. The results of recapitulation data obtained are listed in the table I.

TABLE I. Production Data

No	Machine	Shift Length (Minutes)	Breaks (Minutes)	Downtime (Minutes)	*Cycle Time* (Minutes Per Ton)	Total Pieces (Ton)	Good Pieces (Ton)	*Loading Time* (Minutes) (3) – (4)	*Operating Time* (Minutes) (9) – (5)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1	EAF 1	43200	6434	2808	2,5	6985,70	5470,98	36766	33958
2	EAF 2	43200	7536	2078	2	6985,70	5470,98	35664	33586
3	EAF 3	43200	1797	164	2	6985,70	5470,98	41403	41239
4	LF	43200	6944	2183	0,67	16412,92	15984,24	36256	34073
5	CCM 1	43200	0	929	1	8411,843	8316,319	43200	42271
6	CCM 2	43200	0	941	1	7572,400	7432,280	43200	42259

B. *Calculation Of OEE Values*

OEE value calculation through three aspects: Availability Ratio, Performance Ratio and rate the quality of each machine. As an example calculation, the calculation will be displayed on the machine Electric Arc Furnace, while the complete calculation results are presented in Table 3.

1. *Availability Ratio (A)*

$$Availability\ Ratio = \frac{36766 - 2808}{36766} x100\%$$

$$Availability\ Ratio = 92{,}36\%$$

2. *Performance Ratio* (P)

$$Performance\ Ratio = \frac{6885{,}70\ x\ 2{,}5}{33958} x100$$

$$Performance\ Ratio = 51{,}43\%$$

3. *Quality Ratio (QR)*

$$Quality\ Rate = \frac{5470{,}98}{6985{,}70} x100$$

$$Quality\ Rate = 78{,}32\%$$

4. OEE

$$OEE = 92{,}36\% \; X \; 51{,}43\% \; X \; 78{,}32\%$$
$$OEE = 37{,}20\%$$

Based on the calculations (Table II), the OEE value is 17.21%, which means that production can not be considered world-class for the reason that the world-class standard OEE value is above 85%.

TABLE II. OEE VALUE FOR EVERY MACHINE

NO	Machine	*Avalibality (%)*	Performance (%)	Quality Rate (%)	OEE (%)
1	EAF 1	92,36	51,43	78,32	37,20
2	EAF 2	94,17	41,60	78,32	30,68
3	EAF 3	99,60	33,88	78,32	26,43
4	LF	93,98	32,11	97,39	29,39
5	CCM 1	97,85	19,90	98,86	19,25
6	CCM 2	97,82	17,92	98,15	17,21

C. Cause Analysis Of OEE Lowest Value

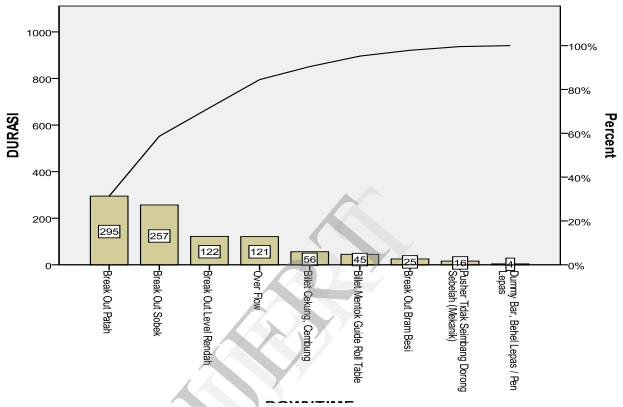

Fig 2. Downtine Pareto diagram causes of down time

Based on the recapitulation of the OEE, which has the lowest value of OEE is CCM 2. Based on the three factors that influence OEE, the lowest is the performance of CCM 2. Performance is caused by total pieces or TBT the input of low CCM 2.

While the value of its operating time is affected by the amount of downtime. Based on actual data obtained, the type of downtime at most takes on the CCM 2 is broken busted, tear break out, low level break out the and over flow.

D. Analysis of Broken Busted Causes

To analyze the cause of the fracture is used to break out a causal diagram. Causal diagram made consists of four entities, namely material, environment, man and machine. In a material entity, there is the problem of raw materials caused by the delay of raw materials and the composition of the different sponge and scrap. On the environment entities, are a source of energy, which is based on electrical problems ranging from a power failure and the problem of power plant / KDL. In humans there are problems entity work experience due to lack of socialization, monotonous work patterns due to the lack of knowledge transfer. While the effectiveness of the entity's machine less than the maximum engine caused by mouldrop died from a motor trip, pump motors damaged due to problems of lubrication oil pump and pipes.

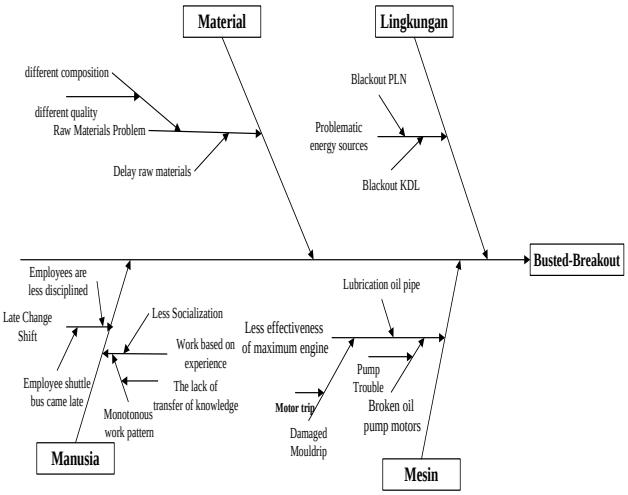

Fig 3. Broken Busted Cause and Effect Diagram

Based on the identification by using a fishbone diagram, the next step is to identify quantitatively by using the FTA. Here is given information about the cause and probability of fracture to break out.

TABLE III. CAUSES BROKEN BUSTED

NO	Type Of Causes	Number of Problem (Minutes)	Probability (P)
1	Problem pumps	52	0.1763
2	Motor trip	48	0.1627
3	Lubrication oil pipe	36	0.1220
4	KDL	30	0.1017
5	PLN	28	0.0949
6	Delay Raw Materials	15	0.0508
7	Different quality of ingredients	10	0.0339
8	Late Shuttle Bus pick up	20	0.0678
9	Employees are less disciplined	18	0.0610
10	Monotonous work pattern	19	0.0644
11	Lack of socialization	19	0.0644
Amount		295	

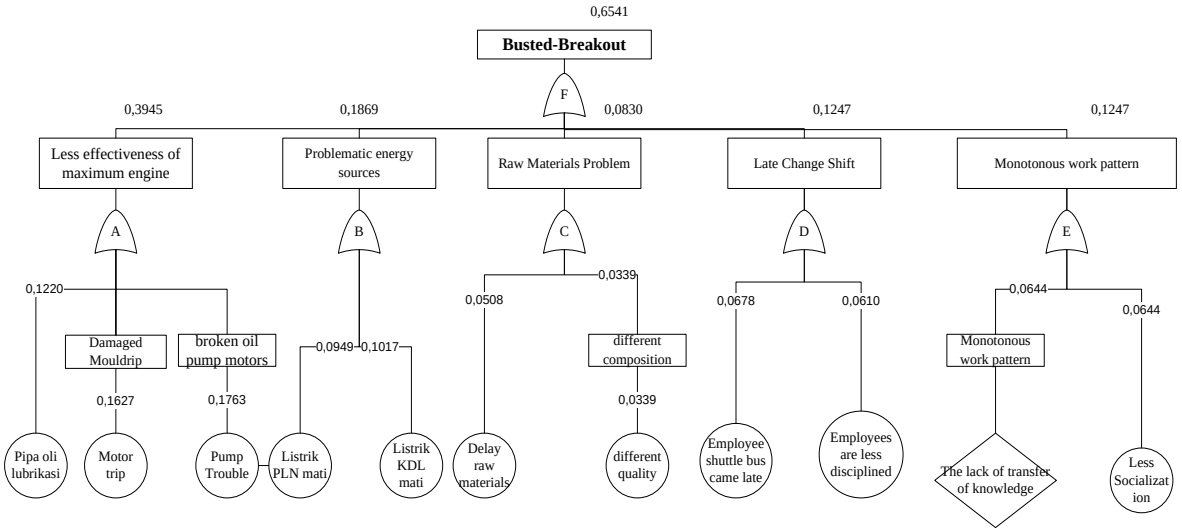

Fig 4. FTA for Busted-breakout

For each type of disability, identified basic event and gate logic, their contributions in the event of disability. Based on this identification can be structured fault tree for product defects. The structure of the fault tree to Busted Break out can be seen in the following fig 4.

F logic gate is a gate that shows the busted-breakout and the results of these calculations can be seen that the probability value of busted-breakout is equal to 0.6541.. In the picture of the busted- breakout fault tree can be shown that the less effectiveness of maximum engine is the primary cause that has a high probability value that is equal to 0.3945, with a secondary cause which has the largest probability value is broken oil pump motors with a probability value of 0.1763. Based on the concept of FTA which has been analyzed above, it can be given priority of corrective action plans to reduce busted-breakout by looking at the value of the probability causes of busted-breakouts. The priority of corrective action plan is shown in the following table IV.

TABLE IV. ACTION PLAN TO REDUCE THE BUSTED-BREAKOUT

Improvement priorities	Primary Cause	Prob	Secondary Cause	Prob	*Basic event*	Prob	Corrective Action Plan
I	less effectiveness of maximum engine	0,3945	broken oil pump motors	0,1763	Pump Trouble	0,1763	1. If the motor Mould Lubrication damaged, replace the motor with spare parts that have been prepared. 2. Perform routine maintenance every two weeks.
			Damaged Mouldrip	0,1627	Motor trip	0,1627	1. Find the damaged cause of motor Mould Drive, because many factors that cause it 2. Perform routine maintenance every two weeks.
			Lubrication oil pipe	0,1220	Lubrication oil pipe	0,1220	If the lubrication pipes are damaged, immediately replaced with parts that are readily available, if there is a path that is clogged, needs flushing by using compressed air.
II	Problematic energy sources	0,1869	Electricity from PT. Krakatau Daya Listrik (KDL) is balckout	0,1017	Blackout KDL	0,1017	1. Waiting for the power to return to normal 2. Coordination with KDL for troubleshooting.
			Electricity from electricity state company (PLN) is balckout	0,0949	Blackout PLN	0,0949	1. Waiting for the power to return to normal 2. Coordination with PLN to overcome the interference.
III	Work based on experience	0,1247	Monotonous work pattern	0,0644	The lack of transfer of knowledge	-	1. Improving knowledge transfer to new employees 2. Better understanding of standard operating procedures that have been made
			Less Socialization	0,0644	Less Socialization	0,0644	
IV	Late Change Shift	0,1247	Employees are less disciplined	0,939	Employees are less disciplined	0,939	Provide discipline training material
			Employee shuttle bus came late	0,09322	Employee shuttle bus came late	0,09322	Coordination with the employee shuttle bus driver
V	Raw Materials Problem	0,0830	Delay raw materials	0,0508	Delay raw materials	0,0508	Availability of raw materials should be calculated back from the amount and time of the booking, in order to avoid delay in raw material back
			different composition	0,0339	different quality	0,0339	The quality of the raw material should be more standardization

VIII. CONCLUSIONS

1. OEE value for each machines 3 EAF, 1 LF and 2 CCM which is 37,20%; 30,68%; 26,43%; 29,39%; 19,25% and 17,21%.
2. Based on the value of OEE seen that there are no machines that achieve world-class standards.
3. The critical point is the production unit CCM machine OEE 2 that has the lowest value where the performance aspect is an aspect that has the lowest OEE value is equal to 17.92% while the availability and quality aspects of the CCM second rate that is equal to 97.82 and 98, 15. This suggests that aspects of performance need improvement priorities in an effort to increase the value of effectiveness.
4. Based on actual data obtained, the type of downtime which most consuming time to CCM 2 is busted-broken.
5. In the analysis of the FTA, it is known that the less maximum engine effectiveness factor has the highest probability value is equal to 0.3945 so that the first priority factor in the reduction of busted-breakout

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