Sborník vědeckých prací Vysoké školy báňské - Technické univerzity Ostrava
číslo 1, rok 2008, ročník LIV, řada strojní
článek č. 1584

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OPERATING ABILITY EVALUATING OF MAIN BEAM PIPELINE SADDLE

STANOVENÍ PROVOZUSCHOPNOSTI HLAVNÍHO NOSNÍKU SEDLA POTRUBÍ

Abstract

In next chapters is done load parameters calculation of main beam pipe saddle on level -929 m in shaft no. 2 of mine Dukla, Mine Lazy, v.o.j. OKD, a.s. All universal sections we evaluated like supported beams, because during shaft operating is able to consider, that in rigid fixing places to concrete masonry took place beam and concrete gall.

Abstrakt

V následujících kapitolách je proveden výpočet parametrů zatížení hlavního nosníku sedla potrubí v hloubce 929 m v jámě č. 2 na dole Dukla, Důl Lazy, o.z. OKD, a.s. Jednotlivé profily považujeme za nosníky na dvou podporách, neboť za dobu provozu jámy je možné uvažovat, že v místě vetknutí profilů do betonového zdiva došlo k mírnému otlačení.

1 Pipeline weight

Height, pipeline length, which has influence to beam loading is given by heights difference in elevation - distance of two saddles. Maximum section is between saddles at depth -867 m and saddle at depth -929 m with pipeline length H = 62 m.

At pipeline with air medium I contemplate medium weight approximately 1 % from overall pipeline weight and density of liquid medium ρ= 1000 kg.m^{-3}. Further, pipeline weight I increase by 30 %, safeness coefficient k_B = 1,3 respectively, what includes uncertainty at corrosion of loaded pieces, further additional weights (flanges, seals, screws etc.), quality of building materials (concrete), that pertinent to pipeline saddle and loading uncertainty - weight of pipelines transferred to solved beam of I 500 profile.

Weights of the pipelines are:

Js 100 / Jt 16 - effluent

$$G_{VO}^{O} \doteq 10 \cdot m_{VO}^{O} = 10 \cdot H \cdot k_B \cdot \left(m_O + m_{Ot}^{VO}\right) = 10 \cdot 62 \cdot 1{,}3 \cdot \left(9{,}64 + 7{,}86\right) \tag{1}$$

$$G_{VO}^{O} \doteq 14110\ N$$

Js 500 / Jt 10 - degassing

$$G_{VD} \doteq 10 \cdot m_{VD} = 10 \cdot H \cdot k_B \cdot \left(m_D + m_{Dt}\right) = 10 \cdot H \cdot k_B \cdot m_D \left(1 + 0{,}01\right) = 10 \cdot 62 \cdot 1{,}3 \cdot 1{,}01 \cdot 64{,}7 \tag{2}$$

$$G_{VD} \doteq 52670\ N$$

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Js 150 / Jt 100 - fire flaw

$$G_{PV} \doteq 10 \cdot m_{VPV} = 10 \cdot H \cdot k_B \cdot \left(m_{PV} + m_{PVt}\right) = 10 \cdot 62 \cdot 1{,}3 \cdot \left(36{,}7 + 17{,}68\right) \qquad (3)$$

$$G_{PV} \doteq 43830\ N$$

Js 100 / Jt 16 - channel water

$$G_{VO}^{K} = G_{VO}^{O} \doteq 14110\ N \qquad (4)$$

Js 100 / Jt 16 - low-pressure air

$$G_{VO}^{V} \doteq 10 \cdot m_{VO}^{V} = 10 \cdot H \cdot k_B \cdot \left(m_O + m_{Ot}^{VZ}\right) = 10 \cdot H \cdot k_B \cdot m_O \cdot \left(1 + 0{,}01\right) = 10 \cdot 62 \cdot 1{,}3 \cdot 1{,}01 \cdot 9{,}64 \qquad (5)$$

$$G_{VO}^{V} \doteq 7850\ N$$

Js 150 / Jt 64 - old fire flow

$$G_{SV} \doteq 10 \cdot m_{VSV} = 10 \cdot H \cdot k_B \cdot \left(m_{SV} + m_{SVt}\right) = 10 \cdot 62 \cdot 1{,}3 \cdot \left(26{,}2 + 17{,}68\right) \qquad (6)$$

$$G_{SV} \doteq 35380\ N$$

2 Force calculation - loading of saddle main beam

Solved pipelines weights are necessary to convert to points A to H - reactions on the beam I 500 (Figure no. 1). I contemplate, it is necessary to speculate about supported beams I 240 a I 260 profiles, instead of fixed beams, thanks to concrete walling conditions ignorance.

Pipeline weights converting to separate points:

$$F_A = \frac{G_{VO}^{O}}{2} \cdot \frac{630 - 230}{630} = 4480\ N \qquad (7)$$

$$F_B = \frac{G_{VO}^{O}}{2} \cdot \frac{1125 - 230}{1125} = 5615\ N \qquad (8)$$

$$F_C = \frac{G_{VD}}{2} \cdot \frac{1445 - 980}{1445} = 8475\ N \qquad (9)$$

$$F_D = \frac{G_{VD}}{2} \cdot \frac{1730 - 980}{1730} = 11420\ N \qquad (10)$$

$$F_E = \frac{G_{PV}}{2} \cdot \frac{1730 - 420}{1730} = 16595\ N \qquad (11)$$

$$F_F = \frac{G_{PV}}{2} \cdot \frac{1750 - 420}{1750} = 16655\ N \qquad (12)$$

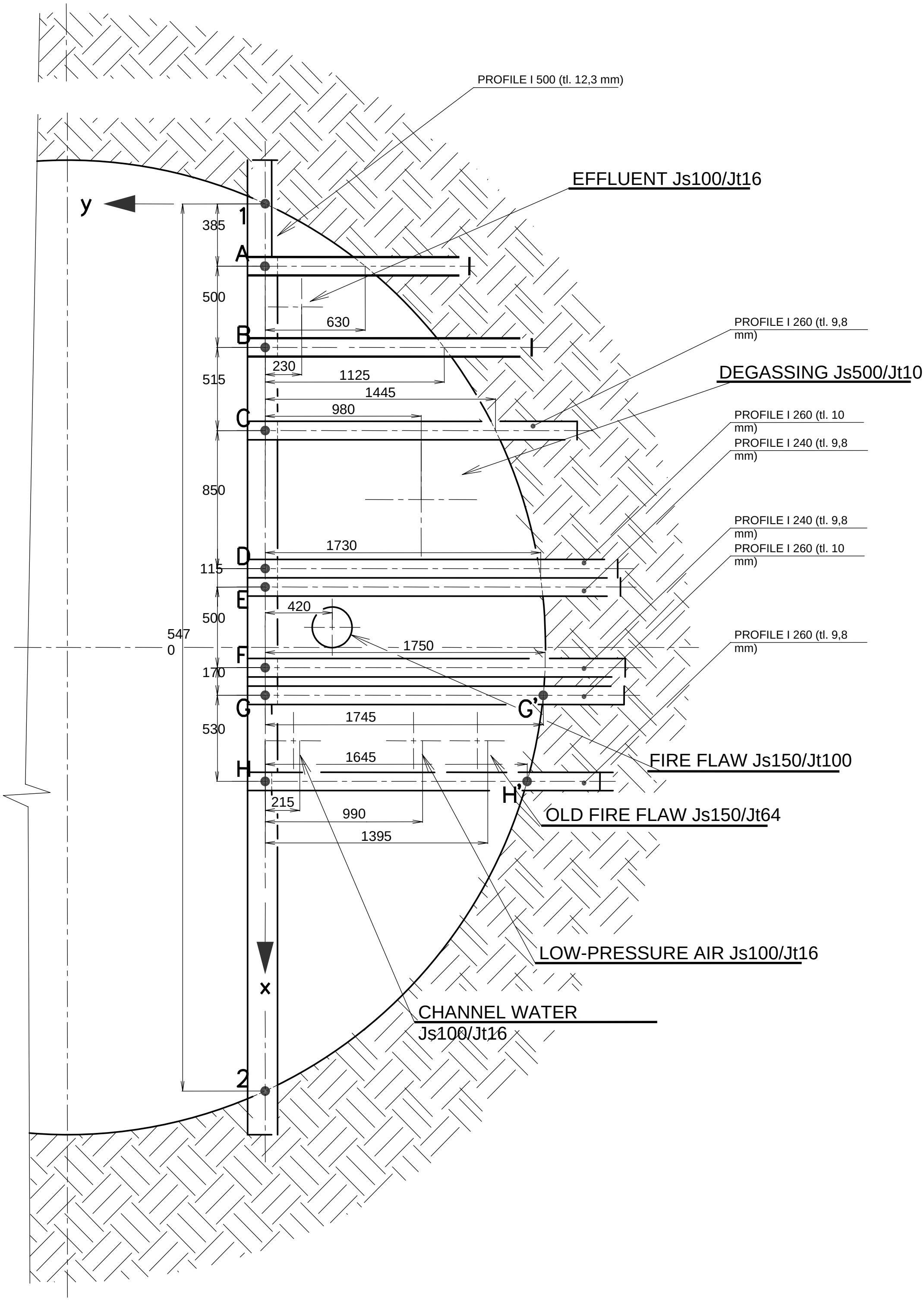

Fig. 1 Solved pipeline saddle at -929 m level

Another reaction I obtain by moment clause of static balance:

$$\sum M_{G'} = 0 \tag{13}$$

$$F_G \cdot 1745 - \frac{G_{VO}^K}{2} \cdot (1745 - 215) - \frac{G_{VO}^V}{2} \cdot (1745 - 990) - \frac{G_{SV}}{2} \cdot (1745 - 1395) = 11435\ N$$

Similar I can write:

$$\sum M_{H'} = 0 \Rightarrow F_H = 10385\ N \tag{14}$$

From the solved forces F_A to F_H I determine beam I 500 reactions on points 1 and 2 from criterion of static balance: $R_1 = 47960\ N$ and $R_2 = 37100\ N$.

3 Stress calculation

Except maximum torque moment I will need to stress calculation also "minimal" torque modulus of resistance of beam. It can be calculated from quadratic section modulus, because beam was worn-down by corrosion during operation and it became lighter and with smaller cross section of I 500 profile.

Table no. 1 shows actual and new one beam parameters. There were measured by ultrasonic actual beam stalk width of 12,3 mm instead of 18 mm as at new beam. Further I speculate about uniform corrosion on whole beam surface, with about 30% value.

Maximal torque moment is on point, where shear force intersect zero line (beam), what is point **F** at my case.

Torque moment at the point is:

$$M_{O\max} = R_2 \cdot (1905 + 530 + 170) - F_H \cdot (530 + 170) - F_G \cdot 170 = 87{,}4 \cdot 10^6\ N \cdot mm \tag{15}$$

Tab. 1 Profiles parameters

Parameters	Beam as new	Worn beam (measured at mine)
Profile high	500,0 mm	492,0 mm
Web high	446,0 mm	454,0 mm
Web thickness	18,0 mm	12,3 mm
Profile width	185,0 mm	185,0 mm
Covering strip thickness	27,0 mm	19,0 mm
Quadratic moment of cross section	$687{,}4.10^6$ mm^4	$490{,}0.10^6$ mm^4
Bending modulus of resistance	2,75 mm^3	2,00 mm^3

Stress at the point is:

$$\sigma_{O\max} = \frac{M_{O\max}}{W_{O\min}} = \frac{87{,}4 \cdot 10^6}{2 \cdot 10^6} \doteq 45\ MPa \tag{16}$$

Safety to yield point of tension:

$$k_e = \frac{R_e}{\sigma_O} = \frac{220}{45} \doteq 4{,}9 \tag{17}$$

4 Calculation of maximum sag of beam

To maximum sag of beam calculation I used Clebsch's method. Basic supposition for the method is bending moment determination in random point of beam. It is necessary keep appropriate rules, such us don't removing parentheses at binomial upon integrating (we work with them such as independent variable) or taking subexpression from previous integral and complementing them by influence of new admitting load upon moment equation determination.

Bending moment at random point of beam:

$$E \cdot I \cdot w'' = -M$$

$$E \cdot I \cdot w'' = -R_1 \cdot x + \left|F_A\right._{x>385} \cdot (x-385) + \left|F_B\right._{x>885} \cdot (x-885) + \left|F_C\right._{x>1400} \cdot (x-1400) + \left|F_D\right._{x>2250} \cdot (x-2250) + \\ + \left|F_E\right._{x>2365} \cdot (x-2365) + \left|F_F\right._{x>2865} \cdot (x-2865) + \left|F_G\right._{x>3035} \cdot (x-3035) + \left|F_H\right._{x>3565} \cdot (x-3565) \quad (18)$$

By integration we obtain equation of cross section slewing at random point of beam:

$$E \cdot I \cdot w' = -R_1 \cdot \frac{x^2}{2} + \left|F_A\right._{x>385} \cdot \frac{(x-385)^2}{2} + \left|F_B\right._{x>885} \cdot \frac{(x-885)^2}{2} + \left|F_C\right._{x>1400} \cdot \frac{(x-1400)^2}{2} + \left|F_D\right._{x>2250} \cdot \frac{(x-2250)^2}{2} + \\ + \left|F_E\right._{x>2365} \cdot \frac{(x-2365)^2}{2} + \left|F_F\right._{x>2865} \cdot \frac{(x-2865)^2}{2} + \left|F_G\right._{x>3035} \cdot \frac{(x-3035)^2}{2} + \\ + \left|F_H\right._{x>3565} \cdot \frac{(x-3565)^2}{2} + C_1 \quad (19)$$

By next integration we obtain equation of deflection curve at random point of beam:

$$E \cdot I \cdot w = -R_1 \cdot \frac{x^3}{6} + \left|F_A\right._{x>385} \cdot \frac{(x-385)^3}{6} + \left|F_B\right._{x>885} \cdot \frac{(x-885)^3}{6} + \left|F_C\right._{x>1400} \cdot \frac{(x-1400)^3}{6} + \left|F_D\right._{x>2250} \cdot \frac{(x-2250)^3}{6} + \\ + \left|F_E\right._{x>2365} \cdot \frac{(x-2365)^3}{6} + \left|F_F\right._{x>2865} \cdot \frac{(x-2865)^3}{6} + \left|F_G\right._{x>3035} \cdot \frac{(x-3035)^3}{6} + \\ + \left|F_H\right._{x>3565} \cdot \frac{(x-3565)^3}{6} + C_1 \cdot x + C_2 \quad (20)$$

For next calculation is necessary determine constants of integrations - edge conditions. Optimal is selection of x = 0 and x = 5470 – beam supports, where sag of beam is zero. We can write:

$$x = 0;\ w = 0 \Rightarrow C_2 = 0 \\ x = 5470;\ w = 0 \Rightarrow C_1 = 1{,}442 \cdot 10^{11} \quad (21)$$

After constants introducing to equations (19) and (20) we can write the equation at simplified shape:

$$w' = \frac{1}{2 \cdot E \cdot I} \cdot \left[-R_1 \cdot x^2 + \sum_{i=A}^{H} \left|F_i\right._{x>x_i} \cdot (x-x_i)^2 + 2 \cdot 1{,}442 \cdot 10^{11} \right] \quad (22)$$

$$w = \frac{1}{6 \cdot E \cdot I} \cdot \left[-R_1 \cdot x^3 + \sum_{i=A}^{H} \left|F_i\right._{x>x_i} \cdot (x-x_i)^3 + 6 \cdot 1{,}442 \cdot 10^{11} \cdot x \right] \quad (23)$$

After maximal sag of beam solution, it is necessary to know the point position on the beam. We are able solving the point from equation (22), equate it to 0, because it is fact, at the place with maximal sag of beam has cross section slewing equate zero too:

$$w' = 0 \Rightarrow \left[-R_1 \cdot x^2 + \sum_{i=A}^{H} \left|F_i\right._{x>x_i} \cdot (x-x_i)^2 + 2 \cdot 1{,}442 \cdot 10^{11} \right] = 0 \quad (24)$$

After the parameters replacement to equation (24) we obtain quadratic equation at shape:

$$37100 \cdot x^2 - 404644950 \cdot x + 8{,}303 \cdot 10^{11} = 0 \quad (25)$$

By solving of the equation, we obtain alone real result, which indicate point of maximal sag of beam (cross section slewing equate zero) at distance from support no. 1:

$$x_{w'=0} \doteq 2740\ mm \tag{26}$$

After replacement the result – coordinate to equation (23) we are able exactly express in numbers maximal sag of beam:

$$w_{\max}^{2740} = \frac{1}{6 \cdot E \cdot I_x^s} \cdot \left[-R_1 \cdot 2740^3 + \sum_{i=A}^{E} \left| F_i \right._{2740>x_i} \cdot (2740 - x_i)^3 + 6 \cdot 1{,}442 \cdot 10^{11} \cdot 2740 \right] = 2{,}500\ mm \tag{27}$$

Sag of beam values of separate beam points (point of loading - forces):

$$w_A^{385} = \frac{1}{6 \cdot E \cdot I_x^s} \cdot \left[-R_1 \cdot 385^3 + 6 \cdot 1{,}442 \cdot 10^{11} \cdot 385 \right] = 0{,}545\ mm \tag{28}$$

$$w_B^{885} = \frac{1}{6 \cdot E \cdot I_x^s} \cdot \left[-R_1 \cdot 885^3 + F_A \cdot 500^3 + 6 \cdot 1{,}442 \cdot 10^{11} \cdot 885 \right] = 1{,}213\ mm \tag{29}$$

$$w_C^{1400} = \frac{1}{6 \cdot E \cdot I_x^s} \cdot \left[-R_1 \cdot 1400^3 + \sum_{i=A}^{B} F_i \cdot (1400 - x_i)^3 + 6 \cdot 1{,}442 \cdot 10^{11} \cdot 1400 \right] = 1{,}791\ mm \tag{30}$$

$$w_D^{2250} = \frac{1}{6 \cdot E \cdot I_x^s} \cdot \left[-R_1 \cdot 2250^3 + \sum_{i=A}^{C} F_i \cdot (2250 - x_i)^3 + 6 \cdot 1{,}442 \cdot 10^{11} \cdot 2250 \right] = 2{,}392\ mm \tag{31}$$

$$w_E^{2365} = \frac{1}{6 \cdot E \cdot I_x^s} \cdot \left[-R_1 \cdot 2365^3 + \sum_{i=A}^{D} F_i \cdot (2365 - x_i)^3 + 6 \cdot 1{,}442 \cdot 10^{11} \cdot 2365 \right] = 2{,}431\ mm \tag{32}$$

$$w_F^{2865} = \frac{1}{6 \cdot E \cdot I_x^s} \cdot \left[-R_1 \cdot 2865^3 + \sum_{i=A}^{E} F_i \cdot (2865 - x_i)^3 + 6 \cdot 1{,}442 \cdot 10^{11} \cdot 2865 \right] = 2{,}434\ mm \tag{33}$$

$$w_G^{3035} = \frac{1}{6 \cdot E \cdot I_x^s} \cdot \left[-R_1 \cdot 3035^3 + \sum_{i=A}^{F} F_i \cdot (3035 - x_i)^3 + 6 \cdot 1{,}442 \cdot 10^{11} \cdot 3035 \right] = 2{,}429\ mm \tag{34}$$

$$w_H^{3505} = \frac{1}{6 \cdot E \cdot I_x^s} \cdot \left[-R_1 \cdot 3505^3 + \sum_{i=A}^{G} F_i \cdot (3505 - x_i)^3 + 6 \cdot 1{,}442 \cdot 10^{11} \cdot 3505 \right] = 2{,}200\ mm \tag{35}$$

5 Conclusion

At the mentioned chapters no. 4. and no. 5. are calculated maximal stresses of main beam. There is calculated sag of beam including separate sags at contact points of pipeline profiles with main beam. From calculated values is evident, that main beam of saddle (profile I 500) at level – 929 m complies with mentioned loading, despite of relatively big wear (corrosion) of the main beam of pipelines saddle. Therefore is possible to apply completive system of mine water repump from 8th to 7th floor of pit no. 2 of Dukla Mine.

For acquiring of saddle complex evaluation, it would be convenient to make structural engineering appreciation of pipeline profiles fixation to concrete walling.

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