15th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2011, Prague, Czech Republic, 12-18 September 2011

RECALCULATION OF PIPING SYSTEMS FOR LIVE AND INTERMEDIATE SUPERHEATED STEAM WITH MEASURED VALUES R_m AND $R_{p0,2}$

Professor Dr. Dusan Vukojevic,
Faculty of Mechanical Engineering Zenica, Bosnia and Herzegovina

Mr. Dino Tica TPP Kakanj, Bosnia and Herzegovina

ABSTRACT
Fresh steam steam pipe as an integral part of block 5, with 110 MW in the TE "Kakanj" are in operation since the commissioning of this block of 1969th years and 31.12.2005. The total generated 186,953 operating hours. By early July 2008. The total number of operating hours has passed 190,000. Block has had more than 1,000 starts, of which about 500 were cold after a delay longer than 32 hours. The survey was conducted in accordance with technical requirements of a series of European standards EN 13 480 or EN 13 480 standard-Part 5: Inspection and testing.
Keywords: High-pressure steam pipe

1. INTRODUCTION
This calculation follows up stress forces and remaining service life of pipelines for fresh and superheated steam at the 5th block of the power plant KAKANJ 100MW. Besides standard input data (pipeline geometry, assembly adjustment of flexible suspensions, assembly prestressing, mechanical and physical properties of materials), were submitted and results of ultrasound measuring of wall thickness at selected points of both piping systems. Based on the input data, relevant calculation models were set up and static stress calculation were made. Following these calculations it can be said that, considering the high corrosive and erosive attrition and degradation of the material, indicated by low values of hardness measured, both piping systems are at the end of their service life. It was recommended to replace both the piping systems as their continuing usage may be dangerous. Take samples of materials from certain points of the pipeline, tested them for hardness, impact resistance and elongation to fracture and measured the values R_m a $R_{p0,2}$. Results of these tests were submitted in order to enter the results into the computing models and to reassess the strength and service life of the pipelines and reconsider possibilities of extending the steam line service life by 13,000 hours.

2. COMPUTATION MODEL OF PIPING SYSTEMS
Calculations were made with the original computation models using the actual measured wall thickness values. Geometry, boundary conditions, pre-stress and calculated loads are retained completely. Material of both pipelines : ČSN 15 123.1. Mechanical and physical values of the material are taken from the original material sheet ČSN 41 4123 only for reduced inside diameters before turbine. The general inside diameters (DN200 for live steam and DN350 for intermediate superheated steam) use measured values of strength and shear limits.

a) Live Steam Pipeline
Computation model according to 0 POT 4794
Working steam parameters: p = 139 ata, t = 545°C
Dimensions and Execution of Piping Components:

pipes : ∅245 x 28, ∅159 x 18
smooth elbows : ∅245 x 28, R = 1100mm ∅159 x 18, R = 750mm, R = 600mm

Due to the static nature of the load, the set-out of gravity center of fittings is not considered.
Mechanical properties of materials used, as measured on the samples:

- at the temperature of 545°C R_m = 268 MPa, $R_{p0,2}$ = 191 MPa
- at the temperature of 20°C R_m = 489 MPa, $R_{p0,2}$ = 273 MPa

b) Intermediate Superheated Steam Pipeline
Computation model according to 0 POT 4795
Working steam parameters: p = 35.5 ata, t = 545°C
Dimensions and Execution of Piping Components:

pipes : ∅377 x 14, ∅324 x 12
bending elbows : ∅377 x 14, R = 1400mm ∅324 x 12, R = 1200mm
∅377 x 14, R = 1050mm ∅324 x 12, R = 900mm

Mechanical properties of materials used, as measured on the samples:

- at the temperature of 545°C R_m = 246 MPa, $R_{p0,2}$ = 150 MPa
- at the temperature of 20°C R_m = 460 MPa, $R_{p0,2}$ = 265 MPa

The original material ČSN 15 123 has the measured creep limit up to 10^5 hours. The service life diagram for the material 15 123 contains theoretical service life curves up to 10^6 hours, which are used for estimation of remaining service life of live and intermediate superheated steam piping systems. All factors of stress and reduced stress according to τ_{max} theory were computed for both piping systems. Up till now, both pipelines have been in operation for approximately (1.85 – 1.90)x10^5 hours. The customer envisages another 1.3x10^4 operating hours, thus totalling to approximately 2.0x10^5 hours. According to the service life diagram (Enclosure P1), the given operating temperature t = 545°C and required time to fracture 2.0x10^5 hours have to match to the maximum permissible stress level (to fracture) σ_L = 90 MPa. It is also necessary to determine appropriate safety measures to this stress limit value, following from comparison of minimum table-based and actual (measured on samples) values of mechanical properties. Such a comparison (as for 20°C, the material sheet does not indicate any values for working temperature 545°C) is in the following table:

Table 1. Minimum Table and Measured Mechanical Values for Steel 15 123 at t = 20°C

Material ČSN 15 123	Rp0,2 [MPa]	Rm [MPa]	HVB [-]	R [J/cm2]
Live steam (OP)	273	489	143 - 148	18 - 107
Intermediate Superheated Steam (MPP)	265	460	150 - 153	10 - 58
Material Sheet	294	471	135 - 183	49

Based on the table 2 and the Enclosure P2, containing a complete set of values measured on samples, the following conclusions can be arrived at: minimum shear limit is reduced for OP or MPP by 7% and 10% respectively, for OP the maximum measured Rp0.2 is lower than the minimum table value; measured minimum R_m is approximately equal to the table value; measured hardness is within the table interval; measured impact values are very scattered and minimum values very low. This indicates advanced degradation of the material; based on the data from the previous paragraph, we consider the minimum safety for determining permissible level of stress k = 1,5. This means that for the time to fracture 2.0x10^5 hours (= for extending the steam line service life by 13,000 hours) it is necessary to determine the stress at the time to fracture 1.5 times longer, i.e. at 3.0x10^5 hours. According to the service life diagram, this corresponds to the maximum permissible stress level of σ_{red} = 76.0 MPa

Table 2. Calculated Stress at Normal Working Load – Intermediate Superheated Steam System (calculating nodes, sorted by σ_{red})

GENERAL PIPE STRESS REPORT (Stress in N/mm2)										
Calc. node	Stress	Tangent.	Axial stress		Shear	General stress		Reduced		Safety
	combined	stress	Max	Min	stress	Max	Min	stress (σ_{max})	Loc	K
C03 F-	GT1P1	46.0	104.9	-64.6	0.7	104.9	-64.6	55.3	285.0	1.37
C04 N+	GT1P1	46.0	104.3	-63.8	0.7	104.3	-63.8	54.9	90.0	1.38
C03 N+	GT1P1	46.0	97.2	-57.1	14.4	100.6	-59.0	53.5	285.0	1.42
A44	GT1P1	46.2	103.2	-60.3	5.8	103.3	-60.5	53.5	60.0	1.42
C04 F-	GT1P1	46.0	96.5	-55.9	14.4	100.0	-57.9	53.0	105.0	1.43
D03 N+	GT1P1	46.0	98.5	-58.4	-7.1	99.6	-59.0	52.8	75.0	1.44
B46	GT1P1	46.2	99.6	-57.0	-1.4	100.1	-57.0	51.6	270.0	1.47
D04 N+	GT1P1	46.0	92.5	-51.8	6.6	93.0	-52.3	49.3	255.0	1.54
D04 F-	GT1P1	46.0	89.3	-48.7	-6.2	90.3	-49.1	47.8	270.0	1.59
D01	GT1P1	46.0	85.1	-47.2	-7.1	86.6	-47.8	47.2	165.0	1.61
B12 F-	GT1P1	52.2	85.2	-39.6	7.4	86.4	-40.2	46.5	345.0	1.64
C02	GT1P1	46.0	79.8	-40.7	14.4	84.6	-43.0	45.7	195.0	1.66
C01	GT1P1	46.0	78.5	-40.5	14.4	83.4	-42.8	45.6	180.0	1.67
D03 F+	GT1P1	46.0	80.7	-40.2	6.6	81.3	-40.7	43.6	255.0	1.74

Conclusion : The calculation shows 3 points in the piping system which are under such operating loads that the 1.5 times safety as to the time to fraction in operation up to 2.10^5 hours cannot be guaranteed.

Tab.3 Calculated Stress at Normal Working Load – Live Steam System (calculating nodes, sorted by σ_{red})

GENERAL PIPE STRESS REPORT (Stress in N/mm2)										
Calc. node	Stress	Tangent.	Axial stress		Shear	General stress		Reduced		Safety
	combined	stress	Max	Min	stress	Max	Min	stress (σ_{max})	Loc	K
A40	GT1P1	55.1	108.4	-67.1	20	115.1	-70.3	111.6	356	0.68
J01 -	GT1P1	55.1	100.1	-58.9	28.9	114.2	-65.8	110.7	275	0.69
D02 N+	GT1P1	66.6	98.5	-46.2	22.5	110.1	-50.5	105.6	60	0.72
B00	GT1P1	54.5	105.6	-64.3	4	105.9	-64.4	103.3	358	0.74
A00	GT1P1	54.5	99.5	-58.2	4.3	99.9	-58.4	97.9	352	0.78
D01	GT1P1	55.1	91.4	-50.2	20	100.3	-53.9	97.6	91	0.78
J01 +	GT1P1	11.7	83.6	-75.4	28.9	93.8	-84.1	96	275	0.79
D02 N-	GT1P1	55.1	85	-43.9	20	95.1	-47.8	92.7	86	0.82
G11	GT1P1	55.1	90.4	-48.3	1.9	90.5	-48.4	89.7	165	0.85
G11 -	GT1P1	55.1	88.6	-46.7	3.9	89.1	-46.8	88.5	353	0.86
L02 N+	GT1P1	67.5	85.8	-32.7	0.6	85.8	-32.7	88.5	307	0.86
F07 -	GT1P1	55.1	79.2	-39.1	15.9	87.1	-41.7	86.5	78	0.88
B38	GT1P1	55.1	84.1	-43	0.5	84.1	-43	85.1	353	0.89
H01 -	GT1P1	55.1	82.4	-40.4	1.9	82.5	-40.4	83.1	17	0.91
D02 F-	GT1P1	66.6	64.9	-12	22.2	87.9	-17.8	82.7	45	0.92
F07	GT1P1	55.1	54.9	-13.7	28.9	83.9	-24.2	80.5	248	0.94
F04 F-	GT1P1	70.1	61.9	-6.5	18.5	84.9	-10.7	80.2	89	0.95
F06	GT1P1	55.1	70.9	-30.8	15.9	80.8	-33.6	80.2	280	0.95

M04	GT1P1	54.5	76.1	-34.7	1.1	76.2	-34.7	77.9	184	0.98
L01	GT1P1	55.1	74.7	-33.7	0.5	74.8	-33.7	77.6	99	0.98
L02 N-	GT1P1	55.1	72.8	-31.8	0.5	72.8	-31.8	76.2	101	1.00
L02 F-	GT1P1	67.5	49.1	5.1	20.8	81.1	-1.2	74.5	18	1.02
A04	GT1P1	54.5	66.8	-25.5	4.3	68.2	-25.8	71.2	186	1.07
N04	GT1P1	54.5	65.7	-24.7	3.5	66.7	-24.9	70.5	195	1.08
A03	GT1P1	54.5	59.4	-18.1	4.3	61.9	-18.4	65.9	190	1.15

Conclusion: The calculation shows 21 points in the live steam piping system which are under such operating loads that the 1.5 times safety as to the time to fraction in operation up to 2.10^5 hours cannot be guaranteed. At a total of 8 points, the time to fraction is even shorter than 2.10^5 hours.

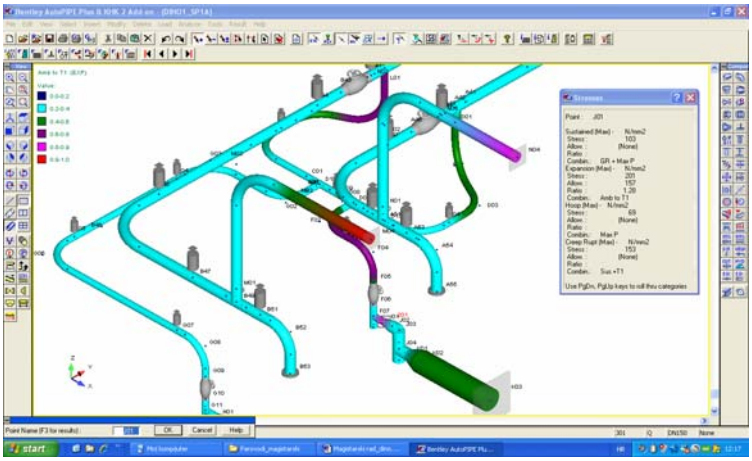

Figure 1. Graphic display of maximum stress steam fresh steam

3. SUMMARY OF RESULTS

Stress calculations in the live and intermediate superheated steam systems indicates that both systems are bordering the very end of their service life. This opinion is corroborated by results of mechanical properties as measured on samples of the material from both pipelines, particularly the impact values (minimum values for MPP 10 J/cm^2, and 18 J/cm^2 for OP are quarter and half respectively to the normal values).

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