The Design Loads in a Design Specification of a Main Coolant Pump for the Integrated Reactor

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1. Introduction

A main coolant pump (MCP) is installed directly on the integrated reactor, so it does not have any pipe connections to pump outside. The MCP interfaces with only the inner bodies of the integrated reactor while the commercial reactor pump (RCP) interfaces with large diameter pipes which are connected to the outer components of the commercial reactor. The MCP design loads are defined at the interface regions, a flange, a flow body and a flow guide duct under the seismic events. In case the RCP, the design loads are defined at the Snubbers, a suction nozzle and a discharge nozzle under the seismic events.

The MCP is a canned motor axial pump and both a motor and an impeller are located in a pressure container[1]. Independent cooling water circulates in the MCP and cools the motor during a normal operation. The complicated thermal loads due to the independent cooling water are produced on a flange, an upper cover, and a stator base under a normal operation. The RCP impeller is separated from a motor by a seal mechanism. The RCP impeller casing is a simple shape and a primary pressure boundary. The primary pressure itself is enough to be considered as the design load for the normal operation.

In this paper, the MCP design loads are presented under the normal operation, plant transient conditions and the seismic events except a branch line pipe break (BLPB) event.

2. Regulations

General Design Criterion (GDC) 1 of Appendix A to 10 CFR Part 50 requires that components important to safety be designed to quality standards. Section 50.55a of 10 CFR Part 50 requires that components of the reactor coolant pressure boundary be designed in accordance with the requirements for class 1 components of the ASME Section III. GDC 2 requires that components important to safety be designed to withstand the effects of earthquakes without a loss of capability to perform their safety functions.

Regulatory guide 1.29 specifies the seismic design classification of a nuclear component. Regulatory guide 1.26 specifies the quality classification of it. ANSI/ANS-51.1 specifies the safety classification of it. The MCP which sustains the primary pressure boundary is classified as a seismic category I, quality A and safety class 1 according to the regulations above. The safety class 1 is the same as the ASME Section III class 1. The component designer shall evaluate the mechanical integrity of the class 1 component in accordance with ASEM Section III with the design loads.

3. Design Loads

3.1 Normal Operating Loads

During a normal operation, thermal loads and mechanical loads are acting on the primary pressure boundary of the MCP. Temperature gradient on the surface produces thermal loads. Operating pressure, dead weight and clamping bolt loads produce mechanical loads. The dead weight of the MCP component is a minor portion in comparison with the pressure force, so it is excluded from the calculation. The flange, upper cover and stator base are the pressure boundary of the MCP. Only the flange is selected for explaining the design load generation because the method to generate its design loads is similar to other parts.

Forced convection heat transfer coefficient should be calculated at the flange's inside and free convection heat transfer coefficient should be calculated at the flange's outside. The flange's inside is divided into three regions commensurate with the flow area size. The thermal loads of the flange are shown in Fig. 1 and the thermal load values[2] are shown in Table 1.

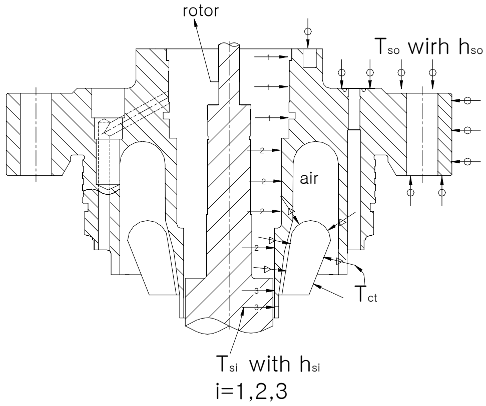

Fig. 1. Thermal Load Acting on the MCP Flange

The operating pressure acting on the flange surface is 14.7MPa. The flange has a particular shape to envelop the stator coil of the MCP motor. This complex shape causes an area reduction that produces a higher compression force than the magnitude of the operating pressure. The clamping loads by the bolts are also generated in Reference 1.

Table 1. Thermal Load Values of the Flange

Notation	Heat Transfer coefficient and Temperature
h_{so}	5.77 W/m^2℃
T_{so}	60℃
h_{s1}	398 W/m^2℃
h_{s2}	644 W/m^2℃
h_{s3}	14,530 W/m^2℃
T_{s1}	70℃
T_{s2}	70℃
T_{s3}	70℃
T_{ct}	112℃

3.2 Transient Conditions

All plant service transients anticipated or postulated to occur during the intended service life of the component shall be considered for evaluating the MCP fatigue integrity. The information of the pressure, temperature, flow rate and the numbers of transient cycles shall be provided for the transient data pertinent to the MCP. The transient data shall be classified as Level A, B, C, and D service conditions. The component designer shall evaluate the MCP fatigue integrity according to the ASME Section III with the service transients.

3.3 Seismic Loads

The system designer of the MCP receives the safe shutdown earthquake (SSE) load at the fixed region of the MCP from other design group. Using the SSE load, the system designer calculates the interface loads that occur at the MCP interface regions. The interface loads are the minimum loads that the component designer needs. The interface regions of the reactor vessel are the flange, flow body, flow guide duct and cooler ends. The load configuration at interface regions is shown in Fig. 2.

The values of the interface loads, that are calculated using the SSE load[3], are shown in Table 2. Location A, B, and C mean the locations at the flange, flow body and flow guide duct, respectively. The displacement D_x and D_y in Fig. 2 are 0.00347mm and 0.000385mm, respectively. The operating basis earthquake (OBE) effect can be obtained by applying 0.7 times the SSE result loads.

4. Conclusion

The MCP design loads are generated for two kinds of conditions, the normal operation and the seismic events. The complicated thermal loads and the mechanical loads are calculated for the MCP design loads under the normal operation condition. The external loads at the MCP interface regions are calculated for the MCP design loads under the seismic events.

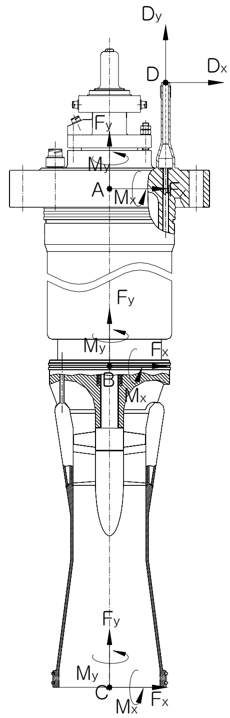

Fig. 2. Reaction Load Locations due to the SSE

Table 2. Reaction Loads due to the SSE

Location	Reaction Force (N)		Reaction Moment (N m)	
	Shear (Fx)	Axial (Fy)	Bending (Mx)	Bending (My)
A	4,542	4,515	2605	0
B	644	0	0	0
C	136	0	0	0

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