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IEAR1 Renewed Primary System Pump B1B Nozzles Stress Analysis

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1. Introduction

The IEA-R1 is an open pool-type Research Reactor moderated and cooled by light water using beryllium/graphite as reflector. The reactor can reach up to 5MW heating power and coolant by two system composed by primary and secondary system. The primary coolant system consist of piping system, a decay tank, two pumps and two heat exchangers [1]. All parts of the primary system are monitoring by data acquisition system, which provide date for the Maintenance Management Program. This way the pump B1-B presents some failure requiring being refurbishment by a new one. Every pump equipment manufacturer has its own requirements for its specific pump models. The requirements to use a pump in research reactor must follow some requirements and specifics codes, design and operational requirement of the IEAR1 Reactor [2]. Aiming the best equipment purchase a detailed specification was prepared to acquire the new Pump. This report present the structural evaluation of the pumping nozzles applying the elastic stress analysis method by Finite Element Model (FEM) [3], the pump and material specification are based on the data book of supply company *AcquaVitae* to the Pump model EQHE-250-29 [4].

2. Methodology

The stress analysis of the new B1B pump nozzles was done following the methodology presented below. First, all properties of the Primary System and the new Pump was collected. Tables I and II shows the summary of the properties used to analyze the pump.

Table I: Table of the Design and Operational process data of the Reactor.

	Pressure (MPa)	Temperature (ºC)
Design	0,69	65,6
Service	0,25	43,9

Table II: Table of the Pump material specification. [5]

	Material	E (Mpa)	SU (Mpa)	SY (Mpa)	SH (Mpa)
Nozzles	A351 CF8	195000	485	205	136
Body	A743 CF8M	195000	485	205	136

The new body pump demand small modifications in the piping trace, therefore the review of the piping stress analysis [6] was done and demanding the added of a new piping support as a consequence redistributing the values of the forces and moments in the piping system. The calculation model was done in accordance with the new routing of the lines and was simulated with the computer program CAESARII [7].
The applied loads used in this analysis comes from this new piping condition. A 3D model of the new Pump

was developed based on preliminary model provided by the supplier and it is used in the FEM analysis model processing in the *Ansys* program [8].
The accompanying Fig.1A shows the Pump-motor set and the Fig. 1B shows the 3D model used by *Ansys* program to perform the stress analysis of the Pump Nozzles. The body pump was decoupled from the skid set to better analyze the nozzles and the 3D model developed was simplified.

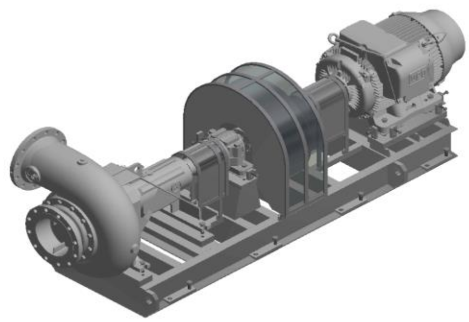

Figure 1A: IEAR1 New Pump-motor set B1B

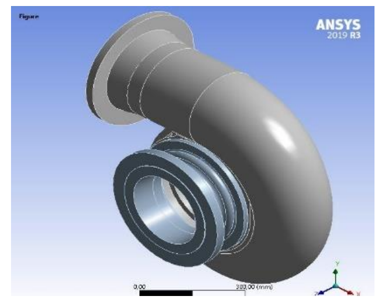

Figure 1B: Ansys 3d Model

The Table III shows the applied loads considering design and service condition adding Mechanical loads and Mechanical decoupling loads.

Table III: Table of the loads considered in the Analysis.

Design Condition	Operational Condition
Design Pressure	Service Pressure
Dead Weight	Dead Weight
Mechanical Loads	Operating Temperature
Mechanical Decoupling Loads	Mechanical Loads
	Mechanical Decoupling Loads

The Table IV shows the applied loads considering design and service condition. The case 1(OPE) means Pump B1B in line with Heat Exchanger 1(IESA), the case 2(OPE) means Pump B1B in line with Heat Exchanger 2 (CBC) and the load case 3(SUS) means Sustained (dead weight) as described in the following.

1(OPE) weight (pipe+water+valve+nozzle) + thermal (pump B1B + HE1 – “on”)
2(OPE) weight (pipe+water+valve+nozzle) + thermal (pump B1B + HE2 – “on”)
3(SUS) weight (pipe+water+valve+nozzle)

Table IV: Table of Forces and Moments

Nozzles	Load Case	Force (N)			Moment (Nm)		
		X	Y	Z	X	Y	Z
Suction	1(OPE)	-5728	6183	-2536	-8231	-5310	-2970
	2(OPE)	-5831	6685	-2824	-8646	-5405	-3029
	3(SUS)	-104	52	-114	4	-118	-5
Discharge	1(OPE)	1814	-2763	12443	-609	9744	1803
	2(OPE)	192	-2831	2028	-429	1599	1891
	3(SUS)	-140	-2845	-98	-393	-64	1909

The stress analysis was developed by the ASME code VIII, division 1 [9]. The code do not contemplate the requirements of Design by analysis of ASME VIII, Division 2, [10] which is usually employed in the stress analysis of equipment nozzles. Nevertheless, the paragraph "U-2(g)" of ASME VIII, Division 1, allows that the designer develops procedures for equipment design, where the code doesn't have specific rules, "setting" the design criteria of ASME VIII, Division 1. These design criteria are satisfied applying Part 4 or Part 5 of ASME VIII, Division 2, with the allowable stress from ASME VIII, Division 1. Therefore, in order to evaluate the protection against plastic collapse, the results of a linear elastic stress analysis of a component, subject to loads due to design pressure and mechanical loads, may be classified and compared to associated limits, with the allowable stress SH= 138 MPa from ASME VIII, Division 1. The equivalent stresses are calculated using the Von Mises criterion [11]. Table V shows categories of equivalent stresses and limits defined according to ASME VIII, Division 2.

Table V: Table Stress Categories and Limits

Pm	General Primary Membrane Stress		
PL	Local Primary Membrane Stress		
Q	Secondary Stress		
Limits	Pm ≤ SH ;	PL ≤ 1.5xSH ;	PL + Q ≤ 3.0xSH

3. Results and Discussion

The obtained results for the maximum calculated stress and linearized equivalent stress are showed in the table VI.

Table VI: Table of the Stress obtained from Design and Service Loads

Nozzles	**Design**				**Service**			
	Calculated (MPa)	**Figure**	**Category**	**Limit (MPa)**	**Calculated (MPa)**	**Figure**	**Category**	**Limit (MPa)**
Suction	60.6	2A	Maximum Stress	136.0	54.4	2C	Maximum Stress	136.0
	15.4		P_M	136.0	12.4		P_M	136.0
	42.5		P_M+P_B	136.0	35.5		P_M+P_B+Q	136.0
Discharge	59.1	2B	Maximum Stress	205.0	54.2	2D	Maximum Stress	205.0
	40.0		P_L	205.0	27.6		P_L	205.0
	59.3		P_L+P_B	205.0	51.1		P_L+P_B+Q	410.0

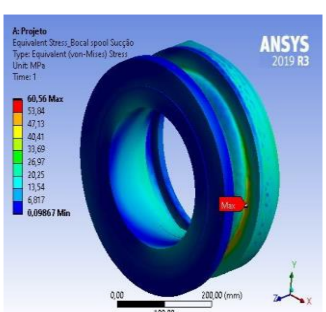

Fig. 2A - Design/Suction

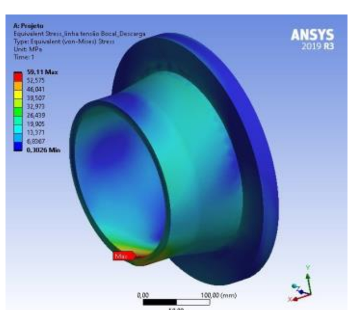

Fig 2B – Design/Discharge

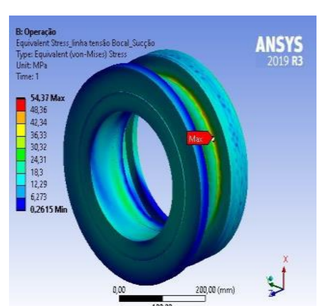

Fig. 2C – Service/Suction

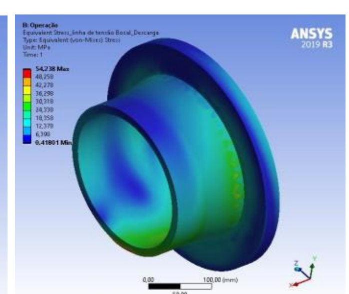

Fig. 2D: Service/Discharge

The maximum stress appears in figures from 2A to 2D, while the linearized stress are presented in the Table VI, in the column “calculated”. The categorization of the linearized equivalent stress occur in the maximum stress region.

4. Conclusions

The stress analysis of the suction and discharge nozzles of the new B1-B Pump was carried out with the development of a numerical calculation model applying the Finite Element method with the computer program for structural analysis ANSYS. The calculated stresses at the suction and discharge nozzles of the new B1-B Pump meet the limits prescribed by the ASME code, Section VIII, Division 1 & 2, for the plant in the design and operating condition. Therefore, the new B1-B Pump is approved for operation at the IEA-R1 Nuclear Research Reactor Primary Circuit.

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