Selection of Component through Failure Effect Analysis according to Verification Procedure for Non-Metallic Parts

Seo Bin Oh [a*], Soon Il Chung [a], Keo Hyoung Lee [a], Kang Min Park [a], Su Hyun Hwang [a], Jae Hyoung Lee [b]
[a]*FNC Technology Co., Ltd., 32 Fl., 13 Heungdeok 1-ro, Giheung-gu, Yongin-si, Gyeonggi-do, Korea*
[b]*Korea Hydro & Nuclear Power Co., 2040 Uljinbuk-ro, Uljin-gun, Gyeongbuk, Korea*
[*]*Corresponding author: ohsb0226@fnctech.com*

1. Introduction

A nuclear power plant consists of structures, systems, equipment and components. Nuclear power plants and facilities should be designed and installed to protect them from the natural environment or disasters, to withstand virtual accident conditions and to perform safety functions. In order to verify this, various performance verifications are required, including Environmental Qualification (EQ) of nuclear equipment.

EQ is to ensure that the equipment can be operated on demand to meet system performance requirements during normal and abnormal operating conditions and virtual Design Basis Accident conditions.

Environmental requirements for safety-related instrumentation and electrical equipment are clearly defined in terms of applicable requirements and verification procedures by legal requirements such as 10CFR50.49, Regulatory Guide 1.89 and IEEE Std. 323. However, domestic nuclear power plants do not have clear legal requirements or related verification programs for non-metallic parts such as gaskets, seals, packings and O-rings of safety-related mechanical component.

The US NRC recommends that the verification of non-metallic parts of mechanical component be carried out in accordance with ASME QME-1 QR-B1000-B7000 (Non-metal qualification guide). In addition, the Korean regulatory organization (KINS) raises the issue of establishing a detailed EQ procedure for safety-related non-metallic parts.

In this regard, research is being conducted in Korea to establish detailed procedures for EQ of non-metallic parts. For environmental impact analysis on non-metallic parts, the selection of non-metallic parts to be verified should be performed first. In order to select non-metallic parts for verification, Failure Mode and Effect Analysis (FMEA) was used to systematically identify and analyze malfunctions of sub-components of safety-related mechanical component.

This paper introduces the results of the FMEA for the selection of non-metallic parts for verification.

2. Selection of Non-Metallic parts and Failure Mode and Effect Analysis

Mechanical components non-metallic parts are parts that are vulnerable to temperature or radiation among mechanical components such as pumps and valves, which include gaskets, seals, packings, O-rings and diaphragm. Commonly used nonmetal materials include rubber and graphite. Rubber is flexible and can be manufactured in any shape. Graphite is used as a material for gasket and packing due to its excellent sealing property.

A list of non-metallic parts for mechanical component should be prepared for the FMEA. Mechanical component corresponding to the items of FSAR 3.11 environmental and earthquake qualification shall be targeted. The list of non-metallic parts shall be listed by referring to the manufacturer's manual.

Flow chart of non-metallic parts selection and FMEA is shown in Fig. 1.

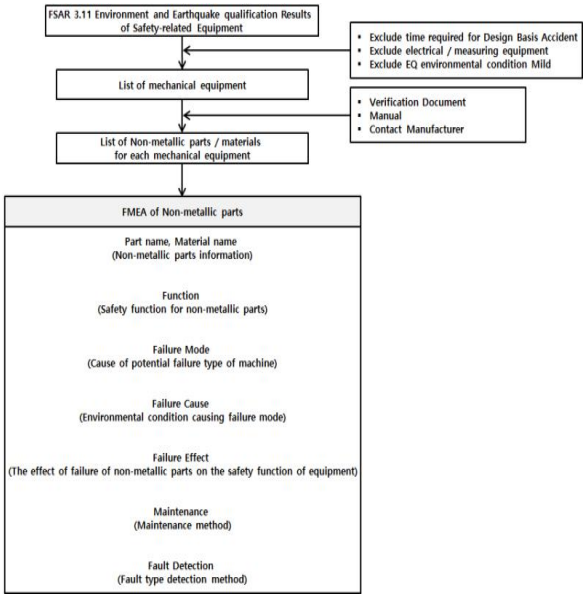

Fig. 1. Flow Chart of Non-metallic Parts and FMEA

2.1 Types of Non-Metallic Parts

Generally, non-metallic parts of valves include gaskets, seals, packings, O-rings and diaphragms.

The gasket is used by inserting it into the contact surface to maintain air tightness and water tightness. The seal prevents leakage from inside or intrusion from outside. The packing prevents high pressure fluid from leaking out of moving parts such as shafts. And then O-ring is a ring with a circular cross section that fits into the groove of the seal to maintain air tightness and water

tightness. Finally, the diaphragm is a thin, elastic membrane plate that measures pressure and opening / closing fluids.

Fig. 2 shows gaskets, seals, packings, O-rings and diaphragms.

Fig. 2. Types of Non-Metallic Parts

2.2 Failure Mode and Effect Analysis Result

The gasket, seal, packing and O-ring of the valve play a role of preventing the leakage of the fluid, but the amount of fluid leakage due to damage is very small and it is estimated that it will not affect the opening / closing function of the valve safety function.

However, diaphragm of air operated valve as shown in Fig. 3 provides the driving force of valve and it is estimated to affect opening / closing function of valve safety function such as not responding to signal or slowing down movement of air to transmit driving force in case of failure.

Table I shows FMEA example of valves.

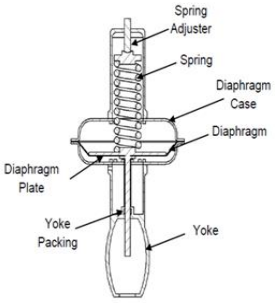

Fig. 3. Air Operated Valve Diaphragm

Table I: FMEA Example of Valve

Valve Name	Non-metallic Material	Non-metallic Parts	Equipment Name	Safety Function	Failure Effect
Check Valve Leakage Isolation Valves	EPDM	DIAPHRAGM	ACTUATOR	Valve Driving Force	If the DIAPHRAGM is damaged, air leaks to transmit the driving force to the global valve, affecting the inherent safety function of opening / closing.
Check Valve Leakage Isolation Valves	Unable to Verify	DIAPHRAGM	FILTER /REGULATOR	Air Filter Regulator Driving Force	Damage to the DIAPHRAGM causes the air pressure to operate the regulator to be lost, affecting the opening and closing of the valve's intrinsic safety feature.
SI Line Isolation Valves	GRAPHITE	GLAND PACKING	VALVE	Keep the Stem Sealed	Leakage due to damage of PACKING is small and this does not affect the opening / closing function of the valve
SC Pump Suction Check Valves	GRAPHITE	GASKET	VALVE	Keep the Body and Cover Sealed	Leakage due to damage of GASKET is small and this does not affect the opening / closing function of the valve
SIT Check Valves	GRAPHITE	SEAL RING	VALVE	Keep the Body and Cover Sealed	Leakage due to damage of SEAL RING is small and this does not affect the opening / closing function of the valve
SI Hot Leg Injection Line Relief Valve	EPR	O-RING	VALVE	Keep the Body and Seat Sealed	Leakage due to damage of O-RING is small and this does not affect the opening / closing function of the valve

It is the O-ring case of the mechanical seal that affects the equipment performance of the pump. The causes of failure are generally aging by heat and radiation, and failure modes are external leakage and internal leakage.

Air leakage may occur due to damage to the gasket, but the leakage is very low because it is tightened with bolts. It can be leaked to the outside due to damage of the seal, but it is estimated that it will not affect the pump safety function because it is a small leak. O-ring damage may weaken the sealing gap and cause leakage. However, a small amount of leakage does not affect the safety function of the pump.

Table II shows FMEA example of pumps.

Table II: FMEA Example of Pump

Pump Name	Non-metallic Material	Non-metallic Parts	Equipment Name	Safety Function	Failure Effect
SI Pumps (1,2,3,4)	GRAPHITE	GASKET	PUMP	Keep Sealed	Leakage due to damage of GASKET is small and this does not affect the safety function of the pump.
SI Pumps (1,2,3,4)	VITON	SEAL	PUMP	Keep Sealed	Leakage due to damage of SEAL is small and this does not affect the safety function of the pump.
SI Pumps (1,2,3,4)	PERFLUOROELASTOMER	GLAND GASKET	MECHANICAL SEAL	Keep Sealed	Leakage due to damage of GASKET is small and this does not affect the safety function of the pump.
Containment Spray Pump (1,2)	PERFLUOROELASTOMER	O-RING-CASE	PUMP	Keep the Pump case and Pump cover Sealed	Damage to O-RING-CASE may affect the fluid transfer, a safety function of PUMP, when air enters through the pump case and pump cover.
Containment Spray Pump (1,2)	KALREZ	O-RING	MECHANICAL SEAL	Maintain Seal Clearance	Leakage due to damage of O-RING is small and this does not affect the safety function of the pump.

3. Conclusions

Internal leakage from pumps and valves, which are mechanical component, affects nuclear power plants or safety functions. In order to prevent this, in this paper, the FMEA method is used to analyze the performance of mechanical component such as pumps and valves due to non-metallic parts. FMEA systematically identifies and analyzes how sub-components of safety-related mechanical component affect safety functions, resulting in a list of non-metallic parts to be verified, such as gasket, seal, packing, O-ring, diaphragm.

Non-metallic parts that later affect the performance of mechanical component need to be subjected to EQ. In addition, according to the results of the EQ, the nuclear power plants should be replaced with verified parts or periodically replaced according to the equipment life recommended by the manufacturer.

REFERENCES

[1] 10CFR50.49 “ Environmental Qualification of Electric Equipment Important to Safety for Nuclear Power Plants”, 1991.
[2] IEEE Standard 323-2003 “ Qualifying Class 1E Equipment for Nuclear Power Generating Stations”, 2003.