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Effectiveness Analysis of a Multiwire Drawing Machine Using Overall Equipment Effectiveness and Failure Mode and Effect Analysis

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ABSTRACT

The copper wire drawing process on the Multiwire Drawing (MWD) machine must run smoothly to ensure that automotive cable production is not disrupted. However, MWD Machine 8 experienced repeated shutdowns from April through June 2026. This study aims to evaluate the machine's effectiveness, identify major disruptions, investigate possible causes of wire breaks, and determine maintenance priorities for components. The study employed a descriptive quantitative approach based on production reports, downtime records, observations, and interviews with operators, production leaders, and supervisors. The data were analyzed sequentially using Overall Equipment Effectiveness (OEE), the Six Big Losses, Fishbone diagrams, and Failure Mode and Effects Analysis (FMEA), supplemented by a sensitivity analysis of risk values. The results showed 243 stoppage incidents, including 168 wire break incidents (69.14%). Out of 1,586 hours of planned production time, downtime totaled 245.78 hours, resulting in a combined availability of 84.50%. The frequency of wire breaks decreased from 17.50 to 8.49 incidents per 100 hours of operation between April and June. However, the final OEE value could not yet be determined because the machine's ideal technical speed had not been verified, and the provisional performance calculation for May reached 111.40%. The FMEA identified defective dies (RPN 288), clogged dryers (280), defective contact tubes (280), and defective capstans (210) as high priorities. Sensitivity analysis showed that the priority of the first three components remained high when a single score changed by one point. The study concluded that wire breaks were the most frequent disruptions, but their contribution to total downtime duration was unknown. Consequently, the company needs to prioritize component inspections, improve the recording of disruption durations, and verify production data. These results provide a basis for developing a more targeted and measurable maintenance schedule.

Keywords: *Overall Equipment Effectiveness, Six Big Losses, Fishbone Diagram, FMEA, Multiwire Drawing.*

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INTRODUCTION

The smooth operation of automotive cable production depends heavily on the machines' ability to operate continuously. One of the key processes in cable manufacturing is the drawing of copper wire using a Multiwire Drawing (MWD) machine. This machine reduces the wire's diameter before it is used in subsequent production processes. If the wire breaks or the machine malfunctions, production must be temporarily halted. Such situations can reduce production time and hinder the achievement of company targets. [1] explain that wire breakage during the drawing process can result from either unsuitable material conditions or improper process settings. Martínez et al. [23] also demonstrate that die geometry, drawing speed, and lubricant conditions affect friction and wire quality. Meanwhile, Wu et al. [24] found that drawing speed influences deformation and damage to the copper material. These research findings indicate that machine conditions and process settings must be carefully monitored to ensure smooth wire production.

A similar issue was identified at PT. XYZ, a company that manufactures automotive cables using eight MWD machines in its Copper department. These machines are used to reduce the diameter of copper wire from approximately 1.5 mm to 0.259 mm. Based on company records from April through June 2026, MWD Machine 8 experienced 243 stoppages the highest number compared to the other seven machines. Of these, 168 incidents, or 69.14%, were caused by wire breaks. Over the three-month period, MWD Machine 8 had a planned production time of 1,586 hours, with a total

downtime of 245.78 hours. This means that approximately 15.50% of the planned production time was not utilized for machine operation. These disruptions indicate the presence of issues that need to be investigated so the machine can operate more efficiently. However, the available data does not yet specify how many hours of downtime were specifically caused by wire breaks. Therefore, the company needs to identify the most frequent types of disruptions, their likely causes, and the components that should be inspected first.

Machine effectiveness can be assessed using the Overall Equipment Effectiveness (OEE) method, which measures three main aspects: availability, performance, and quality. Availability indicates how much time the machine spends operating; performance indicates the machine's ability to produce products at the ideal speed; and quality indicates the proportion of products that meet quality requirements. These three aspects help companies identify the sources of reduced machine effectiveness. [2], through a study on injection molding machines for automotive components, demonstrated that OEE measurements based on operating time, production speed, and defective products can help determine more appropriate corrective actions. However, OEE measurements must use appropriate data. If downtime has already been factored into availability, the impact of that downtime should not be counted again in performance. Therefore, the accuracy of calculations is a critical aspect of this study, particularly since complete technical data on the ideal speed of the MWD 8 machine is not yet available.

Several previous studies have used OEE and Failure Mode and Effects Analysis (FMEA) to evaluate machine effectiveness. [3] reported an OEE value of 56.68% for a fine-drawing machine, indicating the need to improve the maintenance system. [4] found an OEE value of approximately 70% for a cable extruder, with issues related to carbon brushes, bearings, and the heating system. Both studies demonstrate that component failures can disrupt the smooth production of cables. However, the fine drawing and extrusion processes differ from Multiwire Drawing; thus, the types of disruptions and maintenance requirements may not necessarily be the same. [5] applied OEE, the Six Big Losses, the Fishbone diagram, and FMEA to die-attach machines in the semiconductor industry. The study found that idling and minor stoppages were the primary losses, while loose retaining screws were assigned a high-risk score. These differing findings indicate that each type of machine may have distinct sources of disruption. Therefore, research results from one machine cannot be directly applied to determine the causes of failure in another machine.

Previous research has also shown that FMEA is useful for prioritizing risk mitigation, but the assessment results must be examined carefully. [6] explain that the use of the Risk Priority Number (RPN) in FMEA has limitations, primarily because the results can be influenced by the judgments and considerations of the person assigning the scores. Thus, components with a high RPN are not necessarily proven to be the leading causes of failure. These values are more appropriately used as a basis for determining the sequence of inspections and maintenance. Therefore, a sensitivity analysis is necessary to determine whether small changes in FMEA scores can alter the priority order of components.

Based on the studies discussed, there are gaps that require attention. Research on copper wire drawing primarily focuses on the effects of material conditions, dies, lubrication, and speed on wire quality [7]. Meanwhile, OEE and FMEA studies on fine-drawing machines, extruders, and die-attach machines place greater emphasis on measuring effectiveness and determining the priority of failures in the machines under study [8]. These studies have not provided specific answers regarding which components should be prioritized to address wire break failures MWD 8 machines. Additionally, there is a need to distinguish between the number of stoppages and the duration of lost production time, verify the accuracy of OEE calculations, and determine whether the FMEA priority sequence remains the same when assessment scores change. These gaps form the basis of this study.

The novelty of this study lies in its specific analysis of wire break failures in the Multiwire Drawing process, linking machine failure data, examining OEE calculations, identifying potential causes of failure, and determining component maintenance priorities. This study also incorporates an FMEA sensitivity analysis to assess the stability of the failure priority sequence. Unlike studies that merely report OEE or RPN values, this research distinguishes between results supported by company records and failure causes that remain speculative. The combination of OEE, the Six Big Losses, the Fishbone diagram, and FMEA is not a new method. The novelty of this research lies in its application to establish component inspection priorities for the MWD 8 machine based on available data, while also explaining the limitations of the evidence used.

This study aims to: evaluate the effectiveness of the MWD 8 machine from April through June 2026 by calculating availability, performance, and quality, as well as verifying the accuracy of the OEE values; identify the frequency and types of machine malfunctions using the Six Big Losses based on available data; identify possible causes of wire breaks using a Fishbone Diagram; determine the priority of component failure risks using FMEA and test the stability of these priorities through RPN sensitivity analysis; and formulate maintenance recommendations based on the analysis results. This study is expected to provide a clearer basis for the company to determine which components should be

inspected first, develop a maintenance schedule, and improve the documentation of machine malfunctions. The results can also serve as a basis for evaluating maintenance in future studies by comparing the frequency of wire breaks, downtime, and OEE before and after improvements. The resulting recommendations have not yet been implemented, so their impact on improving machine effectiveness still needs to be tested.

MATERIAL AND METHOD

Subject and Data Collection

This study employed a descriptive quantitative approach using a case study of the Multiwire Drawing (MWD) 8 machine in the Copper Department of PT. XYZ. The research covered the period from April to June 2026. Secondary data were collected from company production reports and machine downtime records, including the number of shifts, planned production time, machine downtime, production output, and frequency of machine stoppages. Primary data were obtained through direct observations and interviews with three respondents selected through purposive sampling: one machine operator, one production leader, and one supervisor.

Data analysis was conducted systematically using Overall Equipment Effectiveness (OEE), Six Big Losses, a Fishbone Diagram, and Failure Mode and Effects Analysis (FMEA). Each method was applied sequentially to measure machine effectiveness, identify production losses, investigate possible causes of wire breaks, and determine maintenance priorities [9], [10].

Overall Equipment Effectiveness (OEE)

OEE was used to evaluate machine effectiveness based on three indicators: availability, performance, and quality. The calculations were performed using the following equations [3], [11], [12].

$$\text{Loading time} = \text{Number of shifts} \times \text{Planned production time per shift} \tag{1}$$

$$\text{Operating time} = \text{Loading time} - \text{Downtime} \tag{2}$$

$$\text{Availability} = \frac{\text{Operating time}}{\text{Loading time}} \times 100\% \tag{3}$$

$$\text{Performance} = \frac{\text{Actual Output}}{\text{Ideal Production Rate} \times \text{Operating time}} \times 100\% \tag{4}$$

$$\text{Quality} = \frac{\text{Good Output}}{\text{Total Output}} \times 100\% \tag{5}$$

$$\text{OEE} = \frac{\text{Availability} \times \text{Performance} \times \text{Quality}}{10{,}000} \tag{6}$$

In Equation (6), the OEE value is calculated by multiplying availability, performance, and quality, all expressed as percentages. The ideal production rate indicates the number of products a machine should be able to produce per hour based on the company's ideal or standard capacity. If the ideal rate differs for each shift, the ideal production volume is calculated based on the rate and operating time of each shift. Machine downtime which has already been factored into availability must not be counted again in performance, so that the OEE result does not end up lower than the actual conditions [10], [13], [14].

Loading time is calculated based on the planned production time of 7.93 hours per shift. Scheduled preventive maintenance activities must be consistently factored in to avoid errors in determining machine operating time. Meanwhile, the number of defective products is estimated at 1 kg for each wire break incident, based on the operator's report [8], [15], [16].

Six Big Losses

The Six Big Losses are used to identify the sources of machine inefficiency, which consist of equipment failure, setup and adjustment, idling and minor stoppages, reduced speed, process defects, and reduced yield. Each stoppage is categorized by its cause to determine the frequency of disruptions using the equation [1], [17], [18]:

$$\text{Frequency Percentage} = \frac{\text{Number of Stoppages by Cause}}{\text{Total Number of Stoppages}} \times 100\% \tag{7}$$

Equipment failures and setup and adjustment issues were identified based on records of malfunctions and machine downtime. Meanwhile, losses resulting from reduced speed and defective products required data on short-duration stoppages, ideal machine speed, and the number of defective products. Since the duration of stoppages for each cause has not been fully recorded, this study could only calculate the number of malfunction incidents and total downtime [5], [19], [20]. Therefore, the type of loss that is the greatest in terms of lost production time cannot yet be determined. The percentage of malfunction incidents is also not considered equivalent to the percentage of lost time, as each malfunction may result in a different duration of downtime.

Fishbone Diagram Analysis

The Fishbone Diagram is used to identify potential causes of wire breakage based on the results of the Six Big Losses analysis, observations, and interviews. Causal factors are grouped into three categories: machinery, methods, and materials and fluids [21], [22]. The analysis is conducted by identifying component conditions that could potentially cause wire breakage, then comparing them with information from operators, team leaders, and supervisors. Causes supported by inspection evidence are distinguished from those that are still mere assumptions. The results of the fishbone diagram are used as the basis for determining failure modes in the FMEA [9].

Failure Mode and Effect Analysis (FMEA)

FMEA is used to prioritize component failure risks related to wire breaks. The assessment involves three respondents: the operator, the team leader, and the supervisor. Each failure mode is evaluated based on Severity (S), Occurrence (O), and Detection (D) using a scale of 1–10 according to the criteria in the FMEA evaluation table. If there are differences in evaluation, the final score is determined through discussion to reach a consensus.
The risk value is calculated using the equation [2], [4], [23]:

$$\text{RPN} = \text{Severity} \times \text{Occurrence} \times \text{Detection} \tag{9}$$

RPN results were categorized as high priority (RPN ≥ 200), medium (100–199), and low (RPN < 100). These thresholds are internal research criteria, not universal FMEA standards.

Formulation of Improvement Recommendations

Improvement recommendations are formulated based on OEE measurement results, the distribution of disruptions, the identification of root causes using a fishbone diagram, and RPN priorities. Each recommendation includes maintenance actions, the person responsible, an implementation schedule, and success indicators.
When using a downtime reduction scenario, calculations are performed using the equation [7], [24], [25]:

$$\text{Availability Skenario} = \frac{\text{Loading Time} - \text{Downtime} \times (1 - \text{r})}{\text{Loading Time}} \times 100\% \tag{10}$$

$$\text{OEE Skenario} = \frac{\text{Availability Skenario} \times \text{Performance} \times \text{Quality}}{10.000} \tag{11}$$

Where r is the assumed proportion of downtime reduction. The simulation assumes that performance and quality remain constant and that the additional operating time is used for production. The simulation results are mathematical estimates, not implementation results. These calculations can only be reliably used after baseline performance has been validated. None of the recommendations in this study have been implemented or tested on the MWD 8 machine.

RESULTS

Identifying Malfunctions in Multiwire Drawing Machines

The first stage of the study was to determine which machines stopped most frequently during the production process. An inspection was conducted on eight multiwire drawing machines in the Copper Department. The results were used to identify the machines that required further investigation.

Table 1. Frequency of malfunctions in eight MWD machines

Machine	April	May	June	Total	Percentage (%)
MWD 1	13	24	18	55	4.77
MWD 2	73	39	17	129	11.2
MWD 3	41	66	38	145	12.59
MWD 4	37	52	35	124	10.76

MWD 5	86	65	56	207	17.97
MWD 6	28	40	22	90	7.81
MWD 7	75	61	23	159	13.8
MWD 8	103	85	55	243	21.09
Total	456	432	264	1,152	100

According to Table 1, the MWD 8 machine had the highest number of malfunctions, with 243 incidents out of a total of 1,152 incidents across all machines. This means that approximately 21 out of every 100 shutdown incidents across the eight machines occurred on the MWD 8.

The MWD 8 machine experienced 103 incidents in April, 85 in May, and 55 in June. The number of incidents decreased by 46.60% from April to June. This decrease indicates that malfunctions are being recorded less frequently, but it does not yet prove that the machine's condition has improved, as there may be differences in operating time, production load, or working conditions from month to month.

Calculating Overall Equipment Effectiveness (OEE)

OEE is used to assess how effectively a machine produces products during scheduled production time. This is measured based on three factors: availability, performance, and quality. All three must be calculated correctly to ensure that machine downtime is not counted twice.

Calculating Availability

Availability indicates how much time the machine actually spent operating compared to the planned time.

Table 2. Operating Time and Availability of MWD 8

Indicator	April	May	June	Total
Number of shifts	73	60	67	200
Loading time (hours)	578.89	475.80	531.31	1586.00
Downtime (hours)	98.85	86.98	59.95	245.78
Operating time (hours)	480.04	388.82	471.36	1340.22
Availability (%)	82.92	81.72	88.72	84.50
Recorded stoppages	103	85	55	243
Stoppages per 100 operating hours	21.46	21.86	11.67	18.13
Wire break incidents	84	44	40	168
Wire breaks per 100 operating hours	17.50	11.32	8.49	12.54

The total loading time was 1,586.00 hours, while recorded downtime reached 245.78 hours. Consequently, the machine operated for 1,340.22 hours, producing an overall availability of 84.50%. The recorded downtime represented 15.50% of planned production time.

May recorded the lowest availability at 81.72%, although its downtime was lower than in April. This occurred because the planned production time in May was also shorter. Availability improved to 88.72% in June as downtime decreased to 59.95 hours.

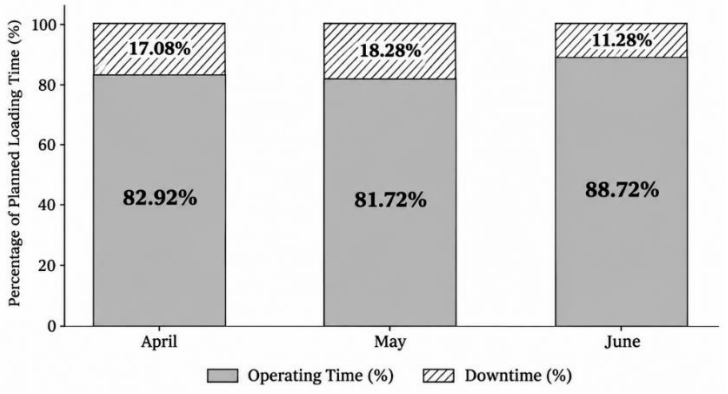


Figure 1. Comparison of operating time and downtime for MWD 8 machines

The graph shows that June has the best operating availability, while May has the lowest. This finding is important because the longer a machine is idle, the less time is available for producing products.

Performance Calculation

Performance is used to determine a machine's ability to produce products while it is actually in operation. This calculation is important because a machine that is running does not necessarily produce products at its ideal speed.

Table 3. Verification of the MWD 8 engine performance calculations

Parameter	April	Mei	Juni
Actual output	220.549.000	196.718.000	202.038.000
Target output	274.650.386	216.094.545	250.224.446
Operating time (jam)	480,04	388,82	471,36
Rata-rata target produksi per jam	474.443,13	454.170,96	470.957,53
Pencapaian target (%)	80,3	91,03	80,74
Performance (%)	96,84	111,4	91,01

According to Table 3, performance in April reached 96.84%, increased to 111.40% in May, and decreased to 91.01% in June.

Quality Calculation

Quality is used to determine the proportion of products that meet quality requirements. The fewer defective products there are, the higher the machine's quality score. Defective products are estimated at 1 kg for every wire break, based on the operator's report.

Table 4. Recalculated production quality results for MWD 8

Parameters	April	May	June	Total
Wire breaks (times)	84	44	40	168
Estimated defective product (kg)	84	44	40	168
Total output (kg)	220.549	196.718	202.038	619.305
Good output (kg)	220.465	196.674	201.998	619.137
Quality (%)	99,9619	99,9776	99,9802	99,9729

Based on Table 4, the quality of the MWD 8 machine was estimated to be very high during the observation period. Its value increased from 99.9619% in April to 99.9802% in June.

The estimated number of defective products also decreased, from 84 kg in April to 40 kg in June. This decrease followed a decline in the number of wire break incidents.

OEE Results Analysis

The recalculated results show that the provisional OEE in April was 80.27%, in May 91.01%, and in June 80.73%, with an average of 84.00%. May had the highest OEE value even though availability was the lowest that month. This occurred because the production target achievement in May reached 91.03%, higher than April's 80.30% and June's 80.74%. However, the performance calculation result for May reached 111.40%. This figure indicates that the production target used in the calculation may not yet align with the machine's actual ideal speed. Therefore, these OEE results are still preliminary and need to be re-examined using more comprehensive data on the machine's ideal speed and operating time.

As a point of comparison, an OEE value of 85% is used as a general benchmark for assessing machine effectiveness. If quality is at 99.97% and availability and performance are assumed to have the same value, then both need to reach approximately 92.21% for the OEE to reach 85%. This means the company needs to maintain machine operating time while ensuring the machines operate at their ideal speed.

Table 5. Summary of OEE Results

Mount	Availability	Performance	Quality	OEE
April	82,92	96,84	99,96	80,27
May	81,72	111,40*	99,98	91,01
June	88,72	91,01	99,98	80,73

Six Big Losses

According to company records, the MWD 8 machine experienced 243 stoppages from April through June 2026. Of that total, 184 incidents were caused by equipment failure, consisting of 168 wire breaks, 15 mechanical repairs, and 1 electrical repair. In addition, there were 52 incidents classified as "setup and adjustment," including 38 instances of waiting for a coil, 8 instances of changing wire size, 4 instances of changing the power supply, and 2 instances of changing the number of elements. Meanwhile, there were 7 recorded instances of preventive maintenance. Based on the number of incidents, equipment failure accounted for 75.72%, setup and adjustment for 21.40%, and preventive maintenance for 2.88%.

These results indicate that machine breakdowns are the most frequent cause of downtime. However, these percentages only reflect the number of incidents, not the duration of machine downtime. Total downtime in April was recorded at 98.85 hours, in May at 86.98 hours, and in June at 59.95 hours. Unfortunately, the company does not yet have detailed downtime figures for each cause of disruption. Therefore, this study has not been able to fully calculate the six types of losses in the Six Big Losses method. The production target achievement rates ranging from 80.30% to 91.03% also cannot yet be used to determine losses due to reduced machine speed, as these figures are still influenced by machine downtime.

Based on Figure 2, wire breakage is the most frequent disruption and thus requires primary attention in machine maintenance. However, this study cannot yet confirm that equipment failure causes the greatest loss of production time. To determine this, the company needs to record how long machines are idle due to each disruption and measure production speed while the machines are operating. With this data, the company can identify which disruptions consume the most production time and determine which improvements should be implemented first.

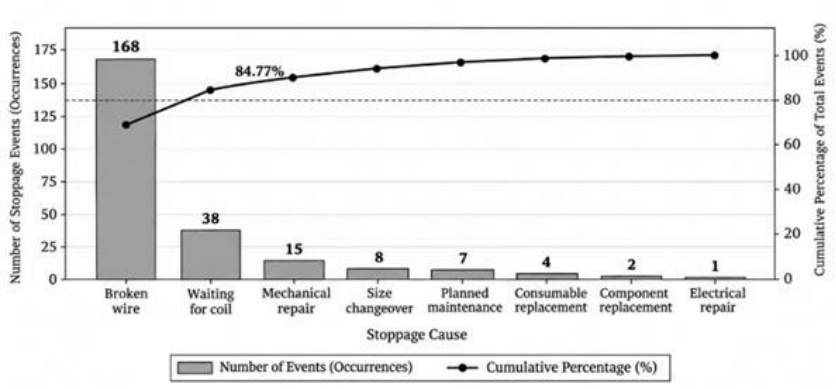


Figure 2. Pareto Chart Showing the Frequency of Causes of MWD 8 Machine

Changes in Wire Break Frequency

To determine whether wire break failures are actually becoming less frequent, the number of incidents must be compared to the machine's operating time. This comparison is more accurate because the number of machine operating hours varies from month to month.

Table 6. Frequency of Malfunctions Per 100 Hours of Operation

Indikator (%)	April	Mei	Juni
Availability	82,92	81,72	88,72
Performance rekonstruksi sementara	96,84	111,4	91,01
Quality estimasi	99,96	99,98	99,98
OEE dilaporkan pada artikel awal	66,56	74,38	71,62
Pencapaian produk baik terhadap target	80,27	91,01	80,73

The results show that wire breaks are occurring less frequently relative to machine operating time. In April, there were approximately 17.50 wire break incidents per 100 hours of operation. That figure dropped to 11.32 incidents in May and 8.49 incidents in June.

Thus, the frequency of wire breaks per 100 operating hours decreased by approximately 51.51% from April to June. This result is more meaningful than simply stating that the number of incidents fell from 84 to 40.

Root Cause Analysis Using a Fishbone Diagram

The fishbone diagram in Figure 2 maps out three groups that correspond to the methodology: Machinery, Methods, and Materials/Fluids. This diagram serves as a hypothesis map, not as evidence of causality. Wire breakage is the effect being analyzed because it occurred 168 times.

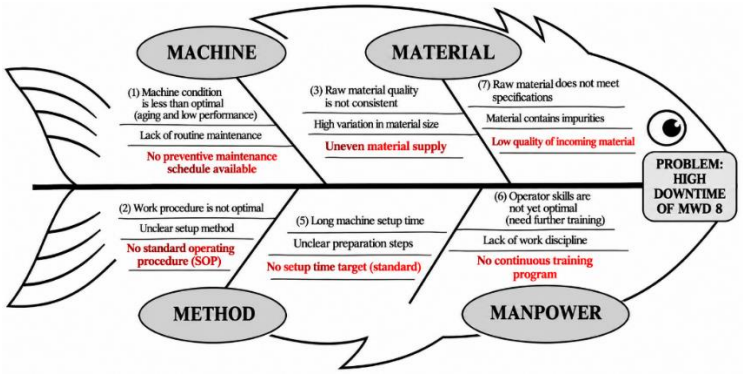


Figure 3. Fishbone diagram of potential causes of wire breakage in MWD 8

The Fishbone analysis shows that wire breakage is likely influenced by the condition of machine components, maintenance practices, and the condition of materials and lubricants. In the machine category, damage to dies, contact tubes, dryers, and capstans requires attention because these components are involved in the wire drawing and movement processes. If component surfaces are damaged or the wire path is disrupted, the wire may be subjected to excessive friction or pressure. In the methods category, replacing components only after they have failed can potentially cause the machine to shut down suddenly. Maintenance performed only after the machine breaks down also makes it difficult for the company to predict when the next failure will occur.

Meanwhile, the condition of the lubricant and the buildup of copper dust require further examination through direct measurement. Information from interviews does help identify possible causes, but it is not sufficient to prove a cause-and-effect relationship.

One key finding is the possibility of a bidirectional relationship between contact tube damage and wire breaks. A broken wire can damage the contact tube, but a damaged contact tube is also suspected of increasing the risk of subsequent wire breaks. The sequence of these events is not yet known from the research data.

FMEA Analysis

FMEA is used to assign a risk value to each component based on three factors: the severity of the failure (Severity), the likelihood of failure (Occurrence), and the difficulty of detecting the failure before it occurs (Detection).

The values of these three factors are multiplied to obtain the Risk Priority Number (RPN). The higher the RPN value, the higher the priority for inspection and maintenance according to the rating system used in this study.

Table 7. Rating scales for severity, occurrence, and detection in FMEA

Score	Severity (Impact)	Occurrence (Frequency)	Detection (Detectability)
1–2	Almost no impact on machine operation	Almost never occurs	Almost certain to be detected before failure
3–4	Machine slows down without stopping	Rarely occurs	High probability of detection
5–6	Machine stops briefly and resumes operation after adjustment	Occasionally occurs	Moderate probability of detection
7–8	Machine stops for a considerable period, requiring component replacement or repair	Frequently occurs	Low probability of detection
9–10	Machine experiences prolonged downtime, major damage, or significant production losses	Almost always occurs	Very unlikely to be detected before failure

Table 8. FMEA Results for the MWD 8 Machine

Failure Mode	Effect	Cause	Indicator	S	O	D	RPN	Priority
Defective dies	Wire breaks and reduced production speed	Excessive operating time	Defects on the inner surface	8	6	6	288	High
Clogged dryer	Wire is compressed and at risk of breaking	Prolonged use and copper dust accumulation	Accumulation of copper dust	8	7	5	280	High
Defective contact tube	Repeated wire breaks and machine stoppages	Contact tube struck by wire during wire break	Scratches on the surface	7	8	5	280	High

Defective capstan	Surface damage and risk of wire scratches or breaks	Insufficient lubricant concentration	Scratches on the surface	7	6	5	210	High
Scratched polisher	Wire scratches and machine stoppages	Scratches caused by wire and excessive pressure	Scratches on the surface	6	6	5	180	Medium
Defective roller	Excessive wire pressure and restricted wire movement	Excessive pressure on the wire	Scratches on the surface	6	5	5	150	Medium

Based on the FMEA results, six types of component failures were analyzed. Four types of failures had an RPN value ≥ 200 and were therefore classified as high priority, while the other two types had RPN values between 100 and 199 and were classified as medium priority. This classification was developed specifically for this study and is not a standard rule in the FMEA method. The higher the RPN value, the greater the attention that needs to be given to that component. However, the RPN value cannot be used as evidence that a component is the direct cause of a wire break.

Defective dies have the highest RPN value, 288, making them the top priority for inspection and repair. Next, the clogged dryer and the defective contact tube have the same RPN value, 280. Although their values are the same, the dryer is prioritized first because the severity of its damage is higher. Meanwhile, the defective capstan has an RPN value of 210, just slightly above the high-priority threshold of 200. Therefore, the capstan's priority level may change if the assessment results change.

The scratched polisher has an RPN value of 180, while the defective roller has an RPN value of 150. Both of these components are classified as medium priority but still require routine inspection to prevent the damage from worsening. Additionally, the "Occurrence" value the likelihood of failure still needs to be re-examined using records of component failures and replacements, as this data was not available in this study.

The four high-priority components die, dryer, contact tube, and capstan are suspected to be associated with wire break incidents. However, this study has not yet been able to determine how many wire breaks were caused by each component. The total of 168 wire break incidents represents the overall number of wire breaks during the study, not the number of failures proven to have been caused by these four components. Therefore, the company needs to document which components failed, the inspection results, the replacement dates, and any wire break incidents that occurred after repairs. This data is necessary to identify which components actually contribute to wire breaks and to determine the most appropriate maintenance measures.

Proposed Improvements to the Maintenance System

Based on the results of the OEE, Six Big Losses, Fishbone, and FMEA analyses, the next step is to develop corrective actions. The goal is to reduce machine downtime through more systematic component inspections and maintenance. The proposals were developed by taking into account high-risk components and frequently occurring operational issues. All of the following activities constitute the improvement plan.

Table 9. Proposed Corrective Actions for The MWD 8 Machine

Problem	Proposed Corrective Action	Proposed Person in Charge	Proposed Schedule	Success Indicator
Defective dies	Inspect the surface condition and record the operating hours of the dies	Operators and maintenance team	Inspection every shift	Reduction in wire breaks caused by defective dies
Clogged dryer	Remove copper dust and inspect the dryer condition	Maintenance team	Routine inspection every shift	Reduction in dryer blockages
Defective contact tube	Inspect for scratches and replace damaged components	Operators and maintenance team	After a wire break occurs	Reduction in repeated component failures
Defective capstan	Inspect the surface condition and measure lubricant concentration	Maintenance and process teams	Routine inspection	Reduction in surface damage
Polisher and roller	Include component inspections in preventive maintenance (PM) activities	Maintenance team	Regular preventive maintenance schedule	Reduction in component failures
Bobbin waiting time	Record waiting time and improve coordination of bobbin supply	Production leader and bobbin supply team	Weekly evaluation	Reduction in bobbin waiting time

Table 10 shows that improvements should begin with the components with the highest RPN values, particularly the dies, dryer, and contact tube. These three have relatively stable priorities based on the results of the sensitivity analysis. Inspections should be conducted before components suffer severe damage. For example, if dies are already showing signs of wear, maintenance measures can be planned before they cause disruptions to the wire.

In addition to machine components, issues related to waiting for bobbins also require attention. Of the 38 incidents involving waiting for bobbins, 29 occurred in May. This situation highlights the need to inspect the bobbin supply system to prevent machines from stopping simply because they are waiting for supporting materials.

Downtime Reduction Simulation

To estimate the potential benefits of maintenance, a simple simulation was conducted based on downtime reduction. This simulation did not use data from the implementation of improvements, but simply calculated what would happen if machine downtime could be reduced.

Three scenarios were used: a 5%, 10%, and 20% reduction in downtime. The availability value was recalculated with a fixed loading time of 1,586 hours.

Table 11. Simulation of Downtime Reduction and Availability Improvement for MWD 8 Machine

Parameter	Initial Condition	5% Reduction	10% Reduction	20% Reduction
Loading time (hours)	1586.00	1586.00	1586.00	1586.00
Downtime (hours)	245.78	233.49	221.20	196.62
Additional operating time (hours)	0.00	12.29	24.58	49.16
Availability (%)	84.50	85.28	86.05	87.60

The simulation results show that reducing downtime can increase machine uptime. If downtime is reduced by 10%, the company could potentially gain an additional 24.58 hours of operating time over three months. In this scenario, availability increases from 84.50% to 86.05%. If downtime can be reduced by 20%, availability is projected to increase to 87.60%.

DISCUSSION

The results of this study are consistent with several previous studies. [2], [4] found that cable extrusion machines have an OEE of approximately 70%. The problems identified were related to damage to carbon brushes, bearings, and the heating system. Meanwhile, a study on fine-drawing machines [12] showed an OEE of 56.68%. Both studies illustrate that the condition of machine components significantly affects the smooth operation of cable production. If components fail, the production process can be disrupted, and the machine cannot operate at maximum capacity.

These findings align with research on the MWD 8 machine, which showed that wire breaks were the most frequent disruption, accounting for 168 out of 243 stoppages. A study on injection molding machines [8] also indicates that machine breakdowns and reduced production speeds are issues that require attention. A common theme across these studies is the importance of regular machine inspections and maintenance. However, OEE values from various studies cannot be directly compared because the machine types, ideal speeds, observation periods, and methods for calculating downtime may differ. Furthermore, the new MWD 8 study can only demonstrate that wire breaks are the most frequent disruption, but it cannot yet prove that this disruption causes the greatest loss of production time.

Several previous studies have shown differing results. [5] found that the primary losses in die-attach machines in the semiconductor industry stem from machines that stop briefly or remain idle even when production time is still available. The study also found that loose retaining screws pose a high risk of failure. Meanwhile, studies on NPK fertilizer machines [11] and press machines [7] indicate that production issues are not always caused by failures in components that come into direct contact with the material.

These differences arise because each machine has distinct operating mechanisms and types of malfunctions. The MWD 8 machine operates by continuously drawing copper wire through several dies to reduce the wire's diameter. If a component's surface is damaged, the wire's path is disrupted, or the wire is subjected to improper pressure, the risk of wire breakage may increase. Unlike die-attach or press machines, disruptions in the MWD 8 are more closely related to the wire-drawing process. However, this relationship remains a potential cause based on process conditions and interview results. This study has not yet been able to prove that damage to specific components directly causes wire breaks.

Previous research on blanking machines [9], die-attach machines [10], and the control of defective products using Fishbone and FMEA [15] has shown that these methods can help identify which issues need to be addressed first. This study uses the same approach but applies it specifically to examine the risk of component failure in Multiwire Drawing machines.

The contribution of this study lies in the identification of six types of component failures suspected of being related to wire breaks, as well as the prioritization of their maintenance. The FMEA results show that defective dies have the

highest RPN of 288, followed by clogged dryers and defective contact tubes, each with an RPN of 280. These three components remain high priority even if one of their FMEA rating values is increased or decreased by one point [6], [26].

Meanwhile, defective capstans have an RPN of 210 and can become medium priority if their rating value decreases. Conversely, a scratched polisher with an RPN of 180 could become a high priority if its rating increases. These results indicate that the maintenance sequence is not always fixed because it is influenced by risk assessment. Therefore, dies, dryers, and contact tubes require primary attention, while capstans and polishers must still be inspected periodically.

Strengths of the Research Findings and Their Benefits for The Company

The findings of this study are supported by production records and machine malfunction logs from April through June 2026. Company data show that the MWD 8 machine experienced 243 shutdowns, with 168 of these caused by wire breaks. The study also utilized monthly downtime data and FMEA assessments to determine component inspection priorities.

However, several limitations remain. Defective component conditions and copper dust buildup were listed as failure modes in the FMEA assessment, but complete inspection records are not yet available to confirm the relationship between these issues and wire break incidents. Additionally, the condition of the lubricant and the possibility of component damage triggering subsequent wire breaks are still based on interview information. Therefore, these causes still need to be verified through direct inspection and measurement.

OEE calculations also need to use the machine's ideal speed and the correct production units to ensure reliable results. Meanwhile, the Six Big Losses analysis should consider the duration of downtime for each cause, not just the number of occurrences. For example, a disruption that occurs ten times does not necessarily result in greater time loss than a disruption that occurs only twice but lasts longer.

Based on these findings, the company is advised to regularly inspect the dies, dryer, contact tube, and capstan; document the condition of the components; and establish a maintenance schedule based on the failure history. The company also needs to more thoroughly record component replacement times, the number of wire break incidents, and the duration of downtime.

After maintenance measures are implemented, the company can compare the machine's condition before and after the repairs. This comparison is made by examining the number of wire breaks per 100 operating hours, total downtime, the number of good products, and the correctly calculated OEE value. In this way, the company can determine whether the maintenance measures are truly effective in reducing disruptions and improving machine efficiency. Since the improvement recommendations from this study have not yet been implemented, their benefits in terms of OEE improvement still need to be demonstrated through further research.

CONCLUSION

A study of Multiwire Drawing (MWD) Machine showed that the machine experienced 243 stoppages with a total downtime of 245.78 hours and an availability rate of 84.50%. However, the OEE value could not yet be determined because the performance calculation still requires accurate data on the machine's ideal speed. The results of the Six Big Losses analysis indicate that wire breaks are the most frequent disruption, accounting for 168 incidents, or 69.14% of all stoppages. Nevertheless, the disruption causing the greatest loss of production time cannot yet be determined because the duration of each cause is not yet available. The Fishbone analysis suggests that wire breaks are likely related to machine component failure, maintenance practices, copper dust buildup, and lubricant condition; however, these causal relationships still need to be verified through direct inspection. The FMEA results identified four components as high priority: defective dies (RPN 288), clogged dryers (RPN 280), defective contact tubes (RPN 280), and defective capstans (RPN 210). Sensitivity analysis indicates that the dies, dryer, and contact tube remain high priorities even though their assessment values have changed slightly, whereas the capstan's priority is more variable. Based on these results, the recommended improvements include routine component inspections, component replacement before severe damage occurs, copper dust removal, lubricant monitoring, and improved downtime record-keeping. The contribution of this study is to provide a basis for more targeted maintenance prioritization to reduce the risk of wire breakage.

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CONFLICT OF INTEREST
The authors declare that they have no conflicts of interest related to this research.

DATA AVAILABILITY STATEMENT
The data supporting this study were obtained from production reports, machine downtime records, observations, and interviews conducted at PT. XYZ from April to June 2026. The company data are not publicly available due to their internal and confidential nature. Access to the data is subject to permission from PT. XYZ.

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DECLARATION OF AI TOOL USAGE
No AI tools were used for field observations, primary data collection, or the original FMEA assessments.

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