

# Cause Analysis of Pressure Plate Breakage of Valve Limit Switch in Turbine Bypass System of Nuclear Power Plant

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**Abstract.** The limit switch plates of nuclear power plant unit 1 in the turbine bypass system valve are finding multiple fractures. On the basis of metallographic analysis and vibration analysis, the stress state of the pressure plate is simulated and calculated. The results show that there are some creases in the original plate of the limit switch and the installation error of the pressure plate is the main reason for the break.

## 1. Introduction

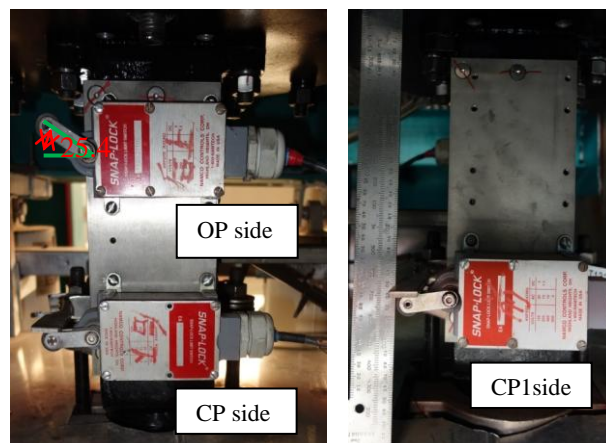
Turbine Bypass System (GCT) consists of the Condenser Steam System (GCT-c) and the Atmospheric Steam System (GCT-a). When the reactor power is not consistent with the turbine load, the steam turbine bypass system (short for GCT) discharges excess steam to the condenser, deaerator, the atmosphere, according to the actual situation. So that ensure unit safety by avoiding the nuclear steam supply system temperature and pressure exceeds the protection threshold. According to the different power levels of the unit, the steam turbine bypass line condenser control valve is used to maintain the power balance of the primary and secondary circuits during the turbine load rejection stage, manual control power plant operation stage or special steady-state operation phase<sup>[1]</sup>. GCT-c emission control valve has three groups; the opening order is GCT121VV, GCT117VV, and GCT113VV. As the operating characteristic of the GCT121VV is priority to open, so its action is relatively frequent.

GCT121VV valve limit switch pressure plate material is the 316 stainless steel, it triggers limit switch when running up and down. The failure of the pressure plate will cause the logic signal of fully open / fully closed cannot produce when the valve closing, these may affect the water level setting and the final power setting of the steam generator (short for SG) generate. And that will affect water level control of the SG, and it also influence the power, temperature, and water level of regulators automatically adjustment. By metallological analysis, vibration influence analysis and failure simulation analysis, this paper analysis manufacturing defects, operation problems and installation problems. Based on the analysis of the vibration, the failure model of the plate of the steam turbine bypass system is established. The root causes of GCT-c valve's limit switch plate failure reason are explored in the nuclear power plant.

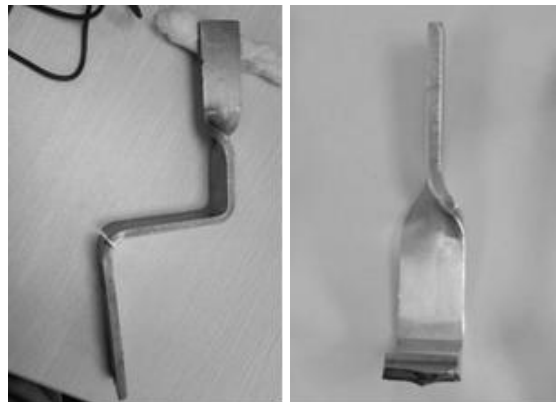
## 2. Metal performance analysis

The breakage pressure plate of the GCT121VV valve has CP1, OP and CP 3 limit switches. As shown in Fig.1, the OP side is used to display the fully open position of the valve, the CP side is used to show the valve clearance position, and participate in the final power setting settings functions, and the CP1 side is used to the feedback valve is open. On both sides of the stem connector, the limit switch has a pressure plate. There are two fracture plates on the site, see Fig2.



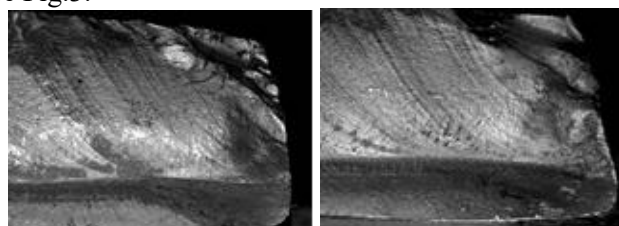


**Figure 1.** The limit switch of GCT121VV valve.



**Figure 2.** The fracture morphology of GCT121VV limit switch pressure plate.

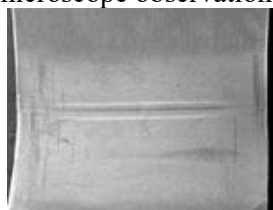
By inspecting, there are significant processing creases at the corner of the pressure plate. The cross section of the pressure plate is located at the crease. There was no significant plastic deformation in the rest of the area except for the slight plastic deformation of the outer side. The fracture surface can see fatigue beige line, see Fig.3.



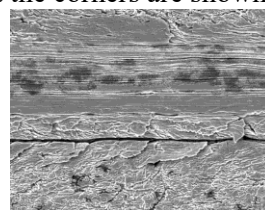
**Figure 3.** The analysis photo of pressure plate.

### *2.1. Electron microscopic observation of the pressure plate*

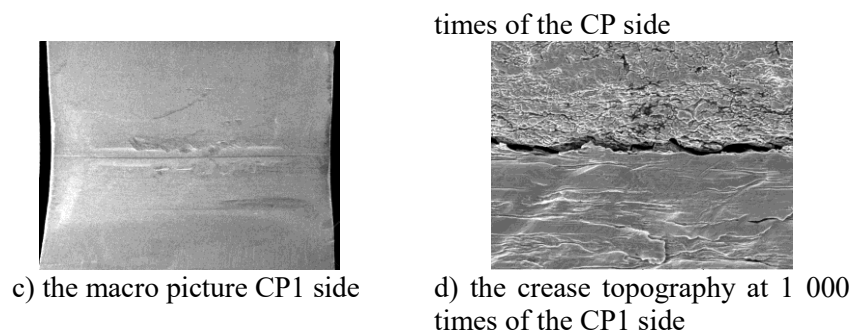
Scanning electron microscopy (SEM) was used to observe the microstructures of the fracture plates; the scanning electron microscope is TESCAN VEGA TS5136XM. Macroscopic observation and scanning electron microscope observation of the crease at the corners are shown in Fig.4.



a) the macro picture CP side;



b) the crease topography at 1 000

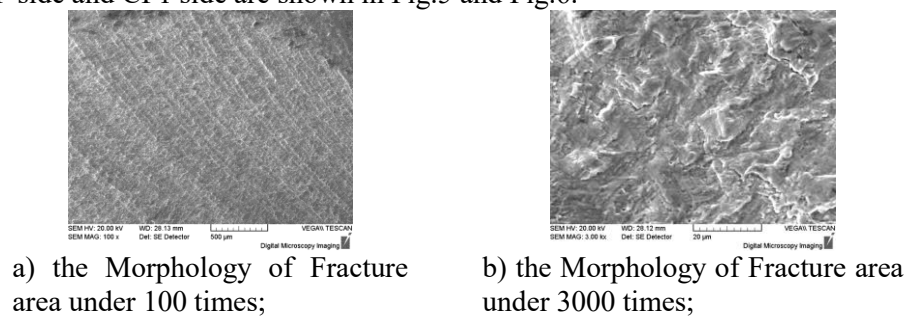


**Figure 4.** Microstructure of crease at the corner of the pressure plate.

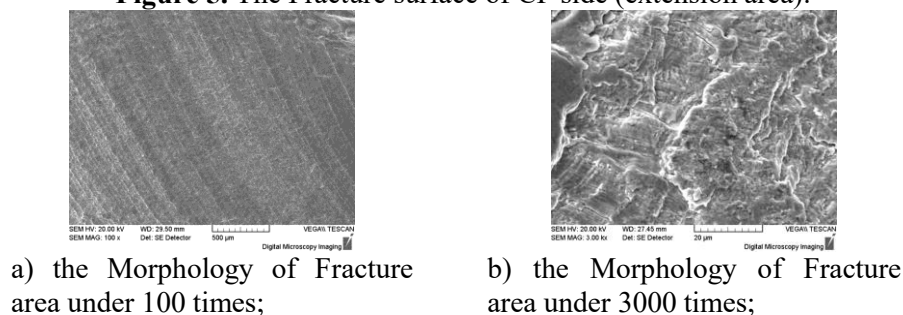
Microscopic observation of the crease at the corners show that there are obvious micro cracks on the edge of the CP side and the CP1 side, and the micro cracks of surface are the original manufacturing defects <sup>[2]</sup>.

## 2.2. Fracture surface analysis

Scanning electron microscopy (SEM) was used to observe the microstructures of the fracture plates; the scanning electron microscope is TESCAN VEGA TS5136XM. The extension area of fracture surface of CP side and CP1 side are shown in Fig.5 and Fig.6.



**Figure 5.** The Fracture surface of CP side (extension area).



**Figure 6.** The Fracture surface of CP1 side (extension area).

It is found that the fracture of CP side, CP1 side fracture plates are cracked by the inner surface of the inner arc and expanded at the angle of the outer arc side, and finally at the corner of the outer arc. Fracture extension area macroscopic visible white stripe lines, microscopic visible obvious fatigue characteristics.

## 2.3. Hardness analysis

The micro hardness test is carried out on each part of the press plate. The test equipment is 402MVD digital micro-Vickers hardness tester. The test load is 1kg and the holding time is 10s. According to the characteristics of the fracture, the micro hardness of the curved section, middle layer, outer arc section, straight section inner layer, middle layer and outer layer is tested. The results of hardness test on the CP side and the CP1 side plate is shown in Table 1.

The results of hardness test on the CP side and the CP1 side plate show that the hardness of the inner arc and the outer arc are higher than that of the middle layer. There is no obvious abnormality in the hardness of the press plate.

Table 1. The results of hardness test on the CP side and the CP1 side plate

NO.	position	hardness ( HV1 )				average value
CP side	the curved surface of the bend	329	320	329	338	329
	the outer arc of the bend	318	309	311	306	311
CP1 side	the curved surface of the bend	323	327	327	330	327
	the outer arc of the bend	293	296	294	293	294

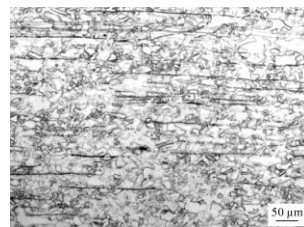
#### 2.4. Metallographic analysis

Metallographic specimens are prepared according to ASTM E3 "Standard Method for Fabrication of Metallographic Samples". Metallographic tests are performed on the CP side and CP1 side press plates of the fracture plates. The microstructure of the pressure plate is shown in Fig.7.

The result of metallographic examination shows that the structure of CP side press plate is austenite and ferrite. There is a deformation flow line and a slight dimple defect in the curved part. The inner arc and outer arc surface are not found cracks, and other defects. The organization of the pressure plate of CP1 side is also the austenite and ferrite, and on the plate, there are deformation flow lines. On the bending parts, the inner arc surface and the outer arc surface of straight parts are not found cracks, fine crystal layer defects.



a) the bending part of the middle layer of CP Side;



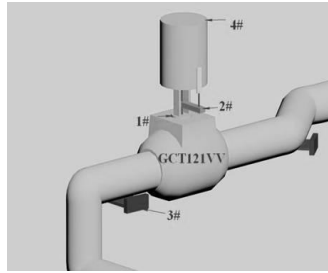
b) the straight part of the middle layer of CP1 Side

**Figure 7.** The microstructure of the pressure plate.

The results of scanning electron microscopy, metallographic analysis and hardness analysis show that, there are many surface micro cracks in the creases of the fracture plates; the grain structure of the inner surface of the pressure plate is not abnormal; there was no obvious abnormality in the hardness of the parts; the fracture surface of the arc surface side is the multi-source crack, expansion to the outward arc side<sup>[3]</sup>; Fracture microscopic observation shows typical fatigue flaky features on the fracture<sup>[4]</sup>.

### 3. Vibration analysis

The vibration of GCT121VV valve is analysed, vibration measurement position is shown in Fig.8, The vibration values of GCT121VV valve fully closed, 100% opening, 35% of the opening are measured, shown in Table 2. The vibration results show that the vibration of the GCT121VV valve is low frequency vibration. Comparing the results of vibration measurement with the vibration data of the same position of other nuclear power plants, the vibration level of GCT-c valve in this nuclear power plant is not obvious abnormality.



**Figure 8.** Vibration position of GCT121VV valve.

**Table 2.** The valve vibration value of GCT121VV (mm/s)

opening degree	1H	1V	1A	2H	2V	3H	3V	4H	4V	4A
0%	1.60	4.87	2.24	2.42	4.90	2.50	2.68	10.30	13.00	3.16
100%	9.82	9.13	10.30	14.70	13.30	11.80	13.10	15.70	13.90	10.32
35%	10.60	10.00	14.70	10.60	9.97	12.20	11.10	9.43	11.30	9.73

H—Horizontal vibration; V—Vertical vibration; A—Axial vibration

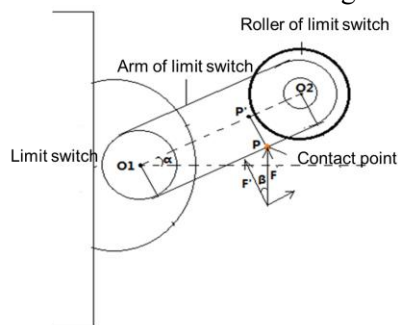
#### 4. Analysis of operating conditions

Measuring the stroke of the GCT121VV valve when it is in fully open and fully closed state, the whole stroke is 167mm. The stroke of the valve is consistent with the Equipment Operation and Maintenance Manual (short for EOMM); the process of positioning the feedback plate and other equipment did not scratch the situation.

Through the action test, it is found that there is no obvious impact phenomenon, and the pressure plate is not obvious deformation when the valve in the fast opening and closing process.

#### 5. Failure simulations

According to the size of the pressure plate and the installation operation, the stress state of the pressure plate is simulated. The limit switch action torque is 23in • lbs (about 2.599Nm), the swing arm length is 38.4mm. The force is about 67.4N when the limit switch just action (action stroke 10 °) by calculating, and the force is about 170N when the limit switch act to pressure to the limit position (Full stroke: 37 °). The force situation of limit switch is shown in Fig.9.



**Figure 9.** The force situation of limit switch.

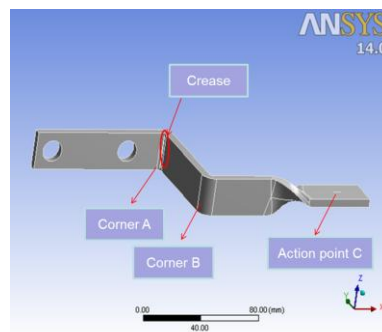
When the lower limit switch of GCT121VV valve is operating, if the pressure plate cannot be pressed to the roller directly during the action, the force arm will be shortened. Inspecting GCT121VV valve installation, finding that the upper limit switch arm and the pressure plate has contact marks. When the wheel directly contacts the arm it will cause the force increasing.

According to the size of the pressure plate and the installation and operation of the field, the finite element simulation analysis of the stress state of the pressure plate is carried out. The geometrical dimensions used in the modeling process are as follows: the actual thickness of the press plate is 5.5



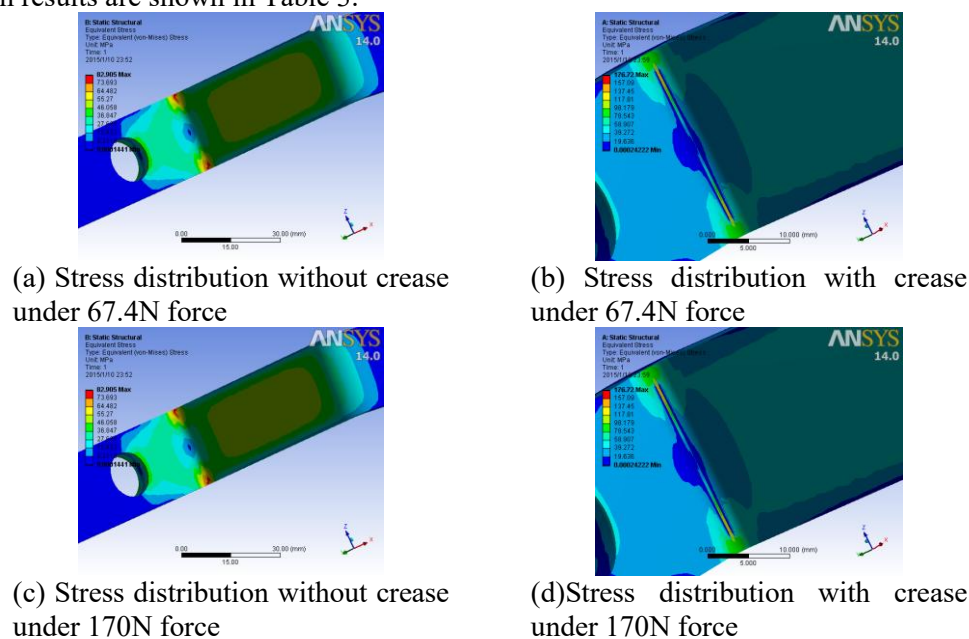
mm, the crease depth is about 0.2 mm, the crease and the width are 0.2 mm. The inner surface of the bolt hole is set to a fixed confinement boundary condition, and a concentrated force  $F$  which is vertically downward in the plate width direction is applied at the C of the right side of the platen. The simulation model is shown in Fig.10.

According to the angle of the scene, the position of the contact point and the analysis of the action stroke data, the pressure check force is 67.4N and 170N respectively.



**Figure 10.** The Simulation model of pressure plate.

The stress nephogram of pressure plate under different force are shown in Fig.11, and the stress calculation results are shown in Table 3.



**Figure 11.** The stress nephogram of pressure plate under different force.

**Table 3.** Stress calculation results (Mpa)

maximum equivalent stress	the roller touches the press plate	the roller is not touch the press plate
The corner of plate without creases	82.9	209.0
The corner of plate with creases	176.0	445.0

The stress distribution of the two kinds of press plates under different loads is simulated by finite element simulation, which is with and without processing creases. When the limit switch act, the roller is not contact with the pressure plate, and the force is 67.4N; when roller contacts plate, the force is

170N. The simulation results are shown in Table 3. The results show that the maximum equivalent stress of the corners is 445.7MPa, and the 316 stainless steel generally allowable stress of 480MPa.

The maximum stress of the crease plate at 170.0N (i.e. the plate pressures on the roller and close to the limit switch) is 445.0MPa, closing to the allowable stress of the material 480.0MPa. Compared with the non-crease plate, the stress of the crease part of the crease plate is obviously increased, and the stress concentration at the crease is obvious which is consistent with the failure of the failure plate, and it greatly reduces the strength of the pressure plate<sup>[5]</sup>. Inspecting the valve and finding that the valve is improper install. the upper limit switch on the valve arm and the pressure plate has contact marks, resulting in full stroke force of valve is more than 170.0N, the pressure plate crease stress exceeds the allowable stress.

## 6. Conclusions

The pressure plate of the nuclear power plant GCT121VV valve limit switch are not found abnormal in the microstructure, operating conditions and other aspects. However, there are original defects which are processing creases in the pressure switch plate. And in the crease, there is micro-crack, which results in stress concentration in the crease of the press plate during operating. The maximum stress of the creased plate at 170.0 N is close to the allowable stress of the material by stress check calculation, when the plate pressing on the roller and approaching the full stroke.

Under normal operating conditions, due to the problem of valve installation, resulting in the pressure plate cannot always press the roller and direct contact with the arm during the operation. So the valve full stroke action force is more than 170.0N, making the crease of the pressure plate beyond the material allowable stress. Limit switch plate at the corner of the crease part is the crack source, fatigue to the corner of the arc outside the expansion, and eventually break. Indicating that the original plate processing has problems, the pressure plate manufacturing quality is poor.

This limit switch type is different with other domestic nuclear power plant limit switch. It uses a bent steel plate to trigger the limit switch, if the limit switch is installed properly; it is easy to cause pressure plate cannot press on the roller and easily overpressure. At the same time, due to the actual installation of the difficulties, this type of GCT121VV limit switch cannot accurately adjust the limit switch position, which could avoid the upper limit switch arm contact with pressure plate

## 7. Improvement measures

Through the above analysis, the creases and micro cracks exist in the bending angle is the main reason of GCT121VV valve limit switch plate fracture. To prevent the occurrence of similar incidents, the following precautions should be taken:

- 1) Replace the same type of valve limit switch plate for GCT-c system of the nuclear power plant to ensure that the replacement plate has no quality defects, including no creases and micro cracks at the corner. And to check the blanks spare parts, requiring the manufacturer to provide quality qualified pressure plate.
- 2) To verify the installation of the nuclear power plant limit switch, adjust the limit switch which does not meet the requirements.

## References

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