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Analysis of Fill Switch Failure Leading to Transmission Inability to Shift Speeds in the Haulpak 530M Unit

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ABSTRACT

The Haulpak 530M unit utilizes a Torqflow Transmission as its power transmission system, where the Torqflow Transmission is a fluid-controlled power transmission device that regulates the speed, forward, and reverse motion, as well as the crucial function of increasing torque by reducing the rotational speed through the gear ratio of the transmission. The Electric Control Modulating Valve plays a crucial role in this system, as it is responsible for modulating the oil pressure entering the clutch in the transmission to facilitate gear shifting. However, the Haulpak 530M unit has encountered an issue where the "02" (b021) error message, indicating a lock-up clutch failure, is displayed on the Message for Operation and Maintenance monitor, preventing the unit from moving forward beyond the F2 gear, limiting its top speed. The root cause of this problem is the failure of the Fill Switch component, which is responsible for the proper functioning of the ECMV and the lock-up clutch.

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Introduction

Haulpak 530M, a prominent mining truck, utilizes a specialized power transmission system known as Torqflow Transmission to facilitate the transfer of power from the engine to the wheels. This transmission system, which is essential for the operation of large equipment, relies on the use of fluid, specifically oil, as the primary control mechanism [1][2].

The Torqflow Transmission serves a crucial role in regulating the speed, forward and reverse motion, and most importantly, increasing the torque of the vehicle by reducing the rotational speed through the gear ratio design [3]. To achieve smooth gear shifting, the Torqflow Transmission employs an Electric Control Modulating Valve that modulates the oil pressure entering the transmission's clutch system [4].

Any issues with the Torqflow Transmission can significantly impact the production efficiency of the Haulpak 530M. The author encountered such a problem firsthand at PT X, where they were tasked with analyzing and resolving a specific issue related to the Torqflow Transmission.

The problem arose when the operator attempted to shift the transmission from second to third gear, but the transmission remained stuck in second gear, accompanied by an error code B021, indicating a Lock-Up Clutch Failure. The investigation into the issue revealed that the ECMV sensor, which is responsible for controlling the lock-up clutch, had malfunctioned, preventing the successful gear shift and resulting in the production disruption [5].

This research paper aims to provide a comprehensive understanding of the Torqflow Transmission system, its role in the Haulpak 530M, and the specific issue encountered during the author's experience.

Torqflow Transmission, a specialized power transmission system, utilizes the inherent properties of fluid, namely oil, as the driving force behind its intricate workings. The primary function of this transmission system is to regulate the speed, direction, and torque generation of heavy-duty equipment, enabling them to operate at their peak performance. [6] A significant benefit of the Torqflow Transmission is its capacity to mitigate the torsional vibrations originating from the engine,

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which in turn safeguards the engine from the detrimental effects of abrupt load variations [7].

The distinctive nature of Torqflow Transmission lies in its ability to automatically adjust the engine's power output to the prevailing load conditions, ensuring smooth and seamless gear shifts without the need for the vehicle to come to a complete stop, a feature that further enhances the efficiency and responsiveness of the system by allowing for continuous power delivery and uninterrupted operation [8]. One of the key advantages of Torqflow Transmission is the substantial increase in tractive force, a crucial parameter in the performance of heavy-duty machinery [9]. While the Torqflow Transmission system offers numerous advantages, it is not without its drawbacks, as the system is known to exhibit a degree of slippage within the torque converter, which can result in a partial loss of engine power.

The Torqflow Transmission Haulpak 530M is a remarkable feat of engineering, its inner workings a carefully orchestrated symphony of interconnected components, each playing a crucial role in the overall performance and efficiency of this heavy-duty vehicle [10]. The core of this exceptional transmission is a meticulously crafted mechanical system, a harmonious assembly of essential components responsible for seamlessly transferring power from the engine to the wheels, enabling the Haulpak 530M to navigate demanding terrains with unmatched capability, tackling even the most arduous and rugged environments with unwavering strength and resilience.

At the core of this system is an advanced hydraulic continuously variable transmission, allowing seamless gear ratio adjustments to optimize engine efficiency [11]. This design improves the Haulpak 530M's performance and fuel economy by leveraging the latest in hydraulic transmission technology.

The Haulpak 530M Torqflow Transmission consists of several key components that support the performance of the transmission itself. These components have specific structures and functions according to their roles. The main components are divided into two systems: the mechanical system and the electrical system. For more details, refer to the table 1 below:

Table 1. Mechanical & Electrical System

Mechanical	Electrical
Transmission Pump	Transmission Controller
Main Relief Valve	Transmission Speed sensor
Transmission Lubrication Relief Valve	Transmission oil temperature sensor
Clutch	Shift Limit Switch
	Fill Switch
	Shift Lever Switch
	Power Mode Selector Switch
	Engine Speed Sensor
	ECMV (Electronic Control Modulation Valve)

The following are some issues that have occurred. The HD (Heavy Duty) Dump Truck 530 M, equivalent to the HD 1500-5, has been experiencing a problem where the unit tends to shift into neutral when attempting to engage speed F3. Since this unit uses an automatic transmission, the issue results in the unit being unable to automatically shift from F2 to F3. This problem is accompanied by error code "02" (b021), indicating a ***lock-up clutch failure***, which is displayed on the **Message for Operation and Maintenance Monitor (MOM)**. Due to this fault, the unit cannot move forward beyond F2, limiting the top speed to F2. Based on the description above and the reference to the shop manual regarding error b021, it can be concluded that the ECMV Lock-Up Clutch is damaged, leading to a decline in the unit's performance.

Methods

The inspection and measurement methods were carried out with the aim of identifying the cause of why the unit cannot shift up. The core of this issue is to pinpoint the problem specifically and directly, followed by taking repair actions as a final step to resolve the issue or malfunction. This approach helps minimize the unit's breakdown time [12].

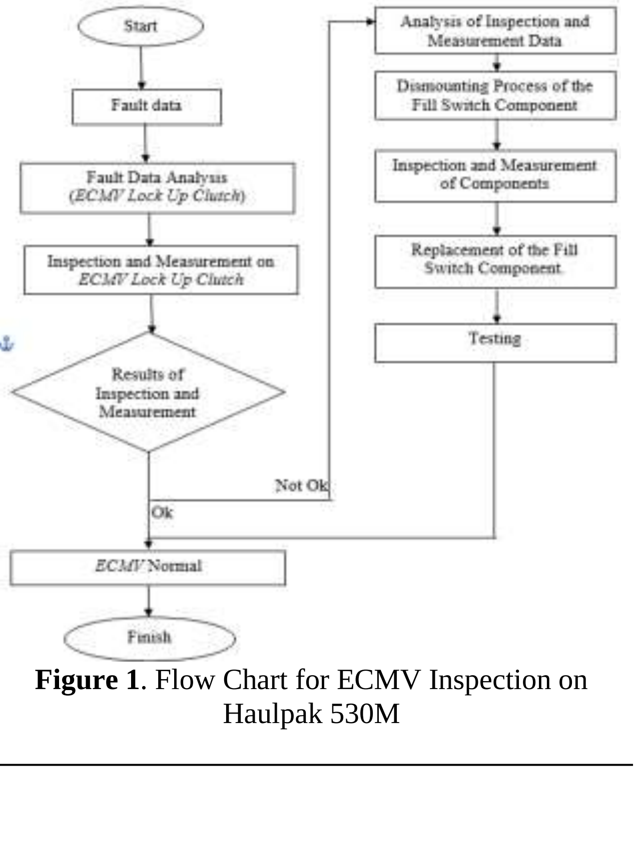


Figure 1. Flow Chart for ECMV Inspection on Haulpak 530M

Results and Discussions

The steps for inspecting and measuring the cause of the unit's inability to shift up are generally outlined below. The components to be inspected on the ECMV Lock-Up Clutch related to the issue are as follows:

1. **Error appearance on the MOM along with buzzer sound.**

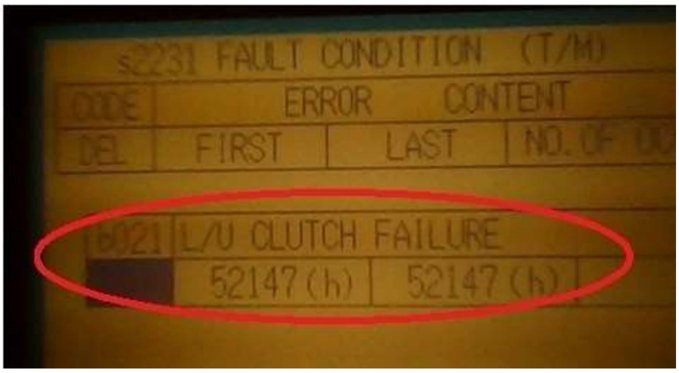


Figure 2. Error b021 on the MOM Monitor

Based on Figure 2, the appearance of this error prompted an inspection and measurement of the ECMV Lock-Up Clutch. Measurement begins with the Lock-Up Clutch Solenoid.

2. **Resistance of the Fill Switch ECMV Lock-Up Clutch (ATC5A Pin 17).**

The inspection of the Solenoid Lock Up Clutch involves measuring the resistance (ohms) of the proportional solenoid. The standard measurement value is between 5-25 Ω. However, after conducting the measurement, the resistance of the proportional solenoid was found to be 23.5 Ω, which is within the standard range, as shown in Figure 3.

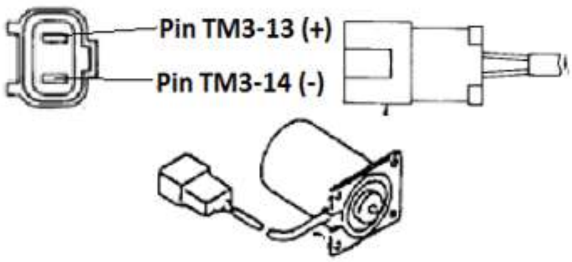


Figure 3. Connector and Proportional Solenoid Components

3. **Hydraulic Pressure in the ECMV.**

This inspection is conducted on each clutch (ECMV) using special tools, namely the Shift Checker and Pressure Gauge, to determine the pressure according to the standard. This allows us to identify whether the Lock-Up Clutch pressure is within the expected range, as a deviation could indicate that the transmission may not reduce its rotational speed properly. Below is a table 2 of the hydraulic pressure measurement results, where it was observed that during the measurement of the ECMV Lock-Up Clutch, the pressure did *not register* as 0 kg/cm^2.

Table 2. Measurement Data

Clutch	Clutch Pressure Standart	Clutch Pressure Actual
H	15 ± 1 kg/cm^2	15.5 kg/cm2
M	18 ± 1 kg/cm^2	18.5 kg/cm2
L	35 ± 1.5 kg/cm^2	36 kg/cm2
3	15 ± 1 kg/cm^2	15.5 kg/cm2
2	35 ± 1.5 kg/cm^2	36 kg/cm2
1	35 ± 1.5 kg/cm^2	36 kg/cm2
R	35 ± 1.5 kg/cm2	36 kg/cm2
L/C	19 ± 1kg/cm2	0 kg/cm2

After obtaining the data from the inspections and measurements, an analysis of the potential issues that have occurred will be conducted. This analysis is based on the inspection data to identify the cause of the trouble, specifically the fill switch damage/puffing, which resulted in the occurrence of error B021. This error is due to a short circuit in the body, where the fill switch sends a negative signal to the Transmission Controller. This causes a mismatch between the input signal to the Transmission Controller and the output current from the Transmission Controller, leading to the transmission tending to move to neutral.

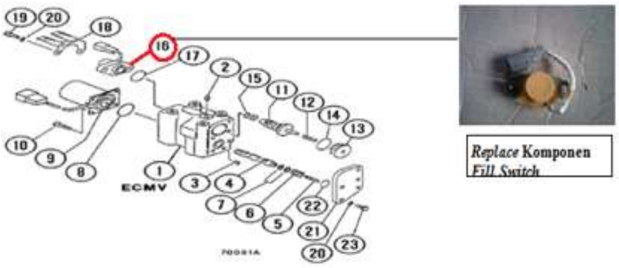
Conclusions

Inspection and Measurement of Resistance in the ECMV Lock-Up Clutch Fill Switch

Visual Inspection of the Fill Switch was conducted to identify any anomalies or damage that might be present. During the inspection, it was noted that the condition of the fill switch exhibited several anomalies, such as the presence of dirt, physical damage, or unusual signs of wear. These irregularities can affect the normal functioning of the fill switch, which plays a crucial role in the operation of the transmission system [13]. Early identification of these issues is important to determine the next steps for repair and to ensure that the transmission system operates effectively, as shown in the figure 4.

Figure 4. Plots of lineation (L) and FeO content showing negative correlation

After analyzing the potential sources of trouble, it was found that the issue lies with the fill switch, which is shorting to the switch body. This causes the fill switch to send an abnormal signal to the transmission controller, resulting in a mismatch between the input signal to the controller and the output from the controller.



1. Valve Body
2. Plug
3. Plug
4. Pressure Control Valve
5. Piston
6. Spring
7. Shim
8. O-ring
9. Solenoid Valve
10. Bolt
11. Flow Detection Valve
12. Spring
13. Plug
14. O-ring
15. Spring
16. Fill Switch
17. O-ring
18. Bracket
19. Bolt
20. Washer
21. Cover Plate
22. O-ring
23. Bolt

Figure 5. ECMV

Due to the malfunction of the fill switch, the unit has been temporarily taken out of service. To minimize production losses, the fill switch was promptly replaced, as shown in the figure 5.

Acknowledgment

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Author Contributions

Rasma, S.T., M.T.: Conceptualized the study, designed the experimental procedures, and conducted the primary data analysis. Provided critical insights into the failure mechanisms and developed the framework for the analysis.

Reza Febriano Armas, S.Pd., M.T.: Assisted in drafting and editing the manuscript, including figures and tables. Reviewed and contributed to the final revision and formatting of the paper.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper. All research and analysis were conducted with impartiality and without any external influence or financial interests that could have affected the outcomes. Any potential conflicts of interest have been disclosed, and the study adhered to ethical standards in research and reporting.

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