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A Study of Air System Performance On EMU KTM Class 83

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Abstract: The air system plays a crucial role in ensuring the safe and efficient operation of the train by facilitating various functions, including brake pipe system, pantograph system, door system, suspension system and more. However, instances of failure in the air system can result in significant disruptions to train services and pose potential safety risks to passengers. This research analyse the Electric Multiple Unit (EMU) air system failure and recommends suggestion to optimise train performance. This research examines failure analysis of air system with 20 set of EMU train from 2020 to 2022 at EMU Sentul Depot. Damage to the train air system can compromise infrastructure safety and longevity. From the data failures that has been analyse, the result showed that the main reservoir dropped had the highest failure rate. The research found that improving EMU component quality before operation, identifying important train system maintenance components, and optimising the train maintenance cycle can reduce failure severity.

Keywords: Air System, Failure Analysis, EMU Train

1. Introduction

KTMB that formerly known as Malayan Railway, was established in 1885. They have expanded its service offerings to include commuter, intercity, cargo, and DMU services. KTM Commuter, is a popular Malaysian commuter train brand, began in 1995 with the first-ever electric rail service between Kuala Lumpur and Rawang. Over time, the service expanded to 153 route kilometers on an electrified double track connecting Rawang to Seremban, Sentul, and Port Klang [1]. The fleet has three EMU types: 3-car coach train with 81, 82, and 83 classes, and a 6-car coach train with 91, 92, and 93 classes [2]. The research focuses on the EMU 83 class.

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This research focusing on the failure in air system. It is aims to identify the factors that contribute to and result in air system failures for the EMU train. The study was conducted analysing data on 20 sets of EMU trains experiencing failures from 2020 to 2022. The purpose of the study is to analyze the failures that occur in the air system of EMU train class 83 and to produce the method to decrease failures in the air system of EMU train.

Air system failures in EMU trains can cause significant operational interruptions, safety issues, and financial consequences for train operators. These malfunctions affect critical functions like brakes, pressure drop, and door operations, causing service delays, passenger discomfort, and higher maintenance expenses. To improve air system reliability and performance, it is crucial to examine the fundamental causes, identify prevalent failure modes, analyze implications, and develop effective mitigation techniques.

A possible area of research is the investigation of the various air system failures that occur in EMU trains, including their types and frequency. This involves identifying the particular components or subsystems that are most prone to failure, such as valves, hoses, reservoirs, and air dryers. By analysing these failures, researchers can develop effective prevention and mitigation strategies. The goal is to develop effective maintenance approaches that reduce failure risk while increasing system reliability. This includes evaluating the use of data analytics and predictive maintenance methods to detect potential problems. These solutions enable preventive maintenance and reduce the possibility of unexpected failures.

1.1 Flow of air system in EMU train

The air system flow in an EMU train shown in Figure 1. It refers to the circulation of compressed air within the air system of the train. The air system is in control variety of operations, such as braking, door operation, suspension, and other pneumatic controls. Figure 1 depicts the air flow in an EMU train.

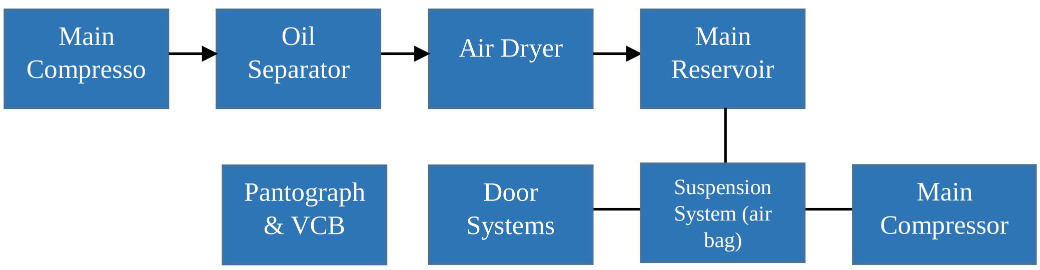


Figure 1: Air system flow in EMU train

1.2 Principle of pneumatic system in train operation

Pneumatic system of EMU train is a system that utilize compressed air to power. It refers to the use of compressed air to operate various functions within the train. Figure 2 displays a typical pneumatic system arrangement, which shares important elements with a hydraulic system [3]. The main difference between the two is the method of energy transfer is hydraulic systems utilise pumps to supply mechanical energy to oil, whereas pneumatic systems use compressors to provide mechanical energy to air. Furthermore, a hydraulic system frequently operates at extremely high pressures in order to transmit huge amounts of force and power, whereas a pneumatic system normally operates at low pressures of 5 - 7 bar for industrial applications.

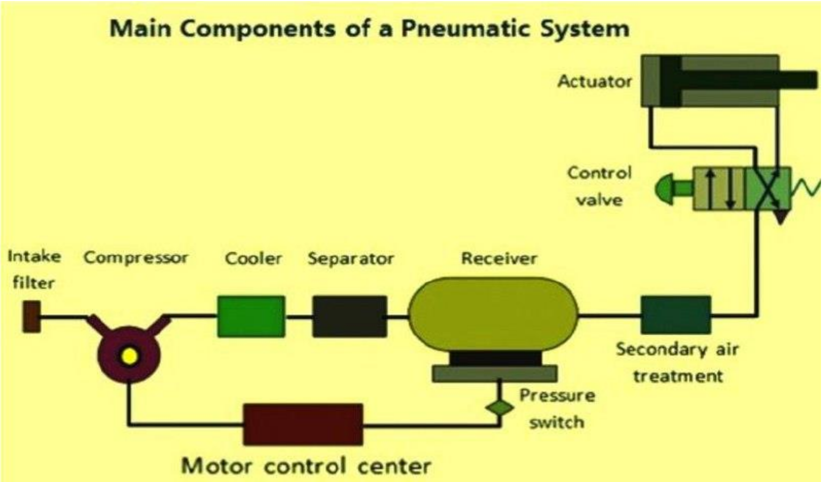


Figure 2: Component of pneumatic system

The pneumatic system is used in train the control of various functions such as the pantograph, internal and external doors, horn, suspension system, brake system and more [4]. The train's air system is produced by compressor, specifically a main compressor unit. This compressed air production system provides air to the brake system, wheel flange lubrication system, sound signals, and electric pneumatic devices such as contactors, pantographs, and reversers. According to the EMU Manual, the primary compressor responsible for generating compressed air at a pressure of 10 bar is operated utilising a full power application method, as documented in AC415V. The air system in railways is crucial for train operation. Ensuring reliability and security is crucial for maintaining competitiveness in pneumatic system. However, due to their intricate rotating equipment, air compressor is more likely to occur failures

1.3 Air dryer in EMU train system

The air dryer's main function is to remove moisture or humidity from compressed air before it enters the pneumatic system. The air dryer keeps moisture out of the pneumatic system, which can lead to corrosion, component damage, and lower system efficiency. It contributes to the dependability and efficiency of the pneumatic system. There is different type of air dryer used in industry include desiccant gel, refrigeration dryer, and membrane dryer. For EMU of KTM class 83, they used the desiccant gel. These air dryers use desiccant gel to remove moisture from the system and give clean, dry air for optimal performance of electro-pneumatic and pneumatic equipment. A twin tower heatless regenerative type air dryer is used to prevent condensation within the system. This lightweight drier weighs less than 100 kg and is installed on the compressor delivery pipeline. It works well at nominal main reservoir pressures ranging from 6 to 8 kg/cm2 [5].

2. Materials and Methods

2.1 Research design

In this particular study, the focus is on analysing the air system of EMU train. The objective to achieve in this study is firstly, to investigate and analyse the failure that occurs in air system of EMU train class 83. The second objective is to produce a method to decrease failures in the air system of EMU train. This study was firstly conducted by collecting the data failure. Flowchart of this study is shown in Figure 3. FMEA (Failure Modes and Effect Analysis) is a method for identifying probable failure modes, their causes, and their impact on the entire system [6]. The FMEA method was used for this study to analyze data failure that help identify major failure modes and action taken to reduce the failures.

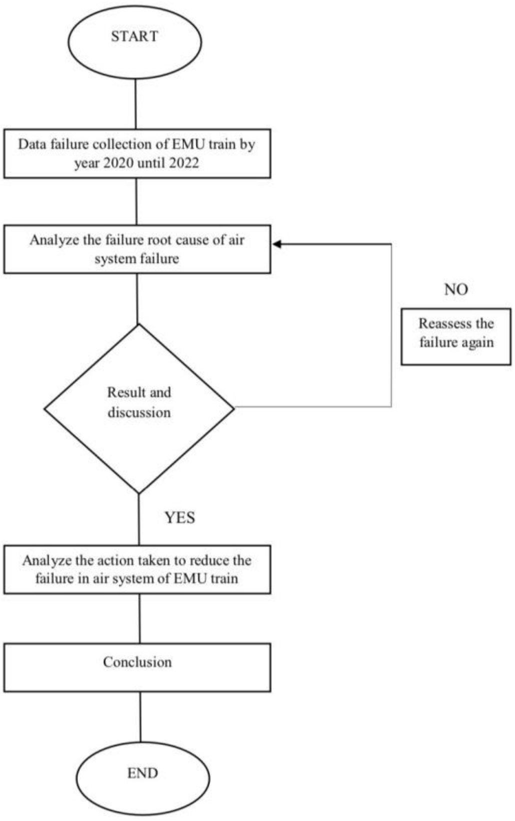
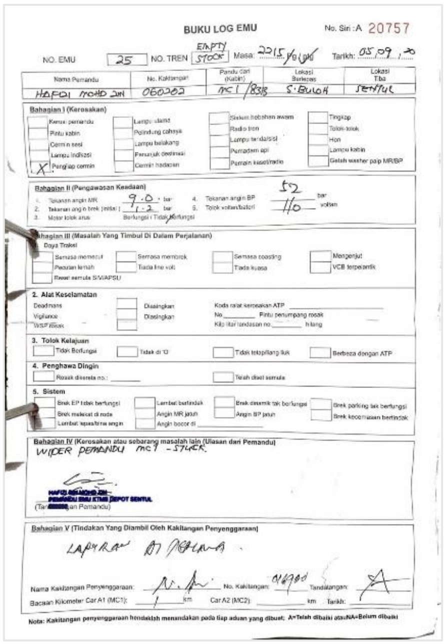


Figure 3: Flowchart of studying air system failures

First, the data failure was collected. The data failure was obtained by driver report, daily logbook record, and TCCC (Train Control Command Centre). When the set fails to function or is damaged, the driver will record the damage in the EMU log book, as illustrated in Figure 4. On every train set, there is an EMU logbook that been provided. It is located at the driver cab. The logbook will contain details for each train set. The train's damage will be recorded in Part IV of the logbook. Each unit team will be informed about the failure or damage of the train set by their supervisor.



BUKU LOG EMU

No. Siri :A 20757

NO. EMU 25 NO. TREN EMPTY STOCK Masa: 2215 Tarikh: 05/09/20

Nama Pemandu	No. Kakitangan	Pandu dari (Kabin)	Lokasi Berlepas	Lokasi Tiba
HAFDI MOHD ZIN	060282	MC1 / 8318	S.BULOH	SENTUL

Bahagian I (Kerosakan)

Kerusi pemandu; Pintu kabin; Cermin sisi; Lampu indikasi; X Pengelap cermin; Lampu utama; Pelindung cahaya; Lampu belakang; Penunjuk destinasi; Cermin hadapan; Sistem hebahan awam; Radio tren; Lampu tandas; Pemadam api; Pemain kaset/radio; Tingkap; Tolok-tolok; Hon; Lampu kabin; Getah washer paip MR/BP

Bahagian II (Pengawasan Keadaan)

1. Tekanan angin MR 9.0 bar
2. Tekanan angin brek (initial) 1.2 bar
3. Motor kipas arus Berfungsi / Tidak Berfungsi
4. Tekanan angin BP 5.2 bar
5. Tolok voltan/bateri 110 voltan

Bahagian III (Masalah Yang Timbul Di Dalam Perjalanan)

1. Daya Tarikan: Semasa memecut; Pecutan lemah; Reset semula SIV/APSU; Semasa membrek; Tiada line volt; Semasa coasting; Tiada kuasa; Mengenjut; VCB terpelantik

2. Alat Keselamatan: Deadmans; Vigilance; WSP rosak; Diasingkan; Diasingkan; Kod ralat kerosakan ATP; No. Pintu penumpang rosak; Kilo liter landasan no. hilang

3. Tolok Kelajuan: Tidak Berfungsi; Tidak di '0'; Tidak tetap/ilang ilok; Berbeza dengan ATP

4. Penghawa Dingin: Rosak disereta no.:; Telah diset semula

5. Sistem: Brek EP tidak berfungsi; Brek melekat di roda; Lambat lepas/tiras angin; Lambat bertindak; Angin MR jatuh; Angin bocor di; Brek dinamik tak berfungsi; Angin BP jatuh; Brek parking tak berfungsi; Brek kecemasan bertindak

Bahagian IV (Kerosakan atau sebarang masalah lain (Ulasan dari Pemandu)

WIPER PEMANDU MC1 - STUCK.

PEMANDU EMU KTMB DEPOT SENTUL

(Tan[redacted]an Pemandu)

Bahagian V (Tindakan Yang Diambil Oleh Kakitangan Penyenggaraan)

LAPORAN DI TERIMA.

Nama Kakitangan Penyenggaraan: No. Kakitangan: 016900 Tandatangan:

Bacaan Kilometer Car A1 (MC1): km Car A2 (MC2): km Tarikh:

Nota: Kakitangan penyenggaraan hendaklah menandakan pada tiap aduan yang dibuat; A=Telah dibaiki atau NA=Belum dibaiki

Figure 4: EMU Logbook

Another data failure also was obtained by the shift leader. Each damage will be reported to the shift section's unit leader. The leader of this shift unit will then be informed of the train's damage and will decide on a suitable time to do the maintenance work. Team shift will do the daily maintenance at each set of the train. Figure 5 is the daily maintenance flow chart. The work should be completed by the maintenance team referring to the Daily Maintenance Examination Report Card as shown in Figure 6. All current work must be documented on the Daily Maintenance Examination Report Card and followed in the maintenance logbook.

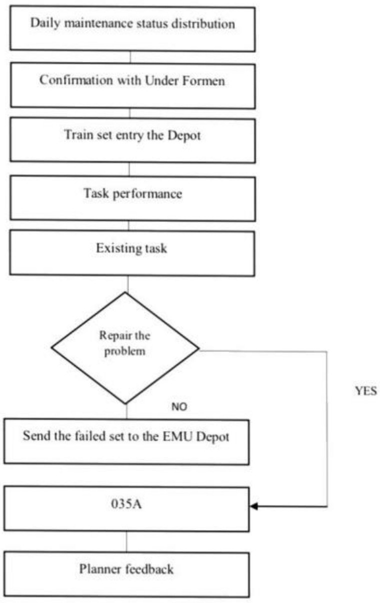


Figure 5: Daily maintenance flowchart

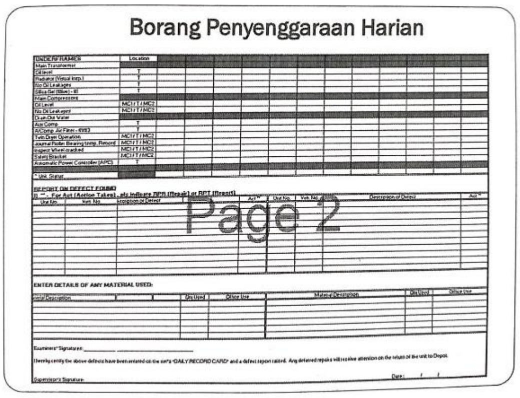

Borang Penyenggaraan Harian

Figure 6: Daily maintenance flow chart and daily maintenance examination card

In this study, data failures were collected from 2020 to 2022 using 20 sets of EMU trains. The data will then be analysed in Excel to determine the root cause of the air system failure. The investigation then continues to identify the most prevalent problems in the air system. After the common failure has been identified, research and discussion will take place to discover the root cause of the failure and the impact of the component's damage. Finally, improvement and recommendations will be made.

2.2 Method used to reduce the failure and testing

The research reveals that major failures in air systems are primarily caused by main reservoir dropped, primarily due to air component leaks, that attributed to the piston valve. Regular check-ups and inspections are crucial to prevent more significant issues. Seals are essential for maintaining the integrity of the pneumatic system, and regular inspections are crucial. The piston valve is crucial for removing moisture purified by the air dryer, ensuring clean air entering the main reservoir. After replacement components are replaced, the piston valve is tested to determine system durability using a special test machine which is test bracket for air dryer and piston valve as shown in Figure 7. The testing was carried out on 5 piston valves that were recently replaced with new item from the valve kit. Tests are carried out to detect if there is a leak in the piston valve. It is tested using a special test machine called the test bracket for air dryer and piston valve as shown in Figure 7. There were two tests that were conducted: leakage tests and function tests.

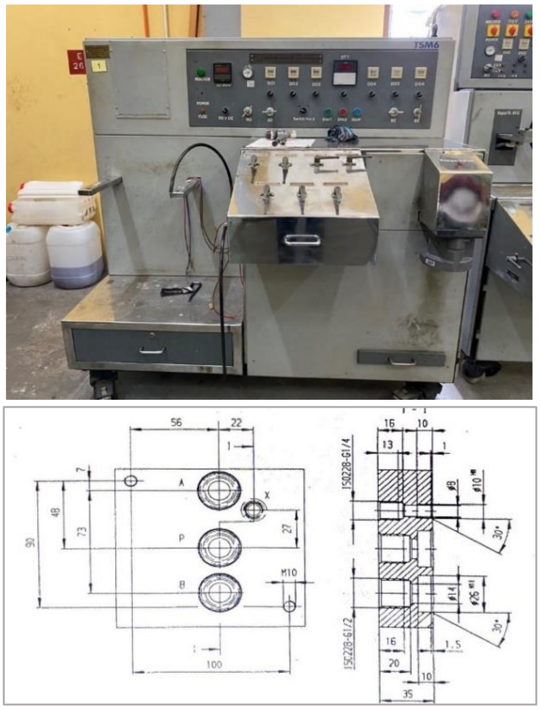


Figure 7: Test Bracket for piston valve and air dryer

2.2.1 Leakage Test

The piston valve was fastening to the test bench with the help of the sleeves and O-rings from the air dryer unit and install in a test setup according to Figure 8. The cock must all be closed. Then, the test pressure on the pressure reducing valve (DMV) was set to 10.5 bar (pressure gauges M1 and M2). Cock H1 was open, tower R1 was charged. Leakage at R was tested as soon as pressure gauge M3 showed the same reading as M1 O1 and cock H2. No air must escape. Cock H2 then been opened, the piston valve must shuttle audibly. Tower R1 was vented and R2 charged. As soon as pressure gauge M4 shows the same reading as M1, test for leakage at R, O2 and the valve body. No air must escape. Cock H2 was closed. The piston valve must shuttle audibly. Tower R1 was charged and R2 vented. Cock H1 was closed then tower R1 is vented.

2.2.2 Function Test

Refer to Figure 8, pressure reducing valve DMV2 was set to 0 bar (pressure gauge M2). DMV1 was still set to 10.5 bar. Cock H1 and H2 be opened. Tower R1 is charged and pressure gauge M3 must show the same reading as M1. The pressure been increase slowly at pressure reducing valve DMV2 and pressure gauge M2 been observed. The piston valve must be shuttle audibly at a pressure of not more than 3.5 bar. Tower R1 was vented (reading on M3 must drop to 0 bar) and R2 was charged. Ensure that the pressure gauge M4 showed the same reading with M1. After tower R1 has vented, leakage at R been tested. The piston valve must be absolutely airtight. The pressure at pressure reducing valve DMV2 were slowly lower and pressure gauge M2 been observe. The piston valve must switch back audibly at a pressure at least 0.5 bar then tower R2 was then been vented (reading on m4 must drop to 0 bar) and R1 was charged. Pressure gauge M3 must showed the same reading as M1. Tower R2 is vented (reading on M4 must drop to 0 bar) and R1 is charged. Pressure gauge M3 must showed the same reading as M1. After tower R2 has vented, leakage at R was tested. The piston valve must be absolutely airtight. Finally, close cock H1 and H2. The test setup was vented, pressure reading at M3 and M4 was fall to 0 bar. The piston valve was removed from the test setup. All the piston valve that is found good, a durable test mark will be applied to it (green tag).

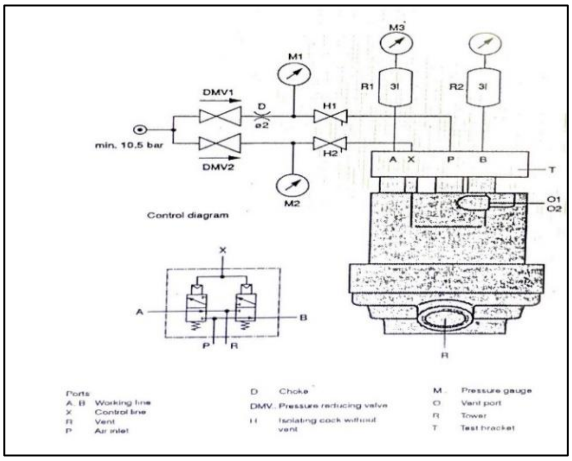


Figure 8: Test Setup for piston valve

The test ensures no leaks in components and takes about a few minutes. 75% of piston valves pass, while 25% fail, and about one of the five piston valves examined exhibited a leak. A green tag will be applied to it to show that the successful testing and it ready to use on the train.

3. Results and Discussion

Table 1 shows EMU train data failures across systems. 2020 to 2022 data was collected. 102 failure categories included air system, ATP, brake system, coachwork, doors, APS, pantographs, air-conditioning system, power equipment, bogies or underframes propulsion, and safety equipment elements. This information was compiled by workers during their daily tasks. It should be noted that each subsequent year saw an increase in the number of reported failures.

Table 1: Data failure of EMU train each three years in all system categories

System Categories	Number of Failure by Years			Percentage
	2020	2021	2022	
Air System	2	9	17	27.45%
Automatic Train Control (ATP)	1	0	0	0.98%
Brake System	0	4	13	16.67%
Coachwork	0	0	0	0%
Doors	0	3	9	11.76%
Auxiliary Power Supply (APS)	0	1	2	2.94%
Pantograph	1	2	4	6.86%
Air-conditioning	0	0	0	0%
Power Equipment	6	11	13	29.41%
Bogies/Underframe	0	1	1	1.96%
Propulsion Equipment	1	0	1	1.96%
Safety Equipment	0	0	0	0%
Total	11	31	60	100%

2022 had the greatest failure rate, with an average percentage of 58.82%. The percentage of failed systems in power equipment was the highest at 29.41%, while ATP had the lowest reading at only 0.98%. During these three years, there were no readings recorded for coachwork, air conditioning, and safety equipment.

3.1 Air system failures

In Figure 9, the focus was on air system failures that were recorded from 2020 to 2022. During this time, 29 failures in total were documented. Interestingly, the year 2020 saw the fewest failures, which was due to the Movement Control Order (MCO) issued by the Malaysian government, which required people to stay at home.

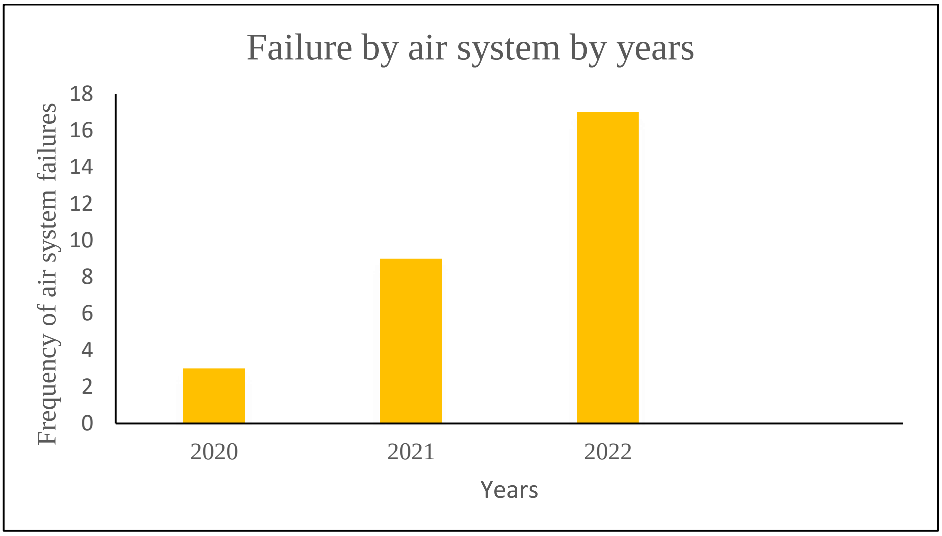


Figure 9: The failure in air system in year 2020, 2021 and 2022

The number of failure in the air system was recorded as 3 in year 2020, while it increased to 9 failures in 2021 and further escalated to 17 failures by 2022. This represents as percentage increase of failure rates by 20.69% from 2020 to 2022. The number of failures has shown a consistent increase from 2021 to 2022 ranging from 9 in 2021 to 17 in 2022, reflecting a considerable rise of around 27.59%. This higher trend in failures can be attributed to the fact that more train sets are now operational in 2022 compared to the previous year.

3.2 Root cause of failure in air system

As indicate in Table 2, main reservoir dropped, main reservoir brake pipe leakage, pantograph problems, PBC, RH3 and check valve leaks, and SIV leakage can all cause air system failures. Any of these component failures can have a severe impact on train operation.

Table 2: Type of failure in air system year 2020 until 2022

Type of failure	Frequency of failure
Main reservoir dropped	15
Main reservoir pipe leak	3
Brake pipe leak	2
Pantograph problem	2
Power Break Control (PBC) leak	2
Check valve leak	2
Pressure Reducing Valve (RH3)	1
Static Inverter (SIV)	1

The failure consequence is the variable that represents the level of severity connected with a failure. This component is closely related to the maintenance requirements of EMU trains and is critical in determining their operational capabilities. Table 2 provides an overview of the damages that cause air system failures. Among these concerns, main reservoir dropped incidents had the highest failure rate, averaging 53.57%. SIV fault and RH3 have substantially lower incidence rates, with averages of 3.57% each.

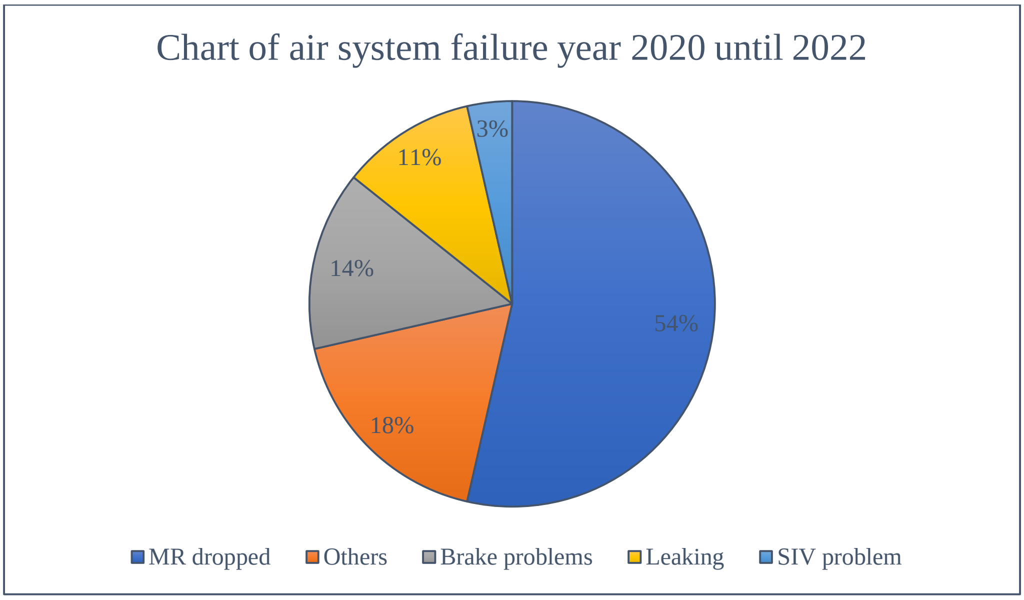


Figure 10: Percentage of air system failure year 2020 until 2022

The air system can be split into five distinct systems based on the data supplied in Figure 10: main reservoir dropped, braking difficulties, leakage issues, SIV problems, and others (which include external heating, valve isolating cock problem, and motor problems damages). The analysis of these systems finds that the main reservoir drop has the highest failure rate, with an average percentage of 54%, necessitating additional maintenance.

Therefore, considering the increased failure probability, attention was focused primarily on minimising main reservoir dropped. The data shows that main reservoir dropped due to a variety of issues, including a leak in the piston valve, a disconnected line between coaches, defective electrical connections on the main compressor, and induction motor failure. Due to the main reservoir dropped, it affects numerous systems, including the brake system, door system, pneumatic suspension system, auxiliary system, and pneumatic control and valve. As a result, the train's smooth functioning will be affected by these flaws.

3.3 Failure in main reservoir and piston valve

As shown in Figure 10, main reservoir dropped was the primary cause of air system failures, with potential causes including damage to the induction motor, leaks in the main reservoir pipe and piston valve, detachment of the pipe between coaches, as well as loose electrical connections at the main compressor. Main reservoir dropped occurs when pressure falls below 7 bars, causing a train to malfunction. Normal reading should be 8-10 bar. The driver will then report the failure and the train is taken to the maintenance team for repair.

The main reservoir stores compressed air from the air compressor and is the primary source for all train systems. It supplies air through a braking pipe. To ensure that only clean air is delivered, air is filtered using an air dryer, which connects to the piston valve. Air dryer uses filtering devices to remove solid particles and moisture through a drying mechanism [7]. The piston valve and air dryer are crucial components in an EMU train's pneumatic system, ensuring reliable performance and efficiency in various operations. Failure in piston valve will affect the main reservoir dropped. The valve kit of piston valve often experiences failure as shown in Figure 11 due to wear and tear, deteriorating seals and gaskets from usage, temperature changes, and exposure to contaminants. This can cause gaps or cracks, causing air leakage then cause to main reservoir dropped. Regular maintenance practices are crucial to address these concerns. In such cases, the maintenance team replaces damaged items with new service kits, as shown in Figure 12.

Figure 11: Defect valve kit (right), normal valve kit (left)

Figure 12: Service Kit for piston valve

3.4 Improvement made

Therefore, to improve the reliability and efficiency of the pneumatic system, one option is to consider upgrading or modifying the system. This can involve replacing outdated components with more advanced and dependable ones or implementing technologies that minimise main reservoir pressure drops. In order to enhance the air quality at the main reservoir in EMU trains, proactive measures were taken by installing an additional air separator with three filters beside the existing air dryer component as shown in Figure 13. Originally, only air dryer and oil separator mechanism was used for filtering purposes. The new air separator serves a similar purpose as these previous components by ensuring that only clean filtered air enters into the main reservoir. The air separator improves efficiency and reduces man power for maintenance work by effectively filtering high-quality air. In cases where the air quality is poor and cannot be efficiently filtered, water may remain in the filtered air and can affect the air system in train.

Figure 13: Air filter

As part of routine visual inspections, thoroughly inspect the air dryer for the presence of damage, leaks, or loose connections. In addition, the air dryer housing must be inspected for condensation or water accumulation. During this process, the intake and output ports, filtration elements, and drying mechanism should all be thoroughly inspected. The desiccant gel, which is housed within the air dryer tower, also needs to be replaced on a regular basis. Because the aim of the air dryer is to eliminate moisture by using a desiccant gel, it is critical to constantly monitor and change the desiccant as needed. Because of its short lifespan, the desiccant gel's ability to absorb moisture reduces over time. A total of 4.5kg of desiccant gel is used within the tower, which typically requires refilling after two years. By properly maintaining the air dryer system, one can increase the overall dependability and lifetime of pneumatic systems on trains. Figure 14 and 15 shows the desiccant gel which has been used in the air dryer for two years. Figure 15 depicts the difference between the two-year desiccant gel and the new gel desiccant. The different in terms of their colors demonstrates that the desiccant gel in the air dryer effectively absorbs the moisture.

Figure 14: Desiccant gel that has been used 2 years inside the air dryer

Figure 15: Different after 2 years the desiccant gel works in the air dryer

4. Conclusion

In summary, the research findings show that air system problems have a major impact on train operation. The most common failure in air system is main reservoir dropped, which causes disruptions in smooth train movement. To address this issue, it is critical to identify and address the root cause of these failures in order to implement effective mitigation measures. The air that enters the main reservoir tank must be properly filtered to ensure that there is no moisture trapped in the tank, which will damage the tank and disrupt the system that requires air to function. It should be emphasised that appropriate solutions for each unique failure scenario can be applied based on its severity level.

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