Thermo Valve Air Compressor Maintenance and Repair Using the Overall Equipment Effectiveness (OEE) Method in Maintenance

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Abstract: Production activities carried out every day can interfere with the effectiveness of the machine, one of which is the compressor, so that sometimes problems in the field are still often encountered, such as the piston drive motor not rotating, the compressor does not turn on and off automatically, corrosion (rust), melted capacitors, and many more. things that can happen beyond the operator's control. Due to these constraints, the authors decided to find out more and made direct observations at PT. INKA Multi Solusi Service, as well as studying good and proper machine maintenance so that the company's productivity does not experience a significant decrease. The research was conducted by direct observation and direct interviews with the maintenance department to find out the steps that are usually taken in solving problems. To determine the value of machine effectiveness based on the measurement of three main ratios, namely: availability, performance efficiency, and rate of quality, is carried out using the Overall Equipment Effectiveness (OEE) method. The conclusion that can be drawn from this study is that maintenance on the Ingersoll Rand MM160 type screw air compressor is carried out to maintain the condition of the compressor in a ready state for use in measuring the level of machine effectiveness using the Overall Equipment Effectiveness (OEE) method at PT. IMSS, starting from May – July 2022, where the highest percentage in May 2022 is 94% and the lowest in June 2022 with a percentage is 90%.

Keywords: Compressor, Effectiveness, OEE, Piston

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Introduction

PT. INKA Multi Solusi Service is a subsidiary of PT. INKA (Persero) provides "Total Solution Provider" services in the construction and trade of railway components/spare parts and land transportation products. As a manufacturing company committed to producing the best and highest quality products (Li et al., 2022). Efforts to realize high-quality products and company productivity require periodic machine maintenance, especially repairs to the compressor to extend the life of each component so that it can function properly. The screw compressor is a type of positive displacement compressor classified as a rotary compressor. This compressor compresses (adds energy) the air or gas by rotating simultaneously due to the rotor teeth or gear rotating in the opposite direction and interrelated (Baniasadi et al., 2021; Lim et al., 2020). One of the rotors has a convex groove (male rotor) and the other has a concave groove (female rotor) that interlocks each other, the two rotors are supported at both ends by bearings, one end of which gives an axial bear to resist the axial force arising from the difference in air pressure acting on the two ends of the rotor. It is this synchronous and counter clockwise rotation that moves and exerts pressure on the air along the rotor groove from the inlet to the outlet PT. INKA, compressors are included in production support machines that supply air to pneumatic hoses and production machines have work systems using pneumatics. There are two types of compressors at PT. INKA is called piston compressors and screw compressors, but the existing piston compressors are no longer operational due to high operational costs. There are many brands and types of compressors at PT. INKA, one of them is the Ingersoll Rand type MM160 compressor (Kalairaj et al., 2020).

Procedure of Ingersoll Rand MM160 Compressor

Air compressor brand Ingersoll Rand type air screw compressor type MM160 uses two rotating screws in a screw chamber called the air end. The rotation of the two screw components will cause suction on the intake valve and produce compressed air at the outlet (discharge). Then the compressed air enters the tank separator, which functions are separated oil and air so that the resulting compressed air does not contain oil. The working principle of this tank separator is that in the middle of the tube there is a foam separator, a type of foam that will pass air particles and catch oil particles and then drop the oil to the bottom of the tube. Oil-free air has a fairly high temperature (80-90 °C), so it must pass through a cooler, before being expelled through the air exhaust to enter the external system (Fink & Schlüchtermann, 2018; Jhwueng, 2020).

High-temperature oil that collects at the bottom of the separator tube moves to the air filter housing unit. This unit consists of an oil filter which functions to separate impurities and a manifold unit which functions to regulate oil distribution to and from the air cooler (Wu et al., 2023). The oil that has passed through the cooler and the temperature has dropped, returns to the Oil Filter Housing Unit, to be redistributed to the air end or screw chamber. Another system that is no less important is the lubrication of the screw bearings. The Air Filter Housing Unit also supplies oil to lubricate the screw bearings. This system has a very big influence on Over Heating or Over Temperature on the Screw Air Compressor (Cui et al., 2022). The compressor system temperature is detected from the oil temperature. In the separator tank, a temperature sensor/thermostat is installed which will read the oil temperature and send this data directly to the Electronic Processing Unit. Normal working temperature is in the range of 85-95°C. If it's over 100°C, the system keeps running with a warning. Usually, the system is set to automatically shut down at 110°C.

Overall Equipment Effectiveness (OEE) method

Overall Equipment Effectiveness (OEE) is a method that can be used to measure machine effectiveness based on the measurement of three main ratios, namely: availability, performance efficiency, and rate of quality (Antônio Mendonça et al., 2022; Ginste et al., 2022). By knowing the value of the effectiveness of the machine, it can be seen how much the loss affects the effectiveness of the machine known as the six big losses of equipment. Production activities that are carried out every day can interfere with the effectiveness of the compressor so that sometimes problems in the field are still often encountered such as the piston drive motor not rotating, the compressor does not turn on and off automatically, corrosion (rust), melted capacitors, and many other things that can happen beyond the operator's control. Due to these constraints, the authors decided to find out more and made direct observations at PT. INKA Multi Solusi Service, as well as studying good and proper machine maintenance so that the company's productivity does not experience a significant decrease (Antônio Mendonça et al., 2022).

Research Method

The research will begin with conducting a preliminary study to make observations on the problem of the engine maintenance process on the compressor section and conclude the method that will be used to solve the problem. Furthermore, a literature study is carried out to study the theories needed to achieve the objectives of the research (Dobra & Jósvai, 2021;

Klimecka-Tatar & Ingaldi, 2022). After that, the identification of data needs is carried out when conducting research. Data collection was carried out by field surveys to obtain the value of the effectiveness of the compressor engine at PT INKA, and direct interviews with the maintenance department to find out the steps that are usually taken in solving problems. To determine the value of machine effectiveness based on the measurement of three main ratios, namely: availability, performance efficiency, and rate of quality, is carried out using the Overall Equipment Effectiveness (OEE) method (Hung et al., 2022).

Maintenance System

Compressor maintenance is carried out to keep the equipment in reliable condition. Before carrying out repairs, you should do the following:

a. Read the Safety Instructions
b. Use the appropriate tool
c. Use recommended spare parts

The other maintenance objectives are:

a) Prevent disruption of the production process due to damage.
b) So that the condition of the compressor does not quickly decline.
c) Knowing the damage as early as possible.
d) Prevent further damage.

The machine maintenance system carried out by PT. INKA is divided into 3 types, namely:

1. Preventive Maintenance is maintenance carried out on machines at PT. INKA regularly and planned, such as:

   a) Daily Period

   - Visual inspection of engine for any leaks, dust, noise/vibration
   - Check coolant level and top up if needed
   - Check the pressure ratio
   - Check for oil leaks

   b) First 1-week period:

   - Check coolant filters
   - Check the lubricating oil level
   - Check the air filter

c) 1-month period

- Check the operation of the flow rate temperature sensor (default 190 °C) the sensor will sound at 106 °C
- Check the operation of the high temperature protection button (default 190 °C)
- Check the cooler box and clean it if the water overflows

d) Period of 3 months

- Operate the safety valve manually to check that the valve mechanism is functioning properly and has released the air inside
- Inspect all compressor body for signs of damage, cracks, etc.

e) Period of 6 months

- Replacing the cooled filter
- Take coolant samples to analyse fluids
- Check the operation of the solenoid valves for signs of damage
- Lubricate the main bearings of the motor according to the information on the motor data plate

f) Period of 1 year

- In the separator tank, check the entire surface, weld joints and report if there is corrosion, damage, leakage, which might hinder the work of the separator mechanically
- Immediately replace the air filter element if the indicator light flashes
- Replacing the starter motor contactor

g) 2-year period

- Replacing ultra-coolant
- Replacing the reparatory element and coolant filter

2. Break Down is a repair due to sudden damage to the machine. This maintenance is based on a maintenance / repair request letter (SPR) that is entered in the administration of the maintenance department.
3. Overhaul is maintenance of the machine as a whole, completely disassembled. This treatment is carried out regularly at intervals of four years, namely:

a) Replace all components

b) For separator tanks, clean the inside thoroughly and check all internal surfaces and welded joints.

Damage to the Ingersoll Rand MM160 Compressor

The thermostatic Valve is a spare part that works to open and close the valve (valve) which is controlled by the oil temperature (compressor). When the temperature reaches above 70 (~75) and below 70(~75) degrees, the valve closes so that the oil is directly filtered by the oil filter so that it goes directly into the air end. The way to find out is to measure the temperature (using a tool like a shot used to measure temperature/infra shot) of oil in the pipe from the Thermo valve to the oil filter (towards the air end), the oil from the radiator to the Thermo valve, and the oil from the Thermo valve to the radiator (Picture schematic diagram flow). If it is found that the temperature from the cooler to the air end (after going through the thermostatic valve and the temperature from the oil tank (after going through the Thermo valve) to the air end is random (not the same), then it is certain that this valve is BROKEN. Therefore, repairs must be carried out by paying attention to the oil flow as which is shown in Figure 1 (Muñoz-Villamizar et al., 2018; Suryaprakash et al., 2021).

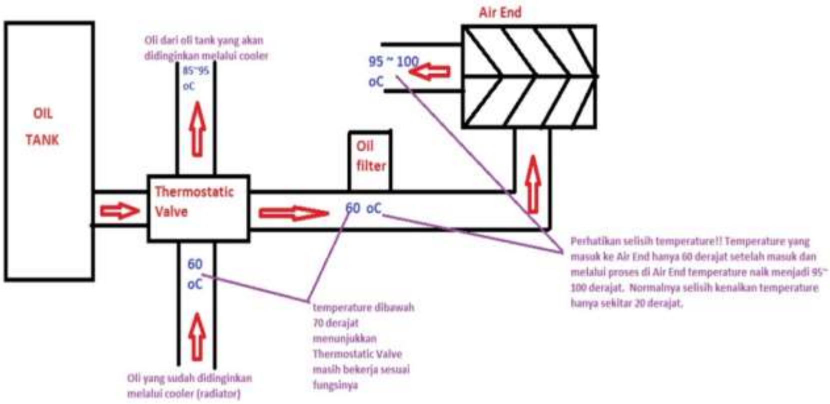

Figure 1 Oil Flow in Thermostatic Valve

Result and Discussion

Gas Production Result Data

Below is the production data at PT. INKA presented in Table 1 and the amount of scrap and rework:

Table 1 Gas Production Result Data for May-July 2022

Month	Total product	Total scrap	Total rework
May	32,8	0	0
June	34,6	0	0
July	33,4	0	0

Working Hours and Machine Delay Data

From the results of observations on the MM160 series Screw Air Compressor machine in the compressor building, the factors that cause delays on the machines are:

1. Schedule Downtime is a planned downtime, which is the time when the machine cannot carry out the production process due to a plane stop of the machine so that it does not produce for a while. Such as the implementation of PM (Preventive Maintenance).
2. Unscheduled Downtime is unplanned downtime, meaning that the machine cannot carry out the production process due to sudden machine damage. Such as damaged spare parts on the machine.

Table 2 Working Hours and Machine Delay Data May – July 2022

Month	Total working hours (hours)	Schedule ddowntime (hours)	Unscheduled ddowntime (hours)	Total Delay (hours)
May	324	15	-	15
June	378	21	13	34
July	378	25	-	25

Data Processing

Determination of Availability Ratio

Availability is the ratio of the operation time to the loading time. To calculate the Availability value, an Equation is used 1. Before calculating the Availability value, you must first know the values of the Loading Time, Operation Time, and Downtime.

Table 3 Engine Breakdown Data May – July 2022

No	Month	Breakdown
1	May	7
2	June	11
3	July	8
Total		26

Table 4 Planned Downtime Data May – July 2022

No	Month	Planned Downtime
1	May	15
2	June	21
3	July	25
Total		61

Table 1 Machine Set Up Data May – July 2022

No	Month	Machine Set Up
1	May	6
2	June	9
3	July	7
Total		22

May

$$Av = \frac{\text{Operating time}}{\text{Loading time}} \text{ x } 100\%$$

$$\begin{aligned} Lt &= Av - Pd \\ &= 324 \text{ hours} - 15 \text{ hours} = 309 \\ &= 309 \text{ hours} \\ \text{Downtime} &= \text{Breakdown} + \text{set up} \\ &= 7 \text{ hours} + 6 \text{ hours} \\ &= 13 \text{ hours} \\ Ot &= Lt - \text{Downtime} \\ &= 309 \text{ hours} - 13 \text{ hours} \\ &= 296 \text{ hours} \end{aligned} \tag{1}$$

$$Av = \frac{296}{309} \text{ x } 100\% = 95{,}79\%$$

Table 2 Calculation of the Availability Ratio for May-July 2022

Month	Loading Time (Hours)	Total Downtime (Hours)	Operation Time (Hours)	Availability Ratio (%)
May	309	13	296	95
June	357	20	337	94
July	353	15	338	95

Calculation of Performance Efficiency (Pe)

The calculation of performance efficiency begins with the calculation of the ideal cycle time. The ideal cycle time is the process cycle time expected to be achieved in optimal conditions or without experiencing obstacles. To calculate the ideal cycle time, it is necessary to pay attention to the percentage of working hours to the delay where to calculate the percentage of working hours we use Eq. 2:

$$\text{Percentage of working hours} = 1 - \frac{\text{Total Delay}}{\text{Available Time}} \times 100\% \tag{2}$$

May

$$\text{Percentage of working hours} = 1 - \frac{15}{324} \times 100\% = 95{,}37\%$$

Table 3 Percentage calculation of working hours 2022

Month	Available Time	Total Delay	Percentage of working hours
May	324	15	95%
June	378	34	91%
July	378	25	93%

Below is the equation used to calculate the cycle time, Eq.3.

$$\text{Cycle time} = \frac{\text{Loading Time}}{\text{Production Result}} \tag{3}$$

May

$$\text{Cycle time} = \frac{309}{32{,}8} = 9{,}42 \text{ hours}/\text{mmscf}$$

After obtaining the percentage value of working hours and cycle time, the ideal cycle time calculated using the formula 4:

$$\text{Ict} = \text{Cycle time x Percentage of working hours} \tag{4}$$

May

$$\text{Ict} = 9{,}42 \times 95\% = 8{,}94 \text{ hours}/\text{mmscf}$$

Table 4 Calculation of the Ideal Cycle Time for May-July 2022

Month	Gas Production	Loading Time	Ideal Cycle Time
May	32,8	309	8,94
June	34.6	357	9,38
July	33.4	353	9,82

After obtaining the Ideal Cycle value, then the value of the performance efficiency can be calculated using Eq. 5.

$$\text{Pe} = \frac{(\text{Pa x Ict})}{\text{Ot}} \times 100\% \tag{5}$$

May

$$\text{Pe} = \frac{(32{,}8 \times 8{,}94)}{296} \times 100\% = 99\%$$

Table 5 Calculation of Performance Efficiency for May – July 2022

Month	Gas Production	Ideal Cycle Time	Operation Time	Performance Efficiency (%)
May	32,8	8,94	296	99
June	34,6	9,38	337	96
July	33,4	9.82	338	97

Calculation of Rate of Quality Product (RQ)

The rate of quality product is a ratio that describes the ability of the equipment to produce products according to standards. To calculate the rate of quality product using Eq. 6:

$$RQ = \frac{(Pa - Da)}{Pa} \text{ x } 100\% \tag{6}$$

May

$$RQ = \frac{(32{,}8 - 0)}{32{,}8} \text{ x } 100\% = 100\%$$

Table 6 Calculation of Rate of Quality Product in May – July 2022

Month	Gross Product (Mmscf)	Total Broke (Mmscf)	Rate Of Quality Product (%)
May	32,8	0	100
June	34,6	0	100
July	33,4	0	100

Calculation of Overall Equipment Effectiveness (OEE)

Table 12 Calculation of the Rate of Quality Product in May – July 2022 To find the effectiveness of the machine/equipment as a whole, you must first know/obtain the Availability, Performance Efficiency, and Rate of Quality Product values. The OEE value calculated using Eq.7:

$$OEE = Av \text{ x } Pe \text{ x } RQ \text{ x } 100\ \% \tag{7}$$

$$May \rightarrow OEE = 0{,}95 \text{ x } 0{,}99 \text{ x } 1{,}0 \text{ x } 100\% = 94\ \%$$

Table 7 OEE Calculation Results in May – July 2022

Month	Availability	Performance Efficiency	Rate Of Quality Product	OEE (%)
May	0.95	0.99	1.0	94
June	0.94	0.96	1.0	90
July	0,95	0.97	1.0	92

Overall Equipment Effectiveness (OEE) Calculation Analysis

Overall Equipment Effectiveness (OEE) Calculation Analysis at PT. The IMSS is carried out to see the level of effectiveness in the use of compressor engines from May until July 2022. This Overall Equipment Effectiveness (OEE) measurement is the multiplication of Availability Ratio, Performance Efficiency, and Rate of Quality Product.

1. During the period May - July, the Overall Equipment Effectiveness (OEE) value was obtained, which was between 90% - 94%. Where are the results of the human work method, raw materials, work environment, machine/equipment breakdown losses, performance efficiency ranging from 96% - 99%, availability results between 94% -95%, and results from the rate of quality product between 0-100%.
2. The highest OEE value occurred in May, which was 94%, this was due to the high-Performance Efficiency ratio of 95%, 99% Availability, and 100% Rate of Quality Product.
3. The lowest OEE value occurred in June, which was 90%, occurred due to the low ratio of Performance Efficiency, Availability, and Rate of Quality Product. Due to damage to the thermostatic valve compressor.

Conclusions

The Ingersoll Rand MM160 type screw air compressor uses two rotating screws to produce compressed air. The main components of the Ingersoll Rand MM160 compressor consist of: (a) Components for air, (b) Lubrication components, (c) Monitor. The operation of an Ingersoll Rand compressor consists of several stages, namely: (a) Preparation before start-up, (b) Inspection during compressor operation, (c) Compressor when it will shut down. Maintenance of the Ingersoll Rand MM160 type screw air compressor is carried out to maintain the condition of the compressor in a ready state for use in measuring the level of machine effectiveness using the Overall Equipment Effectiveness (OEE) method at PT. IMSS starts from May - July 2022, the highest percentage in May 2022 at 94% and the lowest in June 2022 with 90% percentage. Measuring the level of machine effectiveness using the Overall Equipment Effectiveness (OEE) method at PT. IMSS is starts from May – July 2022, where the highest percentage is in May 2022 at 94%, and the lowest is in June 2022 with 90% percentage.

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