Improving the Working Conditions of Circular Welded Pipe under Pressure through the Reinforcing Ribs

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Abstract

During the process of construction of small hydropower plants we face with problems that require specific engineering solutions. Frequently, during the implementation of design, the works supervisor finds no convincing technical parameters that carry risks if we do not intervene to optimize them. Paying more attention to the economic problems, the designer or manufacturer diminishes the security. This phenomenon occurs in the production and engineering calculations of the penstock pipeline of HPP. In a penstock with a large fall, in the case of hydraulic punch, the pipe is charged with the forces of hydrostatic pressure and hydrodynamic pressure. These forces take the maximal value at the part of the pipe near the hydro turbine. The bottom of the pipe is more stressed that is the thickness of the pipe is scaling in the function of pressure.

KEYWORDS: compression, cutting, HPP Ternova, penstock, pressure, reinforcement rib, tension, welded joints.

INTRODUCTION

One of the small hydropower station build in Albania last years is HPP Ternove, power 8.3 Mwh. Tenova Hydropower Plant is located in the northeastern of Albania in Bulqize, Dibra near the Macedonian border. It uses the waters of three natural lakes and a basin with an area of about 65 000 km^2. The natural resource is rich in underground water and heavy snow falls. It's the coldest areas in Albania with temperatures varying from -20^0 C to +38^0 C. The terrain is forested and rugged ranging from 20^0 to 45^0. HPP of Ternova has a gross fall of 982,302 m a.s.l. The intake structure is build to a height of 1630 m a.s.l while the building is constructed at the quota of 647 m a.s.l. It is one of the high-pressure HPP in Albania. For this reason its design and implementation required a high technical responsibility. The most difficult part for construction of this HPP is the Penstock, as it must withstand the large forces due to the pressure in the case of a hydraulic punch. Based on the design specification the test will be done from 1.3 to 1.5 bar.(Fig.9.b). This is one of the reasons we like to treat this HPP in our article.

In this hydropower plant is installed the Penstock of 4640ml , with segments as follows:

MATERIAL AND METHODS

The Subject of the study: HPP of Ternova, Albania

Below there are the distances and quotas for the Penstock line:

Steel line with thickness 21.16 and 13

Distance 0 + 00 up to 1 + 920 = 1920 ml

Quota 647.000 up to 1132.665 = 485.66 m (H1)

Cast iron pipeline

Distance 1 + 920 up to 2+810 = 890 ml

Quota 1131.66 up to 1464.092 = 331.432 m (H2)

Pipe line of G.R.P

Distance 2 + 810 up to 4 + 560 = 1750 ml

Quota 1464.092 up to 1604.98 = 140.88 m (H3)

Steel pipeline over the valve room

Distance 4 + 560 up to 4 + 640 = 80 ml

Quota 1604.98 up to 1629.31 = 24.33 m (H4)

Total

Distance = 4640 m

Quota = 982.302 m (Hb)

Quota of Intake structure : K1 = 1629.310 m

Quota of HPP building: K2 = 647.000 m

The height of gross fall : Hb = 982.302 m

Overall losses: Hw = 30 m

The height of the net fall: Hn = 952.302 m

Installed power: N = 8300 Kw

Generated power: E = 27 000 000Kwh

All the data are part of the engineering assessment in order to solve some problems concerning the penstock stability and security.

All the data are used to carry engineering calculations in the context of determining the load of pressure forces facing the reinforcing rib. Below is described an example of Penstock calculation of the HPP Ternove.

RESULTS AND DISCUSSION

Since we are dealing with a very high pressure, the control of the engineering calculations, visual control of welding and NDT inspection were at the highest levels.

Controls showed that:

1- Based on the calculations the thickness of sheet metal the tube is made should be t = 22mm.
2- Actually s the supplier (pipe manifucturer) has brought to the object pipe t= 21 mm
3- Welding is carried out between month December-March (in the coldest months of the year), the welding seam has resulted with defects in the upper limits of ASME standards.
4- NDT test found defects for reasons stated in point 2.
5- In the judgment of supervisors cutting and and re-welding of joints create unfavorable situation in these joints.

For these reasons it was thought to mend these joints by assembling reinforcing ribs with profile “UPN10/50”DIN 1026-1;1026-2

Pipe diameter is 7 11 mm, Material 60X

Electrodes:

For the first joint: BÖHLER FOX CEL or FOX CEL+

For filling welding with electrodes BÖHLER NiMo1-IG

Or Massive welding wire, EMK 6, EMK 8, SG3-P

Vessels with thin walls are called so when they meet the condition Da/Di ≤ 1.2. When passing from coating to edges, there are moments to be considered.
From the balance of the circular elements we have calculated the stress that appear in this case from the internal pressure.

$$2 \cdot \sigma_t \cdot \Delta l \cdot t = \rho_e \cdot D_i \cdot \Delta l \qquad \sigma_l \cdot \pi \cdot D_i \cdot t \approx \rho_e \cdot \frac{D_i^2 \cdot \pi}{4}$$

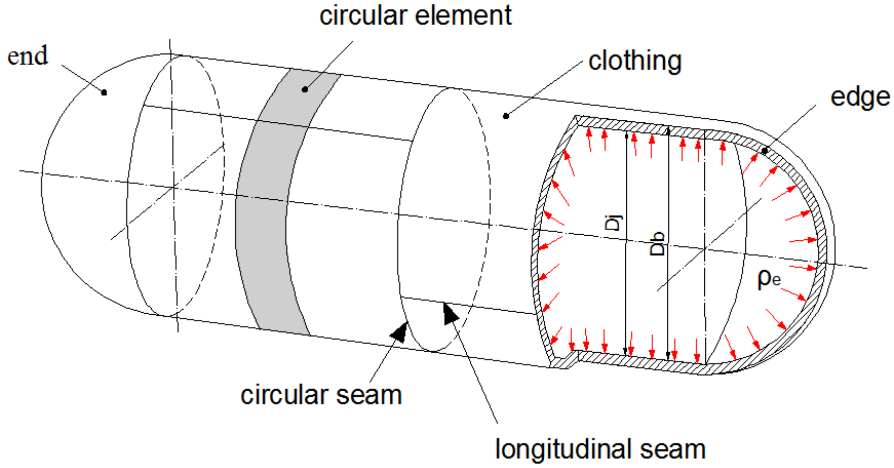
Tangential stress in tension is:

$$\sigma_t \approx \frac{D_i \cdot \rho_e}{2 \cdot t}$$

Longitudinal stress in tension will be:

$$\sigma_l \approx \frac{D_i \cdot \rho_e}{4 \cdot t}$$

if the end of the pipe is opened than the stress will be zero (Figure 1).



$$\sigma_t = \frac{D_j \cdot \rho_e}{2 \cdot t} \qquad \sigma_l = \frac{D_j \cdot \rho_e}{4 \cdot t} \qquad \sigma_r = -\frac{\rho_e}{2}$$

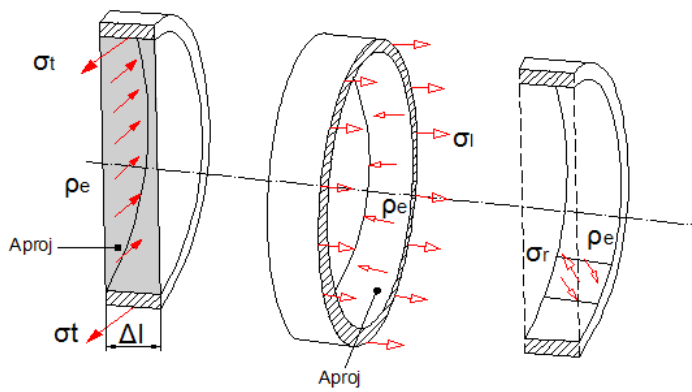


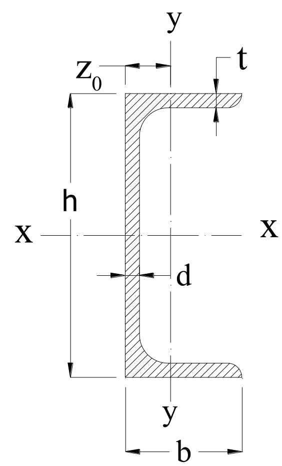
Figure 1. Tangential stress σ_t, longitudinal stress σ_l, radial stress σ_r

According to the hypothesis of tangential stresses we have equivalent tension

$$\sigma_v = \sigma_{max} - \sigma_{min} = \sigma_t - \sigma_r = \frac{D_i \cdot \rho_e}{2 \cdot t} + \frac{\rho_e}{2} \leq \sigma_{zul}$$

D_i - internal diameter of the pipe.
p_e – calculated pressure (≥ maximal allowed pressure (PS))
($1N/mm^2$=10bar=1MPa)
K- features of solidity to the calculated temperature
S - safety coefficient
v – the factor that considers the operation of the allowed calculated stress in the welding seams : usually v=1, when not controlled v=0.85, so the seam is accepted 15% weaker when not well welded than in the case it is welded better.

Facilitate the work of circular tube seam by profile UPN10/50
Profile- C10 to be used has the geometry presented at the Figure 2.



No.prof	Weight	h	b	d	t	Surface	Ix	Wx	ix	Sx	Iy	Wy	iy	z_0
10	8.59	100	46	4.5	7.6	10.9	174	34.8	3.99	20.4	20.4	6.46	1.37	1.44

Figure 2. Geometry of the profile- C10 used

In this case, the calculated scheme is presented at the Figure 3

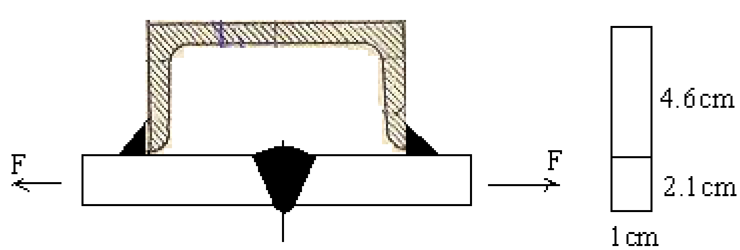


Figure 3. Calculated scheme

Since we have a symmetric scheme and a symmetric load, only internal forces remain symmetric. Curving moment is neglected as d = 0.45cm. So this scheme needs additional equations as it cannot be resolved by statistics. We take these equations using the method of forces. This requires basic scheme (Figure 4):

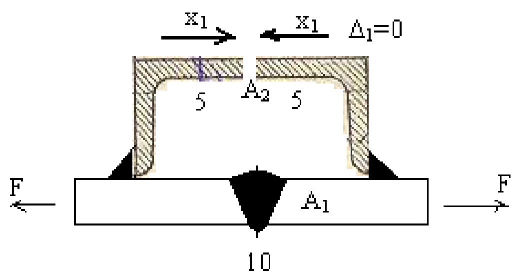


Figure 4. Basic scheme of force methods.

We draw the diagram of the normal force for $x_1 = 1$ and for force F.

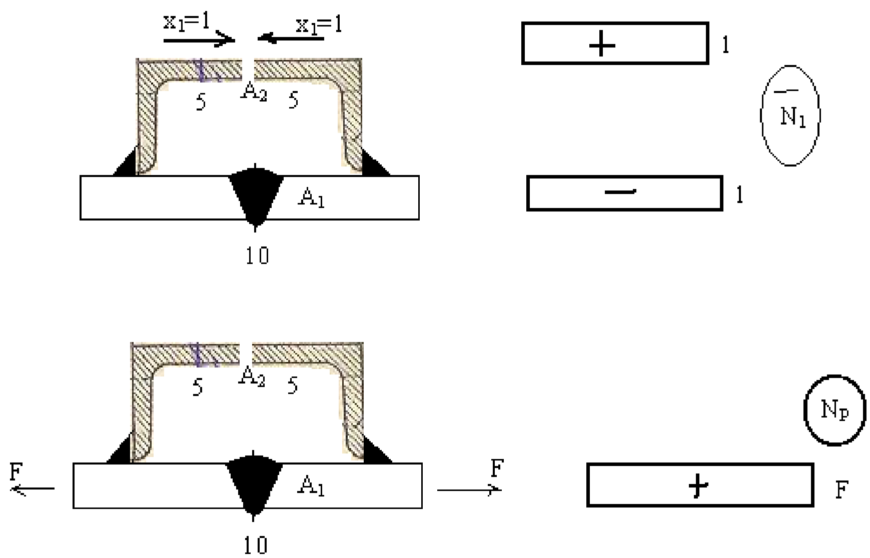


Figure 5. Calculation scheme by forces method together with diagram of the internal forces from special factors

Canonical equation of the forces method is written:
$\Delta_1=\delta_{11}\cdot x_1+\Delta_{1P}=0$

Define the equation coefficients, which are movements of edges where force x_1 acts in both cases.
$\delta_{11}=(5\cdot 1\cdot 1)/(E\cdot A_2)+(5\cdot 1\cdot 1)/(E\cdot A_2)+(10\cdot 1\cdot 1)/(E\cdot A_1)$.

$\Delta_{1P}=-(10\cdot F\cdot 1)/(E\cdot A_1)$.

In this case have $x_1=-\Delta_{1P}/\delta_{11}=[(10\cdot F\cdot 1)/(E\cdot A_1)]/[(5\cdot 1\cdot 1)/(E\cdot A_2)+(5\cdot 1\cdot 1)/(E\cdot A_2)+(10\cdot 1\cdot 1)/(E\cdot A_1)]$ finally after simplifications, knowing that E differs a little from the steels, we have
$x_1 = F/[1+A_1/A_2]$ and $A_1=2.1\cdot 1$ while $A_2=1\cdot 0.45$ so $x_1=F/[1+A_1/A_2]=0.176F$ so 17.6% of the force passes from profile C, while the other part of 82.3% passes to the existing welding seam.

If we increase the section of profile C to dimension d then this percentage increases more and the seam is lighten

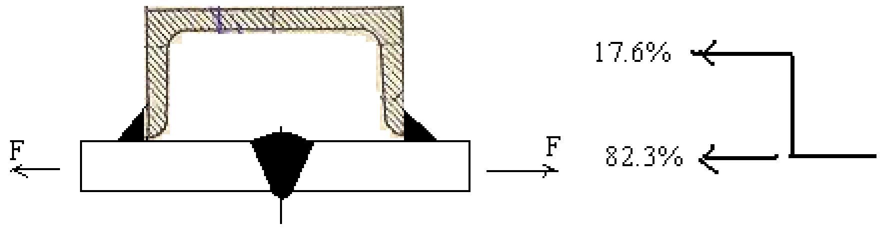


Figure 6. Calculated scheme

Angular seam thickness is calculated based on this force as formula
$h_t = x_1/[0.7 \cdot 1 \cdot 1500]$ in cm, which this must be more than 4 mm and less than $1.2 \cdot 7.6 = 9.12$ mm i.e. 9 mm.

Heating and cooling is not uniform

Welded details are continuously heated by the heat source toward the seam. A non-stationary temperature field about 1500 0C is created in the area of heat source (steel melting point) and in the area limiting the detail, the temperature is about 20^0C. Heat distribution areas in transverse direction and by the thickness depends on the selected welding parameters, the size of the detail and the seam.

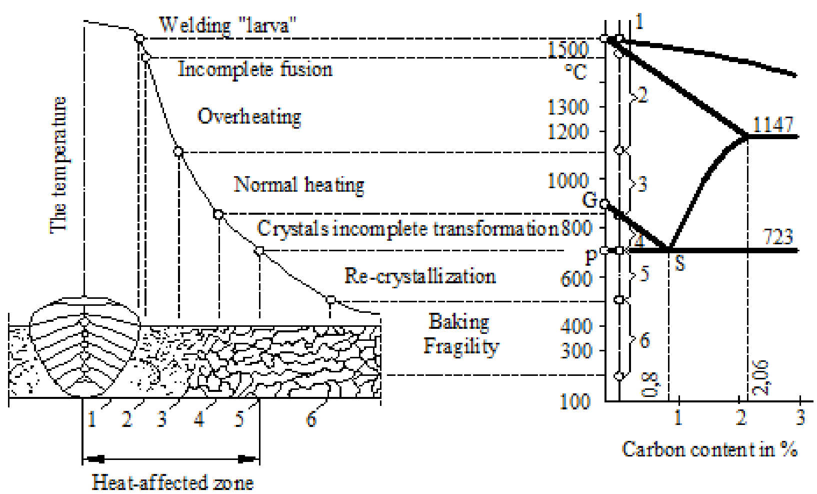


Figure 7. Structural changes in the welded area referring the diagram Fe-C

Metallurgical transformations occur in the area near the seam and in the intermediate area, When a quickly cooled martensity is formed, which reduces the abilities to be deformed. This is eliminated by realizing a pre heating example.
However , we do not have any adverse change to the structure of the tube, which is not common steel, taking into account that the tube presents a big material compared with the seam, the open field where welding happens, the small height of welding 4mm, one pass i.e. very quick.

Figure 8. Welded joint in HPP Ternove

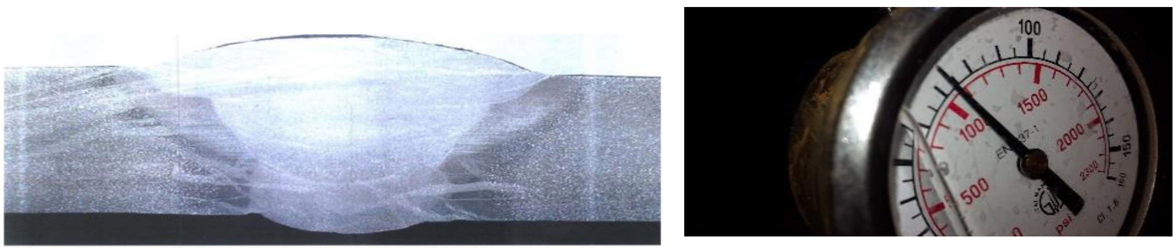


Figure 9: a) X-ray film in the welding joints b) Pressure during the test at the quota 1920m asl (124 bar)

Solidity control of the welding seam

Welds in field conditions are realised by immersed arc or classic methods. The classic method weldinbg is applied in the pipe assembling of the hydro turbine supply. The tube works as pressure vessel at the time the shut-off valve react. On welding seams we practically speak for an average stress as we have no uniform distribution. Preliminary strains and stresses in welds roofs are ignored. Strains that appear in seam are:

- Normal strains indirectly to the direction seam. These are less important and ignored especially for constant load.
- Tangential strain indirectly to the direction of the seam. These appear in the forefront of angular seam. Tangential strain towards the direction of the seam. These appear in the nozzle and joint seams and in the forces transverse links as well,

The equivalent tension is:

$$\sigma = \sqrt{\sigma_{\perp}^2 + \tau_{||}^2 + \tau_{\perp}^2} \leq \sigma_w$$

σ_w is permissible tension of welding seam: $\alpha_w \cdot R_e / S_M$, with α_w from TB 6 – 6, R_e from TB 6 – 5 and $S_M = 1.1$.

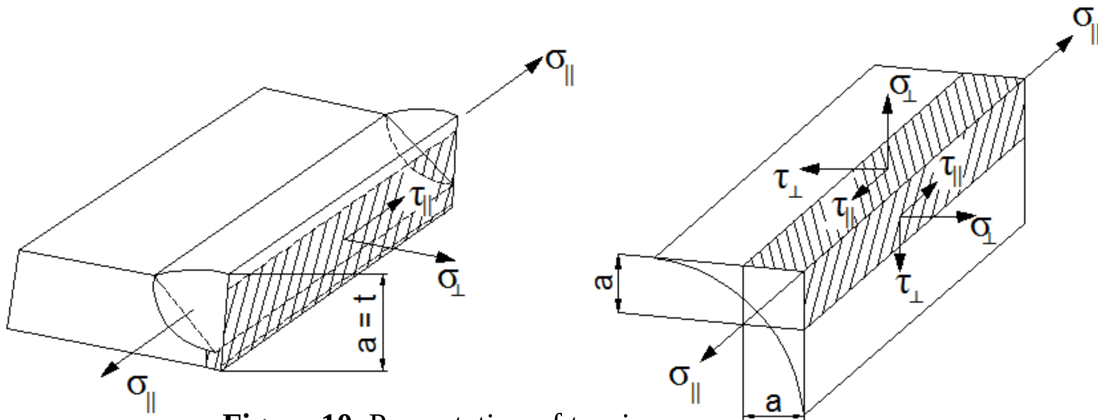


Figure 10. Presentation of tension

Intensile, pressure or cutting loading

For any mentioned loading we have actual stress in the seam.

$$\left.\begin{matrix}\sigma_\perp\\ \tau_\perp\\ \tau_{||}\end{matrix}\right\} = \frac{F}{A_w} = \frac{F}{\sum(a\cdot l)} \le \alpha_w$$

In the actual case l = p (p - pipe perimeter)

CONCLUSIONS

From these calculations we see that the welding seam is more constant and can withstand the loads of hydraulic loads punch. The measures taken during the penstock work loading, we have surety in the solidity of the tube. Placing reinforcement ring with "UPN10 / 50" profile , we make easy the pipe stress in case of a hydraulic punch in the amount 17.6% of loading, arising from pressure forces. Pipe is loaded at 82.3% of the pressure. This intervention gives us a security during penstock operation.

References

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