The Fifth International Conference on Railway Technology
RAILWAYS 2022
22–25 August 2022
Montpellier, France

Proceedings of the Fifth International Conference on
Railway Technology:
Research, Development and Maintenance
Edited by J. Pombo
Civil-Comp Conferences, Volume 1, Paper 5.5
Civil-Comp Press, Edinburgh, United Kingdom, 2022, doi: 10.4203/ccc.1.5.5


# Development of forecasting method for switch malfunction by slipping of a friction clutch

**S. Shiomi**

**Railway Technical Research Institute
Tokyo, Japan**

## Abstract

Forecasting of switch malfunctions is important issue to advance function of a condition monitoring system for electric point machine. In many of previous monitoring systems, switch malfunctions are detected using threshold, however defining unit of thresholds including motor current to forecast switching malfunction are difficult. Maximum slipping torque of a clutch, which is adjusted by contacting force between slipping plates, on electric point machine can relate to switching malfunctions, however forecasting method of the clutch status have not been developed. In this study, a forecasting method of clutch adjustment status is proposed using monitoring parameters like a motor current and switching time. To confirm relationship between switch malfunction and slipping of a friction clutch, we tested and measured statuses of electric point machine using a 1:12 flexible switch, an actuator for artificial switching load and a NS-A point machine equipping an AC induction motor and a friction clutch. By this test, we confirmed that increment of switching time indicates switch malfunction due to a clutch slipping. It is also confirmed that increment of the maximum motor current in operation indicates switch malfunction due to a motor axis slipping. We proposed a method to find reasons of a switch malfunction such as: clutch slipping and overload of motor by increment of switching load. By these results, we proposed a flowchart of switch malfunction forecast relates clutch adjustment using inrush current, switching time and maximum motor current. The flowchart helps adjustment works of a friction clutch. Moreover, the improvement of a clutch adjustment helps safety of point machines in strength, because a large force by tight adjustments produces a risk of large stress on components of a point machine and rods.

**Keywords:** electric point machine, switch malfunction, friction clutch, condition monitoring, switching load, turnout.

# 1 Introduction

For electric point machines, development of forecasting and troubleshooting of switching malfunctions is needed to advance function of a condition monitoring system. Condition monitoring systems normally measure motor current, voltage and position of an operation rod to detect causes of switching malfunction, which include increased values of the switching load of a turnout and slip velocity of a clutch in a point machine.

In many of commercial condition monitoring systems, switch malfunctions are detected using a threshold. On the previous studies, detection methods, which calculate difference from learned data identified as "normal", are also proposed [1], [2]. However, for all types of turnouts and switching machines, defining unit of thresholds including motor current and obtaining "normal" learning data to forecast switching malfunction are difficult, because status relating to switching malfunctions, like switching load, motor voltage and friction force on clutches, are different by machines and turnouts. Due to this reason, definitions should be done for each turnout.

A clutch in electric point machines has functions to shunt large switching torque, exceeding rated torque of a motor, to save components of switching equipment against large strain. A friction clutch is one of the major types of clutches in the world, and its maximum torque is adjusted by the contact pressure on surfaces of clutches. In a friction clutch of Japanese NS-A type point machine, contact pressure is adjusted by a screw mechanism. In addition, the position of a screw should be adjusted when friction coefficient is changed by temperature of atmosphere or when the thickness of friction plates is reduced by slipping of clutches. This status of friction clutch adjustment shows that maximum slipping torque of clutch can relate to switching malfunctions, however forecasting method of the clutch status have not been developed.

In this study, a forecasting method of clutch adjustment status is proposed using monitoring parameters like a motor current and switching time. This study aims at a future development of automated threshold definition method of condition monitoring systems of electric point machines.

# 2 Methods

For confirming relationship between switch malfunction and slipping of a friction clutch, the motor current and the switching load of a NS-A point machine were measured, when artificial switch malfunction by increment of switching load was occurring. Switching load was controlled by a test equipment which the author developed.

Figure 1 shows the experimental setup consisting of the NS-A point machine, a 1:12 flexible turnout and a pneumatic actuator for artificial load. The point machine comprises a single-phase AC induction motor, a friction clutch unit, and cam mechanisms for operation of switch rod (see Figure 2). Due to force transfer characteristics of cam mechanisms, torque in a clutch axis peaks at middle of operation rod's stroke (ORS), if switching load is constant. Switching force of the point machine is 2.9 kN in rated value which is minimum at middle of ORS. In addition, switching force is affected by adjustment of a friction clutch and operation voltage of motor. Therefore, switch malfunction can occur if switching load of turnout is larger than switching force of point machine. In other words, it can occur by increment of switching load, decrement of friction force of the clutch and voltage fluctuation of motor.

The actuator for artificial load is connected at the end of a tie bar to add switching load in opposite direction of tongue rails motion. Artificial load is adjusted from zero to 4.0 kN using a precise pressure valve which automatically adjusts air pressure of actuator.

Using this setup, the author tested relationship between switching load increment and switch malfunction in various motor voltages under the condition where the friction clutch is adjusted to tightest (Test-A). And effects of clutch adjustment were also tested (Test-B). At every test, motor current, voltage, switching load and displacement of switch rod were measured normally for three times. Table 1 shows parameters of Test-A and Test-B. At Test-A, motor voltages were set in AC 84 V to 126 V which are ±20 % of rated voltage. At Test-B, a friction clutch was being loosened from tightest adjustment. Adjustment position is defined by number of rotations for screw mechanism adjusting contact force between friction plates on the clutch. Figure 3 shows relation between parameters for evaluation of test results and measured waveform of current and so on.

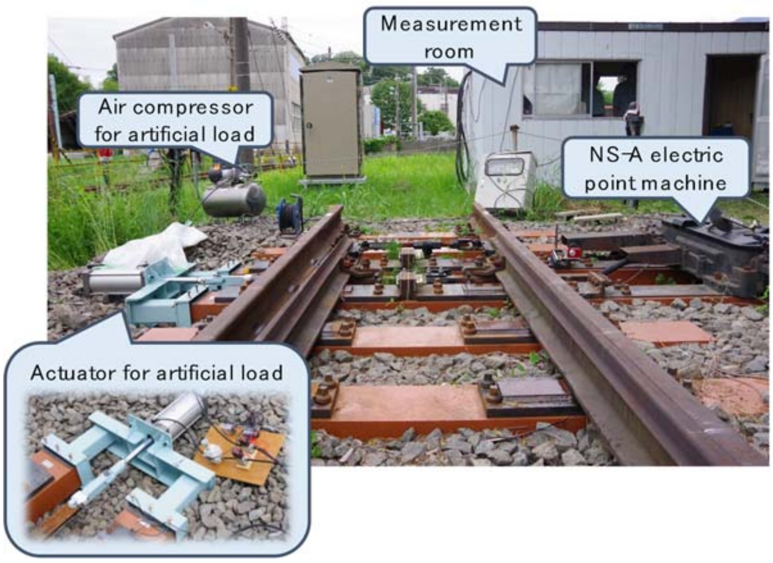



Figure 1: Experimental setup

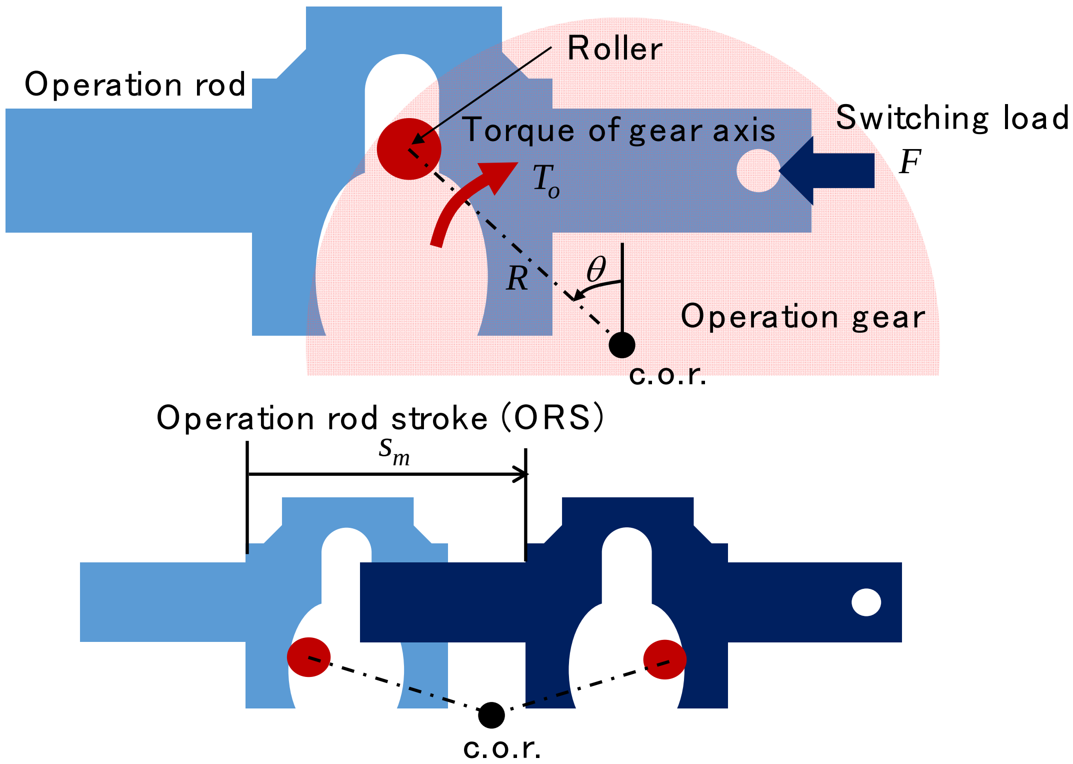


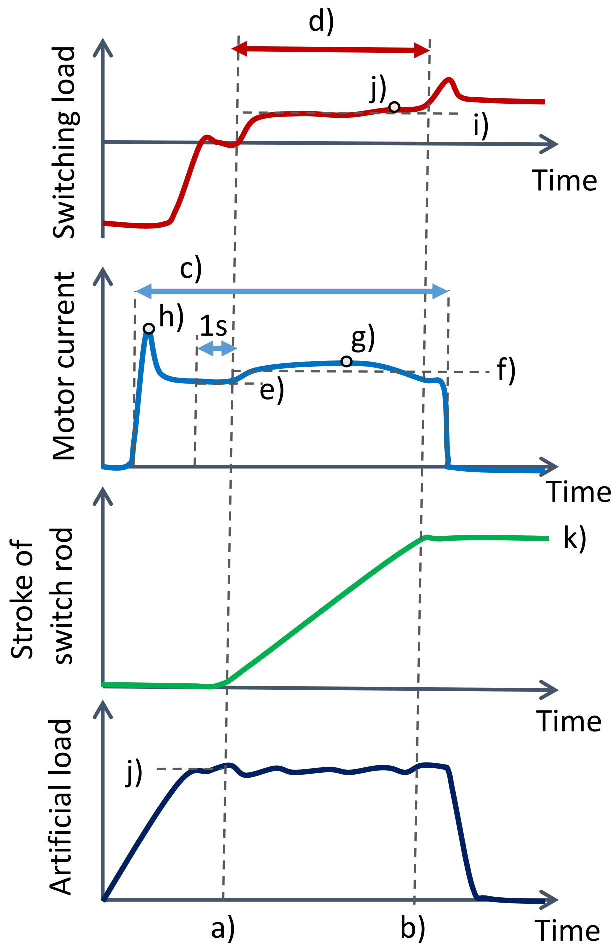

Figure 2: Cam mechanism of NS-A point machine

| Parameters | | Test A | Test B | Note |
|---|---|---|---|---|
| Motor Voltage | (V) | 84, 94.5, 105, 115.5, 126 | 105 | |
| Adjustment of clutch | (rotation) | 0 | 0, 1, 1.5, 2, 3, 4 | Clutch is adjusted by rotations of screw Number means rotations from tightest adjustment |
| Artifical load | (kN) | 0∼4.0 | 0∼4.0 | Increse while switch mulfunction |
| Lublication of bed plate | | well | well | |

Table 1: Parameters of tests

## 3 Results

Figure 4 shows a relation between artificial load and average switching load measured at operation rod of the point machine. Those values are high correlational relationship, and it is confirmed that the proposed method for artificial load generation was able to simulate increment of switching load.




| Mark | Name | Note |
|---|---|---|
| a) | Start of switching operation | When operation rod stroke exceeds 5 mm |
| b) | End of switching operation | When velocity of operation rod falls below 0.2 mm/s |
| c) | Switching Time (Current) | Time between motor current exceeds 0.5 A and falls below 0.5 A |
| d) | Switching Time (Operation rod) | Time between start and end of rod operation |
| e) | Motor current (W/O load) | Average of motor current between 1second before operation and start of operation |
| f) | Average motor current | Average of motor current between start and end of operation |
| g) | Maximum motor current | Maximum of motor current between start and end of operation |
| h) | Inrush current | Motor current before switching rod operate |
| i) | Average swithing load | Average of switching load between start and end of operation |
| j) | Artifical load | Measured artifical load before switching rod operate |
| k) | Operation rod stroke | Maximum of operation rod stroke |

Figure 3: Values for evaluation and measured waveforms

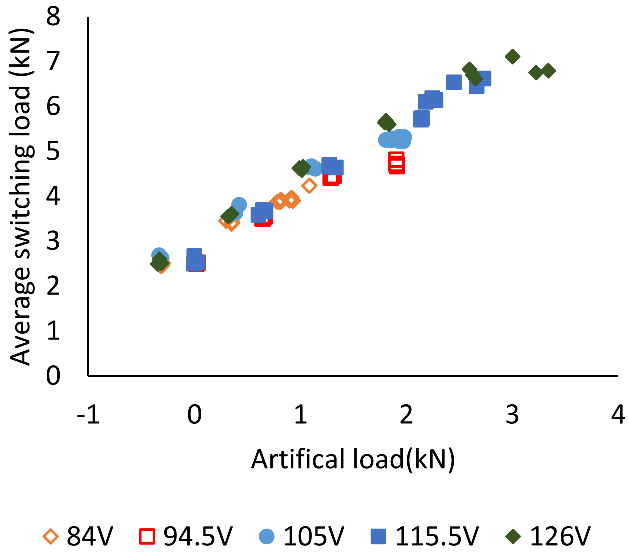



Figure 4: Average switching load and artificial load

By results of Test-A, it is confirmed that switching time, maximum and average motor current are increased by a switching load increment shown in Figure 5. On the other hand, maximum of switching time until motor stops are about 6 seconds even if the voltage is changed. Motor current at this situation is different by the voltages. At all switching malfunctions on this test, the motor axis was stopped because slipping torque of the clutch was adjusted if the torque exceeds the rated value for the motor. In addition, maximum motor currents when malfunction occur are same or higher than the inrush current of the motor in each voltage (see Figure 6). Therefore, switch malfunction in the case of bad tighten adjustment condition by slip of motor axis can be detected by incrementing the switching time and using the inrush current of the motor as the threshold value.

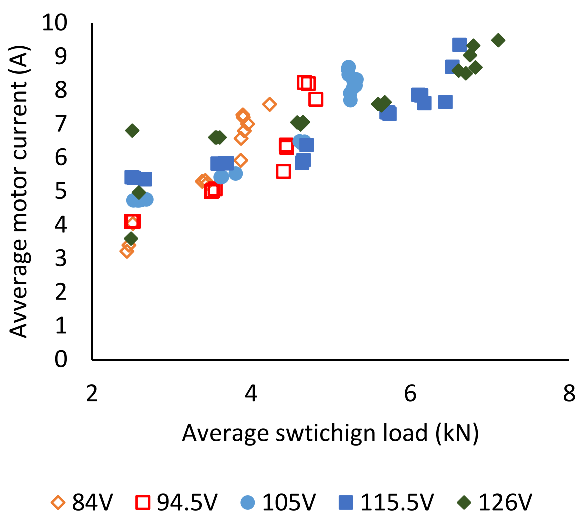



Figure 5: Switching load and average motor current (Test-A: clutch is tightened)

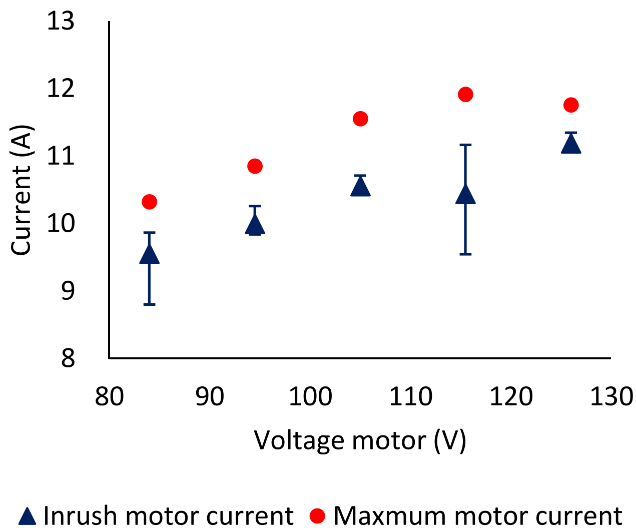



Figure 6: Motor current in switch malfunction, inrush current and motor voltage

A detection method for normal adjustment condition of clutch, which slips a clutch axis before motor axis is locked, can be developed by the results of Test-B. Figure 7 shows relationship between average switching load and average motor current by number of rotations of an adjustment screw of the clutch. It is confirmed that switching load has correlational relationship with motor current, however there is no indication of switch malfunction in any adjustment conditions. On the other hand, the test results of switching time shown in Figure 8 indicates malfunction. In the relationship between average switching load and switching time, it is confirmed that switching time is increased when the clutch is slipping. As the there is a difference of switching time from "normal" operations and abnormal ones are a few seconds, it is easy to set threshold for forecasting of the malfunction, separated with increment of switching time due to high switching load.

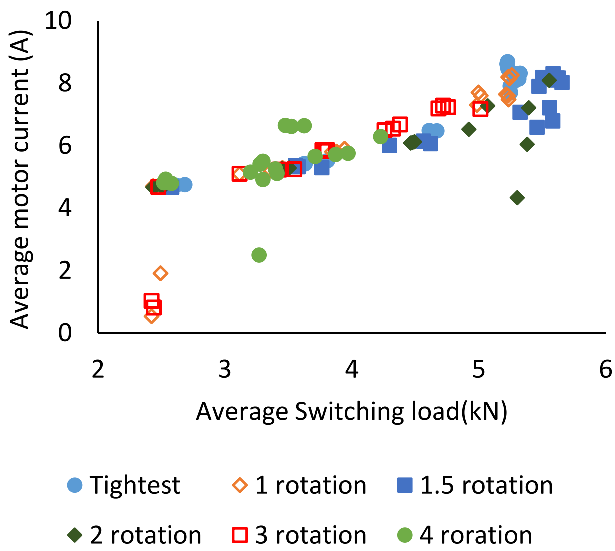



Figure 7: Switching load and average motor current (Test-B: Voltage is AC 105 V)

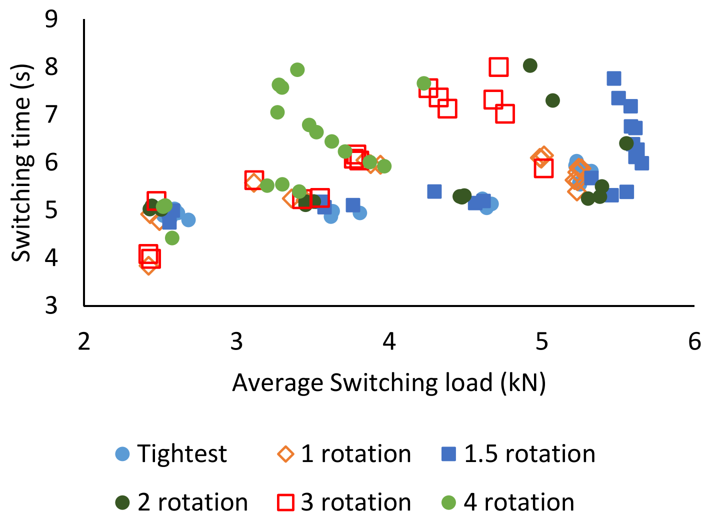



Figure 8: Switching time and switching load

# 4 Conclusions and Contributions

On point machines with a friction clutch and an AC induction motor, it is confirmed that increment of switching time indicates switch malfunction due to a clutch slipping. It is also confirmed that increment of the maximum motor current in operation indicates switch malfunction due to a motor axis slipping. Figure 9 shows a flowchart for forecasting of switch malfunction using these results. As the proposed method is also able to find reasons of a switch malfunction such as: clutch slipping and overload of motor by increment of switching load, it helps adjustment works of a friction clutch. In addition, the improvement of a clutch adjustment helps safety of point machines in strength, because a large force by tight adjustments produces a risk of large stress on components of a point machine and rods.

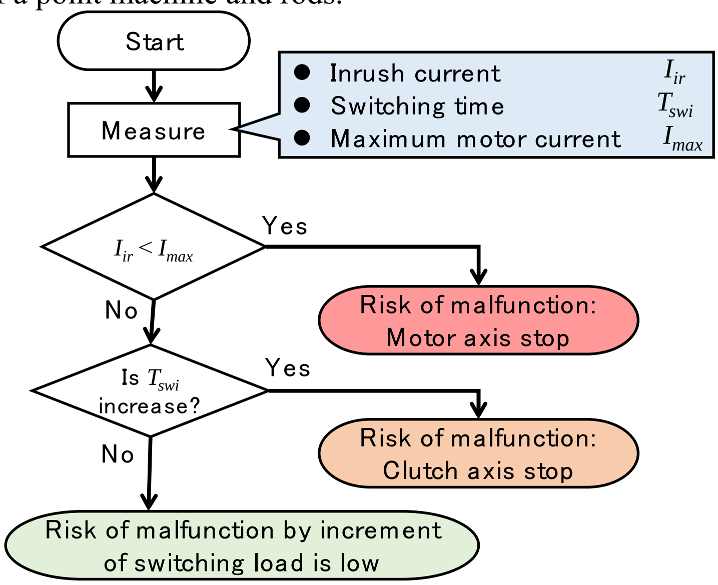



Figure 9: Flowchart for forecasting of switch malfunction

In the world, various types of motors and clutches are used in electric point machines [3]. However, as modern clutches including free-adjustment friction clutches, magnet clutches and oil clutches slip due to large switching load before motor axis is locked, the proposed method is applicable to forecasting of switching malfunction in most of all types of point machines except clutch-less ones.

I would like to thank Y. Oshimi, Y. Tada, T. Sato, T. Nomura, T. Ishii and N. Oko for technical assistance with the experiments.

## References

[1] S. Shiomi, Y. Oshimi, Y. Igarashi, "Development status of condition monitoring methods of the switch and lock movements in Japan", in "proceedings of 11th World Congress on Railway Research (WCRR2016)", Ferrovie dello Stato Italiane, Milano, 2016.

[2] T. Böhm, R. Schenkendorf, K. Lemmer, "Statistical Process Control for Modern Switch Failure Detection", in "proceedings of 11th World Congress on Railway Research (WCRR2016)", Ferrovie dello Stato Italiane, Milano, 2016.

[3] S. Shiomi, K Kitao, K. Numata, "A survey for technical trends of switching machines and equipment in the overseas" (in Japanese), The Papers of Technical Meeting on "Transportation and Electric Railway", IEE Japan, TER-18-062~071, 43-48, 2018.