Structural Analysis of Live Steam Pipelines in the Context of the Replacement System Hanger

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Abstract. In the article subject matter associated with endurance analysis of the pipeline of fresh steam was brought up with using the finite element method calculations described at the work allowed for the validation of effected modernizations of the arrangement of fastening. It enabled also to determine the technical condition of the pipeline and to suggest of further solutions in the destination of the improvement in the work of the object [1].

Keywords: Power engineering · Power boilers · Live steam pipelines · Finite element methods

1 Introduction

They are playing fastening the pipeline important part in the correct work of the installation. The proper selection and the use are ensuring the permanent vitality of the object long and consequently smaller running costs. Also a safety is a relevant aspect of the correct work of the element. Inadequately acting can cause fastening the collision with the supporting structure and creating the stress concentration in material of the pipeline [2].

Therefore in the following article he was brought up with problem of correct conducting the structural analysis of pipelines of fresh steam after the modernization of permanent-weight suspensions. A wrong work of the system of fastening the pipeline in the hot state which it caused was a reason of the exchange wrong dynamic transfers of permanent-weight suspensions from one putting the thermal state in the work in the second estate. Two thermal states of the work of the pipeline of fresh steam are being distinguished:

Cold condition - it is state of the pipeline in which triggered burdens of the increased temperature aren't appearing, the pressure and the weight of the factor. Powers working on the pipeline come exclusively from the weight of the pipeline along with insulatio.

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Hot state - it is state of the pipeline in which the full load is appearing. Burdenit is triggered both with the temperature, the pressure and the weight.

While passing the pipeline from the state of the cold food to hot dynamic transfers are appearing, tied they are with the increase in powers of threshold permanent-weight suspensions. Threshold powers are needed for overcoming internal resistances of suspension at passing the pipeline from one thermal state in second. During the long-term work of suspensions threshold forces are increasing, contributing for big burdening springs what in consequence is leading to, of damaging fastening [3].

The pipeline of fresh PK-1 steam is linking the outlet chamber of the pot with the steam manifold of the block I-go. The course of this installation along with the emphasized scheme of abutments and suspensions is showing Fig. 1. Border of steam OP-130 pipeline / (PK1) are: from the side of the pot: belonging to the pipeline welded joint behind the bolt of the OP-130 pot and in front of the correcting reducer belonging to the pipeline from the side of the interceptor [4].

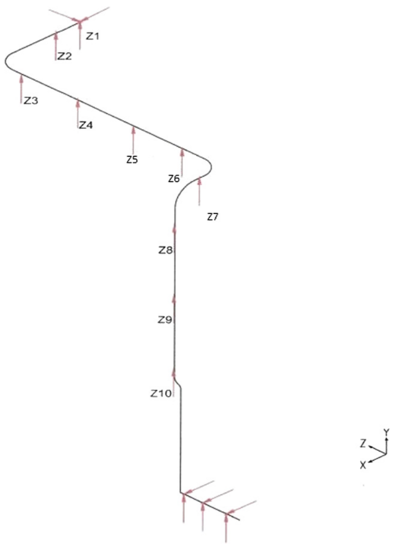

Fig. 1. Scheme of the pipeline PK-1. [5]

Parameters of fresh steam flowing through this pipeline are raising: nominal pressure p_r = 7,2 MPa, the working temperature t_r = 500 °C, he density of steam in the state of the work $\delta_p = 23{,}3\ \frac{kg}{m^3}$ [3].

A geometrical and exploitation following parameters taken into account stayed in calculations of this device: dimension of cross sections of the pipeline Ø298,5 × 17,5, length l_{K1} = 37,7 m, insulation thickness t = 200 mm, density of the isolation $\delta_i = 140\ \frac{kg}{m^3}$, working hours of the pipeline t_{K1} = 102 975 h.

The analysed pipeline is made of steel 15HM(13CrMo4-5), of which mechanical properties and endurance for the room temperature and high equal 500 °C they presented in the Tables 1, 2 and 3.

Table 1. Mechanical properties of steel 15HM in the room temperature according to [6]

Steel grade		Mechanical properties when stretched at room temeperature							Impact properties				
Steel mark	Stell number	Upper yield point or conventional yield stress R_{eH} or $R_{p0,2}$ for Wall thickness T min				Tensile strength R_m	Elongation A min. %		Minimum averange Energy absober KVJ in temperature				
		T ≤ 16	16 < T ≤ 40	40 <T ≤ 60	60 <T ≤ 100		l	t	l			t	
		MPa	MPa	MPa	MPa	MPa			20	0	−10	20	0
15HM	1.7335	290	290	280	–	440 do 590	22	20	40	–	–	27	–

Table 2. The minimal yield point stipulated in the contract $R_{p0,2}$ steel 15HM in the increased temperature according to [6]

Steel grade		Wall thickness	The minimum contract yield strength $R_{p0,2}$ MPa in temperature °C									
Steel mark	Steel number		100	150	200	250	300	350	400	450	500	550
10 HM	1.7335	≤ 60	264	253	245	236	192	182	174	168	166	–

Table 3. Withdrawn physical properties of steel 15HM according to [7]

Density 20 °C kg/dm^3	Modulus of elasticity kN/mm^2 at				Thermal conduvtivity in 20 °C W/mK	Thermal capacity in 20 °C J/kgK	Linear factor 10^{-6}K^{-1} thermal expansion between 20 °C and			
	20 °C	300 °C	400 °C	500 °C			300 °C	400 °C	500 °C	600 °C
7,76	210	185	175	165	33	622	12,9	13,5	13,9	14,1

These properties next were exploited, as the input for defining the model of material in endurance calculations with using the finite element method [8].

2 Geometrical and Numerical Model

For the purposes of endurance calculations a geometric model drawn up of the pipeline stayed. On account of the little thickness of the partition wall in comparing to his external diameter a cover model was defined received after through conducting the coating by the middle of the thickness of his partition wall. By analogy in the destination of more late reflecting the work of the pipeline, was modeled also clamping rings of his supports. Additionally on ends of the installation a flow limiting solid models of bolts of steam was situated (Fig. 2). This way the geometric model drawn up was digitized with the finished respective elements [9].

Fig. 2. Geometric model of the object. Isometric projection.

The discreet model was drawn up among others with coating elements Tinsell type CQUAD4. They reflected with them the geometrical form of the course of the pipeline and clamping rings of supports, their thickness they accepted as corresponding to the real dimension of the partition wall of this organising elements. The number of finished elements took out 28989 [10].

Propping the pipeline was carried out after through getting transfers and turnovers back after all axes in the initial place of the pipeline. The end of the pipeline from the side of the interceptor was blocked this way so that the pipeline as well as the interceptor had free crosswise axes X and Y. The freedom in these axes allows for transfers connected with the thermal expansion of the interceptor. Longitudinal transferring the pipeline was blocked. Turnovers were also frozen in all directions. Suspensions were performed with spring objects of the type 1D CELAS2 (Fig. 4) corresponding to the stiffnesses of these springs hanger The contact of the surface of clamping rings of fastening and the pipeline was carried out with the SURFACE CONTACT. Objects CELAS2 they were fixed in three pivots in the upper hub [11, 12].

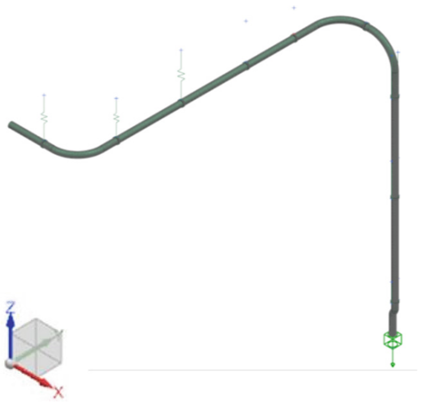

Fig. 3. Outside burdens acting in the cold state of the pipeline.

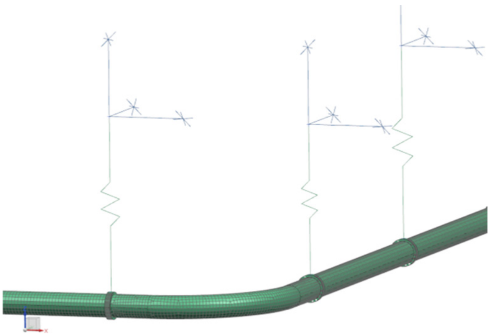

Fig. 4. Completion of supporting fastening.

Determining straining the pipeline two cases of his work discussed to begin with were considered of article. A work of the pipeline is the first case in the cold state. Such a state is straining the pipeline only a gravity working on mass of pipeline and thermal insulation. (Figure 3) a second estate is a hot state. The work in these conditions differs than previous, that to the burden resulting from mass a triggered burden of field is reaching with the temperature, mass and the pressure of the factor [13].

3 Calculations

Four variants of the work of the pipeline were analysed. The first variant is a pipeline in the cold condition before the modernization of suspensions. A second case is an object in the hot state before the modernization of suspensions. Two another coincidences it by analogy to two first but in the state of the pipeline after the exchange of fastening permanent-weight. Below chosen results of the simulation were indicated on the Figs. 5, 6 and 7 [3] (Fig. 8).

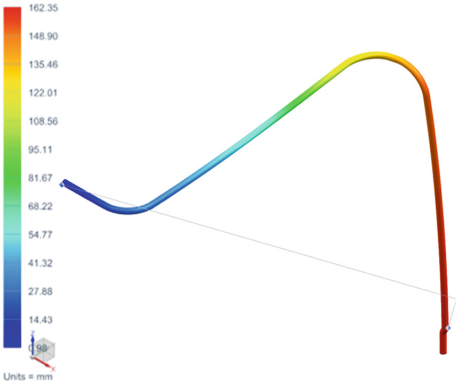

Fig. 5. Distribution of temperature filed - hot state before the modernization.

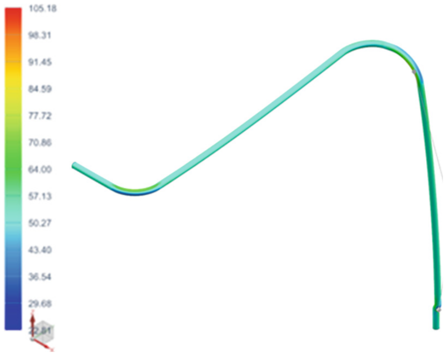

Fig. 6. Distribution of equivalent stress according to Hubera- Misesa hypotheses [MPa] hot state before the modernization.

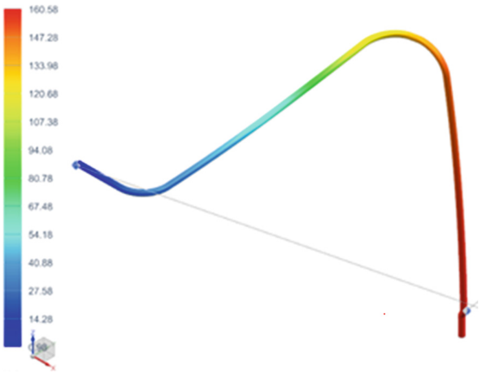

Fig. 7. Distribution of temperature filed - hot state after the modernization.

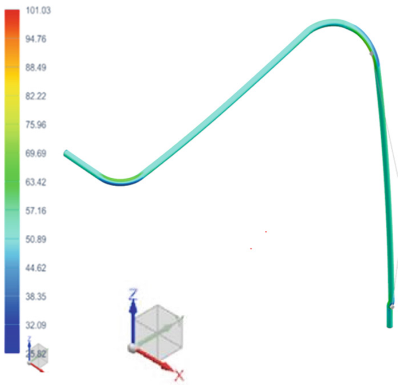

Fig. 8. Distribution of equivalent stress according to Hubera- Misesa hypotheses [MPa] hot state after the modernization.

4 Analysis of the Results

Made simulations allowed to get the row of information about the work of the object. Collected data was drawn up and presented in collective tables (Tables 4, 5 and 6).

Table 4. Putting together results of displacement of hanger before the modernization.

Hanger	Cold state			Hot state			Displacement		
Values in mm	X	Y	Z	X	Y	Z	ΔX	ΔY	ΔZ
Z2	0,189	0,128	−1,434	12,179	1,278	0,528	11,990	1,150	1,962
Z3	0,084	0,291	−7,342	16,825	19,478	2,048	16,741	19,187	9,390
Z4	−0,289	0,110	−10,576	−1,152	42,765	9,574	−0,863	42,655	20,150
Z5	−0,742	−0,078	−8,561	−22,935	66,084	25,492	−22,193	66,162	34,053
Z6	−1,098	−0,124	**−5,015**	−39,781	83,430	41,265	−38,683	83,554	46,280
Z7	**−1,429**	0,038	−0,734	**−45,834**	108,381	75,286	**−44,405**	108,343	76,020
Z8	−0,427	3,173	−0,010	−7,603	131,447	**76,705**	−7,176	128,274	**76,715**
Z9	0,577	6,878	−0,024	21,251	148,891	44,457	20,674	142,013	44,481
Z10	0,811	**8,718**	−0,019	34,221	**157,555**	11,022	33,410	**148,837**	11,041

Table. 5. Putting together results of displacement of hanger after the modernization.

Hanger	Cold state			Hot state			Displacement		
Values in mm	X	Y	Z	X	Y	Z	ΔX	ΔY	ΔZ
Z2	0,254	0,413	−1,950	12,197	1,180	0,415	11,943	0,767	2,366
Z3	−0,656	1,208	−13,789	17,365	19,089	2,193	18,021	17,881	15,983
Z4	−3,128	0,947	−26,370	0,701	42,358	11,305	3,829	41,412	37,675
Z5	−6,315	0,383	**−28,030**	−19,358	65,670	29,131	−13,042	65,287	57,160
Z6	−8,869	0,075	−20,431	−34,817	83,042	46,215	−25,948	82,967	66,646
Z7	**−11,223**	1,235	−5,322	**−39,583**	107,376	**78,189**	**−28,360**	106,141	**83,512**
Z8	−3,504	10,863	0,295	−5,641	130,036	76,515	−2,137	119,173	76,220
Z9	4,893	21,254	0,146	18,478	147,865	44,352	13,585	126,611	44,206
Z10	8,591	**26,398**	0,049	29,248	**156,733**	10,985	20,656	**130,335**	10,936

Table 6. List of stress results reduced by the Huber-Mises hypothesis on pipeline fasteners in various load states

Hanger	Naprężenia Von-Mises			
Values in MPa	Before the modernization		After the modernization	
	Cold state	Hot state	Cold state	Hot state
Z2	10,791	51,403	21,637	51,307
Z3	3,950	54,062	7,477	53,943
Z4	11,048	55,307	23,418	55,099
Z5	5,072	53,894	30,990	53,419
Z6	2,501	53,696	11,467	52,598
Z7	1,783	51,483	6,267	51,600
Z8	1,113	59,133	7,660	56,452
Z9	0,448	55,468	4,527	54,666
Z10	0,499	56,095	4,983	55,793
The greatest stresses on the pipeline	26,427	105,178	39,140	101,025

According to obtained information this pipeline in accordance with the law isn't subject right EU on account of the year of the production. It is possible to determine acceptable stresses of the connection with it based on the value of acceptable stresses. Value these faces oneself from the model $S_d = \frac{S_w}{f}$ where S_d – acceptable stresses expressed in MPa, S_w – value tense acceptable of material in the operating temperature expressed in MPa and f – coefficient of reduction of stresses which he is taking out 1,65. It follows that the allowable stress for the operation of the pipeline at 20 °C is 175 MPa, while during operation at 500 °C is 102 MPa [12].

5 The Summary and Conclusions

Analyzing the obtained values of displacements and reduced stresses, it can be concluded for the pipeline before and after modernization that the modernization of fasteners had a significant impact on its operation. The displacement increments after modernization along the transverse axes X, Y have been reduced, which indicates an increase in the stiffness of the pipeline fastening system in these planes. The further operation of the pipeline for its fastening system characterized by larger displacements could damage the structures located in the vicinity of the pipeline as well as itself. At the same time, the increase in the displacement of the structure in the direction of the Z axis, after structural changes, revealed the incorrect fixing work before modernization, i.e. the fixtures blocked the pipeline in its movements. The movement of the pipeline in this longitudinal direction is not considered harmful due to the compensation of these movements by means of vertical fastenings. Referring to the value of stresses, the pipeline under the influence of the exchange of fasteners "freed itself". The consequence of this was the storage of stress arising during operation. These values have been reduced to the limit values. In summary, the structural analysis of the pipeline shows the correctness of measures taken during the modernization of fixed braces. It should be noted, however, that despite the use of new fixings, the stresses arising in the pipeline continue to oscillate within the permissible limits. In order to reduce the value, further adjustment of the remaining fasteners, observation and continuous inspection of the fasteners is proposed [14, 15].

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