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Risk Analysis of Conveyor Material Handling in the Production Process of Crude Palm Oil and Palm Kernel Oil with FMECA and FTA Methods

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ABSTRACT: Oil palm is one type of plantation crop that occupies an important position in the agricultural sector and the plantation sector, and is a mainstay commodity of Indonesia whose development is very rapid. Good Material Handling is minimizing material handling costs, minimizing disruption or risk and delays in the production process. One of the companies engaged in the palm oil industry is PT. BSI which is a company engaged in the palm fruit processing industry. The products produced are crude palm oil (CPO), kernel, and fiber which implement a material handling system. However, the material handling process that is applied still experiences disturbances whose risks have an impact on the production process. So that researchers want to know the value of material handling risks that occur at PT.BSI with FMECA and FTA methods. The results of this study are at the risk identification stage using the FMECA method obtained six lists of risks that have an RPN value above 200 this is included in the very high and Unacceptable category. Then after further analysis using the FMECA method also that the six risks have decreased where the RPN value is less than 180 so that it is included in the high and tolerable categories. Then for the FTA analysis that the problem of these risks, namely conveyor trips and conveyor blockages, needs to be checked on a regularly scheduled conveyor leaf and implement a routine maintenance schedule and provide training to operators before carrying out work.

KEYWORDS: CPO; PKO; Material Handling; FMECA; FTA

1. INTRODUCTION

Palm oil or Crude Palm Oil (CPO) in the world has a vision to realize Indonesia using new renewable energy sources (fossil substitutes) as much as 25% by 2025 in the context of energy conservation and energy diversification (Mardawati et al., 2019). Based on Indonesian Palm Oil Statistics (2022), oil palm plantations cover 16,833,985 million hectares, Indonesia produces 46.82 million tons/year of palm oil and most of this palm oil production is exported and used to meet the need for domestic cooking oil. Based on data from the Central Statistics Agency (BPS) and the Indonesian Palm Oil Association (GAPKI), 2023, that the total production amounted to 253,347,000 million tons, consumption amounted to 86,977,000 million tons, exports amounted to 172,247,000 million tons of palm oil in Indonesia from 2018-2023. So from this data, it is found that the amount of demand (export + consumption) for palm oil in Indonesia is higher than the amount of production. Not to mention the stock that must be maintained to be able to meet the needs or demand and maintain the influence of inflation and rising prices (Vikaliana et al., 2020). This shows that the amount of palm oil production has not been able to meet the amount of demand each year because each year it continues to increase. This makes oil palm companies have to increase their production capacity and keep the production process running smoothly to meet this demand. One of the companies engaged in the palm oil industry is PT. BSI which is a company engaged in the palm fruit processing industry. The products produced are crude palm oil (CPO), kernel, and fiber.

Based on the results of preliminary observations, it is known that the capacity and amount of production are not in accordance with the required demand because the amount of crude palm oil production at PT.BSI is not met with the capacity and amount of production. This is because several sources of problems were found, which are related to material handling using conveyors that hinder the production process. Methods related to material handling, one of which is the General Analysis Procedure (GAP). According to Putra et all, 2015 in the book Factory Layout and Material Transfer. Third Edition. General Analysis Procedure is a systematic approach and is used to solve problems in material handling, and can help complex material transfer systems and lead to appropriate proposals. The method has been carried out by previous researchers, namely (Putra et al, 2015) where the research used the GAP method which aims to design a complex material handling transfer system so that the production process runs optimally. Then for those related to the production of CPO and PKO, a risk analysis that hinders the production process has also been carried out by (Kuncoro Dkk, 2018) which uses the FMECA and FTA methods which aim to identify and prevent the failure of a product so that the output of a production can be in accordance with the company's desired standards. So that this researcher wants to do a combination of methods that have been done in previous researchers so that the objectives of this study are achieved. But the purpose of using these methods in this study is to minimize the risk of material handling with conveyors so that there are no obstacles to the production process. The General Analysis Procedure consists of several stages, namely, definition, investigation, solution improvement, and installation. At the definition stage, the Failure Mode Effect Critical Analysis (FMECA) method is used which aims to determine the risk priority of improvements made and determine the Risk Priority Number (RPN) value then identify data requirements while collecting data, then at the investigation stage the Fault Tree Analysis (FTA) method is used which aims to identify risk problems and find the root cause of the problem, and at the solution improvement stage a continuous improvement method is used, namely PDCA (Plan Do Check Action) for continuous improvement solutions that will be carried out later. The hope of this research is that it can be a recommendation in steps to minimize the risk of material handling on the conveyor in the palm oil production process so that the company can carry out the production process in accordance with company expectations.

2. METHODS

This research was conducted at PT.BSI, Nunukan, North Kalimantan, Indonesia. This research was conducted for 40 working days. The data collection methods in this study are as follows:

a). Researchers made initial observations in the field to determine the material handling system that occurs at PT.BSI and determine the risk of material handling by calculating the RPN using the Failure Mode Effect Critical Analysis (FMECA) method.

b). After knowing the Risk Priority Number (RPN) value of material handling, then look for the root of the problem using the Fault Tree Analysis (FTA) method.

c). After knowing the root of the problem then provide improvement solutions or continuous improvement using Plan Do Check Action (PDCA).

3. RESULT AND DISCUSSION

Risk event table

Kegiatan	Kode	Kejadian Risiko
Loading ramp	R1	Telat memasukkan buah ke conveyor saat pengisian TBS ke conveyor
	R2	TBS yang diisi ke conveyor melebihi kapasitas produksi
	R3	Kapasitas pengisian conveyor yang tidak tercapai
	R4	Rusaknya roda conveyor
Stasiun Sterilizer	R5	Terjadi kebocoran pada body sterilizer
	R6	Pecahnya bearing pada trolly
	R7	Conveyor sering trip (mati)
Stasiun Tresher	R8	Kisi-kisi drum thresher sering patah
	R9	Rusaknya capstand untuk menarik conveyor
	R10	Tersumbatnya conveyor
	R11	Penuangan buah yang masuk ke drum thresher terlalu banyak
Stasiun Press	R12	Conveyor sering trip (mati)
	R13	Penyumbatan pada cut digester
	R14	Terjadi kebocoran body digester
Statisiun kernel	R15	Rusaknya mesin press
	R16	penyumbatan fiber di conveyor
	R17	conveyor sering trip (mati)

Based on the table, we can see that the risk of damage that occurs in material handling using conveyors at PT.BSI. After knowing this, the next FMECA analysis is to determine the Severity, Occurance, and Detection numbers by referring to the existing risk events summarized in one table and then sorted according to the largest RPN value. RPN itself is a value that states the priority of risk events. Risk Priority Number (RPN) is the result of multiplying the weight of Severity, Occurance and Detection. These results will be able to determine the critical components. RPN = Severity (S) x Occurance (O) x Detection (D) before and after. The value can be seen in the following table.

Kode	Severity	Occurance	Detection	RPN
R12	8	7	7	392
R17	8	7	7	392
R16	6	8	6	288
R10	6	7	6	252
R7	6	6	7	252
R13	6	6	6	216
R4	5	6	6	180
R5	4	4	6	96
R14	4	4	6	96
R15	3	4	6	72
R9	5	3	4	60
R8	4	3	5	60
R6	4	3	4	48
R11	3	3	4	36
R2	2	3	4	24
R3	2	4	3	24
R1	1	3	4	12

Based on the table, it is known that the current Severity, Occurance and Detection values based on the risks that occur at PT.BSI with this RPN value at PT.BSI can be found using the formula RPN = Severity (S) x Occurance (O) x Detection (D). The calculation of RPN as an example on R12

$$\text{RPN} = \text{severity} \times \text{Occurance} \times \text{Detection}$$
$$= 8 \times 7 \times 7$$
$$\text{RPN r12} = 392$$

Based on table 4.12, the RPN value and graph of the current R1-R17 risks based on the criteria value that there is one risk of RPN value of 180 and six risks that get RPN values above 200 so that further analysis or critical analysis needs to be carried out to find out which priority improvements will be made based on the occurrence of risks that occur then proceed with the FTA method.

Based on the results of the FMECA table that has been obtained, a risk matrix is then made. If it turns out that the risk is in the unacceptable zone, then the risk analysis must be carried out again until the risk obtained is acceptable. The way to reduce risk is to reduce the frequency of events or reduce the consequences of events and possibly reduce both. The following is the risk matrix which can be seen in table 4.14

Tabel 4.14 Matriks Risiko

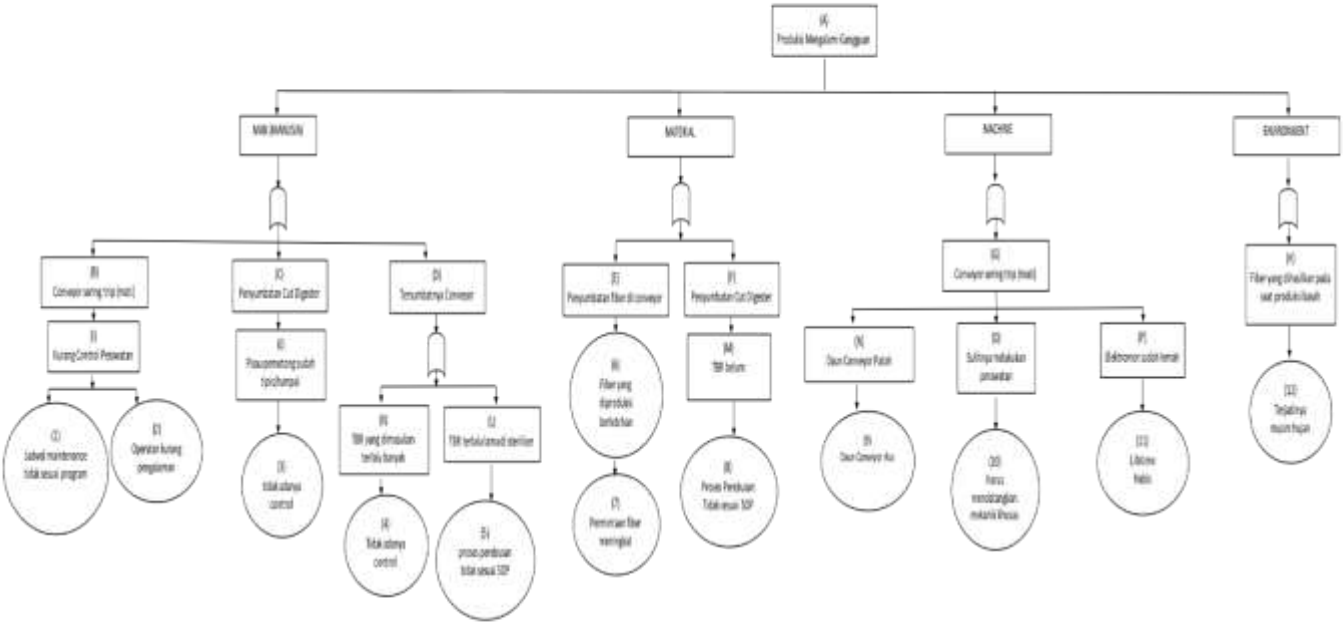
KETERANGAN	
(red)	*Major / Not Acceptable*
(yellow)	*Moderate / As Low as Reasonably Practicable*
(green)	*Minor / Acceptable*

Frekuensi \ Konsekuensi	1	2	3	4	5
5	R4,R5	R17, R12			
4		R14,R15	R16		
3			R8,R9	R7,R10	
2	R2,R3			R6	R13
1	R1				R11

Based on table 4.14 of the risk matrix, there are 3 risks with acceptable or minor/acceptable categories, then there are 8 risks that fall into the moderate/As low as reasonably practicable category or can still be reasonably accepted, and there are 6 risks that are not acceptable or Not acceptable with major categories, so further analysis needs to be done related to these 6 risks. In this case, the next step is to analyze system failures using FMECA. The FMECA Worksheet results are shown in table IV.15 as follows.

Failure Modes Efects Analysis				*Criticality Analysis*		
No	*Station*	*Function*	*Functional Failure*	RPN	*Criticality*	*Risk Category*
01.00	*Loading ramp*	Sebagai tempat penampungan TBS (Tandan Buah Segar) menuju ke station sterilizer untuk perebusan	*Rusaknya roda conveyor* sehingga proses distribusi ke station sterilizer terlambat	*180*	*High*	*Tolerable*
02.00	*Sterilizer*	Sebagai tempat perebusan TBS sebelum di distibusikan ke *station thereser* untuk proses pemisahan tandan dan biji sawit	*Conveyor* sering *trip* (mati) sehingga proses distribusi TBR (Tandan Buah Rebusan) terhenti sesaat.	*252*	*Very High*	*Unacceptable*
03.00	*Tresher*	Sebagai tempat pemisahan tandan dan biji sawit sebelum di distribusikan ke *station Press* untuk di proses di dalam digester akan diputar atau diaduk menggunakan menggunakan pisau pengaduk (stirring arm).	Tersumbatnya *conveyor* sehingga proses distribusi terhambat menuju ke *station press.*	*252*	*Very High*	*Unacceptable*
04.00	*Press*	Sebagai tempat pemisahan CPO dan PKO dengan proses digester dan menggunakan mesin screw press	*Conveyor* sering *trip (mati)* sehingga proses produksi terhenti sesaat	*392*	*Very Critical*	*Unacceptable*
05.00	*Press*	Sebagai tempat pemisahan CPO dan PKO dengan proses digester dan menggunakan mesin screw press sebelum menuju ke *station kernel*	*Penyumbatan pada cut digester sehingga proses pelumatan mengalami penurunan dan tidak maksimal*	*216*	*Very High*	*Unacceptable*
06.00	*Kernel*	Sebagai tempat pemisahan antara biji kernel dan fiber	*penyumbatan fiber di conveyor sehingga proses produksi terhenti sesaat dan distribusi fiber ke boiler terhenti*	*288*	*Critical*	*Unacceptable*
07.00	*Kernel*	Sebagai tempat pemisahan antara biji kernel *dan fiber* sebelum menuju ke *storage PKO*	*conveyor sering trip (mati) sehingga proses produksi terhenti sesaat*	*392*	*Very Critical*	*Unacceptable*

Through FMECA Worksheet, one high category risk event, three very high category risk events, one risk event as a critical component and two risk events as a very critical component in the material handling system with conveyors in the CPO and PKO production process. With this, it is necessary to carry out an investigation stage to find out the root cause of the problem using the Fault Tree Analysis (FTA) method, while the analysis can be seen in the following figure.



Based on Figure IV.9 on Fault Tree Analysis (FTA), the next step is to determine the minimum cut set as follows:

Top Level = Gate A

1. Minimal cut set Gate A
   Gate A will occur if Gate B, Gate C, Gate D, Gate E, Gate F and Gate G happen with this
   Gate A = [B+C+D+E+F+G+H]

2. Minimal cut set Gate B
   Gate B will occur if Gate I happen
   Gate B = [I]

3. Minimal cut set Gate C
   Gate C will occur if Gate J happen
   Gate C = [J]

4. Minimal cut set Gate D
   Gate D will occur if Gate K, and Gate L happen
   Gate D = [K+L]

5. Minimal cut set Gate E
   Gate E will occur if Gate 6, and Gate 7 happen
   Gate E = [6+7]

6. Minimal cut set Gate F
   Gate F will occur if Gate M happen
   Gate F = [M]

7. Minimal cut set Gate G
   Gate G will occur if Gate N, Gate O and Gate P happen
   Gate G = [N+O+P]

8. Minimal cut set Gate H
   Gate H will occur if Gate 12 happen
   Gate H = [12]

9. Minimal cut set Gate I

Gate I will occur if Gate 1, and Gate 2 happen
Gate I = [1+2]

10. Minimal cut set Gate J
Gate J will occur if Gate 3 happen
Gate J = [3]

11. Minimal cut set Gate K
Gate K will occur if Gate 4 happen
Gate K = [4]

12. Minimal cut set Gate L
Gate L will occur if Gate 5 happen
Gate L = [5]

13. Minimal cut set Gate M
Gate M will occur if Gate 8 happen
Gate M = [8]

14. Minimal cut set Gate N
Gate N will occur if Gate 9 happen
Gate N = [9]

15. Minimal cut set Gate O
Gate O will occur if Gate 10 happen
Gate O = [10]

16. Minimal cut set Gate P
Gate P will occur if Gate 11 happen
Gate P = [11]

Based on the determination of the minimum cut set, it is known that Production Disruption in material handling with conveyors will occur if:

1. Maintenance schedule is not in accordance with the program
2. Operators lack experience
3. No control
4. Absence of control
5. Boiling process is not according to SOP
6. Overproduced fiber
7. Demand for fiber is increasing
8. Boiling process is not according to SOP
9. Conveyor leaf worn
10. Must bring in specialized mechanics
11. Lifetime Expired

Table Plan Do Check Action (PDCA)

<table>
<tr><th colspan="2">PLAN</th></tr>
<tr><td>Permasalahan
• Conveyor sering trip (mati)</td><td>Target Perbaikan
• Meminimalisir terjadinya conveyor trip (mati)</td></tr>
<tr><td>Penyebab Permasalahan
• conveyor patah dimana akar masalahnya adalah daun conveyor aus
• kurangnya control perawatan dimana akar masalahnya adalah tidak adanya jadwal rutin perawatan dan operator kurang pengalaman
• kemudian electromotor sudah lemah yang akar masalahnya adalah lifetime habis</td><td>Solusi Permasalahan
• Melakukan pengecekan daun conveyor yang telah dijadwalkan secara rutin
• melakukan jadwal rutin maintenance dan memberikan pelatihan kepada operator sebelum melakukan pekerjaan</td></tr>
<tr><th colspan="2">DO</th></tr>
<tr><td colspan="2">Implementasi
• Mengimplementasikan solusi permasalahan dan melakukan jadwal maintenance sesuai yang telah ditetapkan serta format dibuat lebih mudah agar bisa dipahami</td></tr>
<tr><th colspan="2">CHECK</th></tr>
<tr><td colspan="2">Pengecekan
• Setiap anggota departemen maintenance harus saling berkomunikasi untuk melakukan pengecekan agar sesuai dengan rencana maintenance.
• Melakukan evaluasi terkait proses kerja, apakah telah sesuai dengan Rencana kerja dan syarat-syarat untuk mencapai target yang diinginkan.
• Melakukan pengawasan setiap pekerjaan maintenance berlangsung dan sesudah.</td></tr>
<tr><th colspan="2">ACTION</th></tr>
<tr><td colspan="2">Tindak Lanjut
• Harus konsisten dalam melakukan jadwal maintenance dan pelatihan operator serta pelaksanaan, pengawasan dan menerapkan sumber daya manusia yang baik agar meminimalisir terjadinya conveyor trip.
• Jika pekerja tidak melakukan sesuai dengan yang disarankan maka manager bisa untuk melakukan SP (surat peringatan).</td></tr>
</table>

<table>
<tr><th colspan="2">PLAN</th></tr>
<tr><td>Permasalahan
• Tersumbatnya Conveyor</td><td>Target Perbaikan
• Meminimalisir terjadiya penyumbatan conveyor</td></tr>
<tr><td>Penyebab Permasalahan
• Fiber yang dihasilkan pada saat produksi basah akar masalahnya adalah terjadinya musim hujan
• Fiber yang di produksi berlebihan akar masalahnya adalah permintaan fiber meningkat
• TBR yang dimasukan terlalu banyak akar masalahnya tidak adanya control
• TBR terlalu lama di sterilizer akar masalahnya proses perebusan tidak sesuai SOP</td><td>Solusi Permasalahan
• Memberikan pelindung air hujan di stasiun yang terkena air hujan
• Melakukan peramalan permintaan fiber agar bisa terpenuhi permintaan konsumen dengan baik
• Melakukan control setiap memasukan TBR
• Operator harus mengikuti SOP yang telah dibuat</td></tr>
<tr><th colspan="2">DO</th></tr>
<tr><td colspan="2">Implementasi
• Mengimplementasikan solusi permasalahan dan menjalani SOP produksi sesuai yang telah ditetapkan perusahaan kemudian dibuat lebih mudah agar bisa dipahami</td></tr>
<tr><th colspan="2">CHECK</th></tr>
<tr><td colspan="2">Pengecekan
• Setiap anggota dan kepala departemen produksi harus saling berkomunikasi untuk melakukan control agar sesuai dengan SOP produksi.
• Kepala departemen melakukan pengawasan setiap pekerjaan produksi berlangsung dan sesudah.</td></tr>
<tr><th colspan="2">ACTION</th></tr>
<tr><td colspan="2">Tindak Lanjut
• Harus konsisten dalam melakukan SOP, pengawasan dan menerapkan sumber daya manusia yang baik agar meminimalisir terjadinya penyumbatan conveyor.
• Jika Operator produksi tidak melakukan sesuai SOP dengan yang disarankan maka kepala departemen atau manager bisa untuk melakukan SP (surat peringatan).</td></tr>
</table>

After conducting further analysis with FMECA analysis, FTA and Implementing PDCA that the RPN value after control can be seen in table 4.14. This is based on the events after the PDCA process is carried out at the station which is the source of risk with an RPN value above 200. The form of control is as follows.

1. Conveyors often trip or die
   After knowing that the solution to the problem of conveyor trips or death is to schedule the process of controlling and checking the conveyor leaves in the maintenance department and providing training to operators before doing the following work is its implementation.

Figure 4.10 Providing direction and training prior to work

Figure 4.11 Creation of conveyor check monitoring in the Maintenance department

2. Clogged conveyor
After conducting PDCA analysis, it is known that the solution to the problem of clogged conveyors at the kernel plant station is to eliminate conveyor fiber no. 1 with a note to add body conveyor fiber no. 2 The following is the form of adding conveyor fiber no. 2 and eliminating conveyor fiber no. 1

Figure 4.12 Conveyor fiber before control Figure 4.13 Conveyor fiber after control

Then at the sterilizer station to the thereser station it is known that the solution to the problem is to control when entering TBR and do or follow the SOP that has been made The following is an example of a Standard Operational Work (SOP) on a sterilizer machine that has been made to be considered by the operator.

Figure 4.13 Example SOP

After carrying out several implementations in the previous PDCA analysis with this station, the critical place for the risk has decreased, while the RPN table after the decrease can be seen in tables 4.16 to 4.18 below.

Table 4.16 Severity assessment after

No Risk	Risk Event	Severity									
		1	2	3	4	5	6	7	8	9	10
R1	Telat memasukkan buah ke conveyor saat pengisian TBS ke conveyor	√									
R2	TBS yang diisi ke conveyor melebihi kapasitas produksi		√								
R3	Kapasitas pengisian conveyor yang tidak tercapai		√								
R4	Rusaknya roda conveyor					√					
R5	Terjadi kebocoran pada body sterilizer				√						
R6	Pecahnya bearing pada trolly				√						
R7	Conveyor sering trip (mati)					√					
R8	Kisi-kisi drum thresher sering patah				√						
R9	Rusaknya capstand untuk menarik conveyor					√					
R10	Tersumbatnya conveyor				√						
R11	Penuangan buah yang masuk ke drum thresher terlalu banyak			√							
R12	Conveyor sering trip (mati)						√				
R13	Penyumbatan pada cut digester				√						
R14	Terjadi kebocoran body digester				√						
R15	Rusaknya mesin press			√							
R16	penyumbatan fiber di conveyor				√						
R17	conveyor sering trip (mati)						√				

Source: data processing

Table 4. 17 Occurance assessment after

No Risk	Risk Event	Occurance									
		1	2	3	4	5	6	7	8	9	10
R1	Telat memasukkan buah ke conveyor saat pengisian TBS ke conveyor			√							
R2	TBS yang diisi ke conveyor melebihi kapasitas produksi			√							
R3	Kapasitas pengisian conveyor yang tidak tercapai				√						
R4	Rusaknya roda conveyor						√				
R5	Terjadi kebocoran pada body sterilizer				√						
R6	Pecahnya bearing pada trolly			√							
R7	Conveyor sering trip (mati)				√						
R8	Kisi-kisi drum thresher sering patah			√							
R9	Rusaknya capstand untuk menarik conveyor			√							
R10	Tersumbatnya conveyor					√					
R11	Penuangan buah yang masuk ke drum thresher terlalu banyak			√							
R12	Conveyor sering trip (mati)				√						
R13	Penyumbatan pada cut digester				√						
R14	Terjadi kebocoran body digester				√						
R15	Rusaknya mesin press				√						
R16	penyumbatan fiber di conveyor						√				
R17	conveyor sering trip (mati)				√						

Source: Data processing

Table 4. 18 Detection assessment after

No Risk	Risk Event	Detection									
		1	2	3	4	5	6	7	8	9	10
R1	Telat memasukkan buah ke conveyor saat pengisian TBS ke conveyor				√						
R2	TBS yang diisi ke conveyor melebihi kapasitas produksi				√						
R3	Kapasitas pengisian conveyor yang tidak tercapai			√							
R4	Rusaknya roda conveyor						√				
R5	Terjadi kebocoran pada body sterilizer				√						
R6	Pecahnya bearing pada trolly			√							
R7	Conveyor sering trip (mati)						√				
R8	Kisi-kisi drum thresher sering patah			√							
R9	Rusaknya capstand untuk menarik conveyor			√							
R10	Tersumbatnya conveyor					√					
R11	Penuangan buah yang masuk ke drum thresher terlalu banyak			√							
R12	Conveyor sering trip (mati)						√				
R13	Penyumbatan pada cut digester					√					
R14	Terjadi kebocoran body digester				√						
R15	Rusaknya mesin press				√						
R16	penyumbatan fiber di conveyor						√				
R17	conveyor sering trip (mati)						√				

Source: Data processing

The focus of researchers is on risks R12, R17, R16, R10, R7, R13 as for the RPN value can be seen in table 4.19.

Table 4. 19 RPN value after controlling 6 risks

Kode	Severity	Occurance	Detection	RPN
R12	6	4	6	144
R17	6	4	6	144
R16	4	6	6	144
R10	4	5	6	120
R7	5	4	6	120
R13	4	4	6	96

Source: Data processing

Based on table 4.19 that the RPN value after control for the risks that are the focus of researchers has decreased, this is based on the risk criteria that there are six risks that get an RPN value of less than 180 which are included in the high and tolerable categories, this is obtained based on the implementation of an improvement solution in the Plan DO Check Action (PDCA) method.

4. CONCLUSION

The risk identification stage using the FMECA method obtained six lists of risks that have RPN values above 200 which are included in the very high and Unacceptable categories. This is obtained from the calculation of the multiplication of severity, occurance and detection. Then after further analysis using the FMECA method, the six risks have decreased where the RPN value is less than 180 so that it is included in the high and tolerable categories. Then for the FTA analysis that the problem of these risks, namely conveyor trips and conveyor blockages, needs to be checked on a regularly scheduled conveyor leaf and implement a routine maintenance schedule and provide training to operators before carrying out work. PT. BSI should pay more attention to material handling, especially on conveyors, this is because the palm oil production process is continuous or continuous so that the risk of obstructing the production process is very high and communication between department lines is carried out continuously (Simultaneous Operation) in order to avoid the risk of work. For further research, it can conduct a more in-depth analysis related to the palm oil production process and the risk of material handling not only on the conveyor.

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