Finite-Element Analysis of the Series-Connected Hybrid Hydrant

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Introduction

The hydrant of the Series-Connected Hybrid (SCH) magnet which is bolted underneath the main frame of the SCH, supports the insert resistive magnets through a cylindrical, central tube. The hydrant mechanically transports all loads and the weight of the insert to the SCH cryostat. At the same time, the external hydraulic system is connected to the hydrant circulating coolant through the insert resistive magnets to control the temperature of the resistive coils. A quarter section view of the hydrant is shown in Fig. 1. The coolant flows into the structure through pipe P2, flows through the magnet, returns between double walls in the hydrant and then flows out of the structure through pipe P3. Therefore, the hydrant is a pressure vessel and requires extensive structural integrity analysis. In this research report, advanced finite element analysis (FEA) is used as the primary tool in the design optimization of the hydrant. The design is made in accordance with the new 2013 ASME Boiler & Pressure Vessel Code (BPVC) Section VIII Div. 2 rules. The water flow within each component of the hydrant is checked and compared with the water flow in the 45-T Hybrid system at the NHMFL.

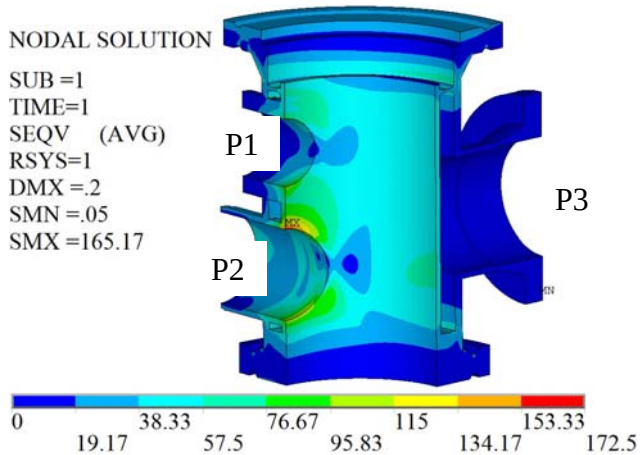

Fig.1. Distribution of von-Mises stress in SCH hydrant during normal operation

FEA Results

FEA is used to solve the stress distributions in the hydrant for different working scenarios, i.e. during normal operation, hydraulic testing and fault conditions such as an insert coil short. After each analysis, the stresses across the thickness of the pressure vessel are evaluated and compared with allowable values defined by BPVC to ensure every component will have enough integrity. Fig.1 is an example of the von-Mises stress distribution in the SCH hydrant during normal operation. The stress contour is capped by the maximum allowed local primary bending plus membrane limit (i.e. 172.5 MPa) in BPVC. It is seen that the local peak stress is less than the allowable limit indicating that the structure is safe during normal operation.

Table 1. Hydraulics in each part of the SCH hydrant and comparison with parts in 45-T

Hydraulics			
SCH		45T	
Max flows (l/s)	138.10	Max flows (l/s)	258.67
Part	Velocity (m/s)	Part	Velocity (m/s)
Inlet 2x8" SCH 80	2.34	Inlet 12" SCH80s	1.85
Outlet 1X10" SCH 80	2.87	Outlet 18" SCH 80s	1.77
Return Flow (in annular zone)	2.23	Return Flow (in annular zone)	4.69
OW&P3 connection	4.52	OW&outlet pipe connection	6.01
Stiff ring	6.36		

Hydraulics

The water velocity of each component in the hydrant is listed in Table 1 and compared with the flow in the 45-T hybrid magnet. The water speeds in general paths (e.g. in P2, P3 and between double walls) are less than the proofed working value, i.e. 3 m/s. The water speeds in local paths (e.g. connections and stiff ring) is comparable to local zone water speeds in the 45-T.

Conclusions

The current design of the SCH hydrant has been evaluated to be safe in operation from both mechanical and hydraulic aspects. It is ready for the next step towards construction.

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