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# CALCULATION OF WALL THICKNESS FOR LONG-DISTANCE SLURRY PIPELINE

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## ABSTRACT
*In this paper the example of calculation of wall thickness for long – distance slurry pipeline is described. It can be mentioned that one of the solutions for ash disposal is that the area designated for the future ash landfill is positioned in the depression of the open pit mine and long distance pipelines come out of fly ash silo and follow the existing route of hydraulic transport up to depot. This solution may have a rather unfavourable impact on the surrounding area considering the dissipation of dumped ash (polluting with fine particles of fly ash and bottom ash) and contamination of mine waters (which are collected and discharged into the nearby river). In order to prevent this situation it is necessary to adapt the hauling technology to given circumstances. The essential characteristic of this technology is that it makes maximal use of the intrinsic property of ash, which tends to solidify in contact with water forming a steady and stable completely ambient-neutral rock mass. So the proper calculation of wall thickness for long – distance slurry pipeline is of great importance.*
**Keywords:** long-distance transport pipeline, fly-ash, bottom ash

## 1. INTRODUCTION
Previous experience from exploitation of the existing disposal area of hydraulic transport and fly ash has shown environment pollution caused by spreading fly ash particles by wind. New technology of hydraulic transport is based on dense slurry in the mass ratio (fly ash: water - 1:1). The basic characteristics of this technology is that the water mixes with fly ash and bottom ash in the ratio 1:1 in the form of dense slurry transporting by high pressure pumps and by pipeline to disposal area. In some thermal plants, there are two lines of long-distance pipeline. First transport line of long-distance pipeline is operational, and the second is reserve. Due to relatively high pressure, pipes for all two lines of long distance pipelines are usually made of steel St 37.4, at section from fly-ash silo up to entrance to the disposal site. Distribution and discharge pipelines, made of PEHD material, will be installed in sticks usually about ten meters long with flange adapters and flanges at ends. In this paper is the described calculation of wall thickness for long – distance slurry pipeline [1] .

## 2. THE WALL THICKNESS OF SYSTEM OF FLY ASH AND BOTTOM ASH TRANSPORT
This calculation refers to nominal transport capacity, maximum length of pipelines and maximum elevation head of unloading [2,8].
List of design input data, which are relevant for calculation of the wall thickness, are shown are shown in tables 1, 2 and 3.

*Table 1. Total maximum production and max mass flows*

| ***Input data*** | ***Value*** |
|---|---|
| Total quantity of fly ash and bottom ash | *[t/h]* |
| Max mass flow of solid substance | *[t/h]* |
| Max mass flow of slurry | *[t/h]* |

Relevant characteristics of slurry are shown in table 2.

*Table 2. Characteristics of slurry*

| ***Input data*** | ***Value*** |
|---|---|
| Density weight of bottom ash | *[kg/m$^3$]* |
| Specific weight of fly ash | *[kg/m$^3$]* |
| Medium size of particles of solid phase, $d_{50}$ | *[μm]* |
| Maximum size of particles of solid phase, $d_{max}$ | *[mm]* |
| Dynamic viscosity | *[Pa s]* |
| Temperature | *t [ºC]* |
| Mass concentration, $c_w$ | *[%]* |
| Volume concentration, $c_v$ | *[%]* |
| Specific weight of slurry | *[kg/m$^3$]* |

Characteristics of pipeline are shown in table 3.

*Table 3. Characteristics of pipeline*

| ***Type of pipe with input data*** | ***Value*** |
|---|---|
| ***1. Steel pipes (steel type St 37.4)*** | |
| Steel Length | *[m]* |
| Outside diameter | *$D_o$ [mm]* |
| Inside diameter | *$D_i$ [mm]* |
| Roughness of pipe (k) | *[μm]* |
| Wall thickness | *[mm]* |
| ***2.Polyethylene of high density PEHD (PE 100)*** | |
| Length | *[m]* |
| Outside diameter | *[mm]* |
| Wall thickness | *[mm]* |
| Inside diameter | *[mm]* |
| Roughness of pipe (k) | *[μm]* |
| Maximum elevation head | *[m]* |
| Medium speed of circulation in steel pipes | *[m/s]* |
| Medium speed of circulation in PE pipes | *[m/s]* |

**Losses due to friction:**

To identify losses in pipes due to friction, it has been used the D'Arcy-Weisbach formula [6,7]

$$H_f = \frac{fLv^2}{2gD}, \tag{1}$$

where $H_f$ is losses due to friction, $L$ is length of pipeline, $D$ is inside diameter, $\upsilon$ is medium speed of circulation in pipes, $g$ is standard gravity and $f$ is Darcy's coefficient of friction is determined according to Chen's equation. This coefficient depends on pipe diameter, flow, specific slurry weight, dynamic viscosity and roughness of pipeline walls [3,6].

Amount of the total losses due to friction [m] is obtained by adding the individual losses due to friction in steel pipeline, losses due to friction in PE pipeline and local losses caused by Losses due to friction in steel pipeline + Losses due to friction in PE pipeline + Local losses caused by compensators, connections and similar.

**Total pressure drop**
Total pressure drop is total necessary effort (which pumps must control) in order to achieve default flow in the system:

$$H = H_d - H_s \,, \qquad (2)$$

where $H$ is total pressure drop ($m$), $H_d$ are the losses on pressure pipeline of pump ($m$) and $H_s$ are the losses of suction ($m$).

Losses on pressure pipeline of pump are given by:

$$H_d = Z_d + H_{fd} + H_{ve} \,, \qquad (3)$$

where $Z_d$ is the height difference between pipe axis on outlet from pipeline and pump, $H_{fd}$ are the losses due to friction in pressure pipeline ($m$) and $H_{ve}$ are the losses of pouring out ($m$).

Losses of suction can be determined by [4]:

$$H_s = Z_s - H_i - H_{fs} \,, \qquad (4)$$

where $Z_s$ is height difference between free surface in suction tank and pump axis ($m$), $H_i$ is inlet losses ($m$) and $H_{fs}$ is losses due to friction pressure pipeline ($m$).

From the other side, in order to realize undisturbed slurry leakage, an additional pressure is necessary (pressure of pouring out) at the end of pipeline. Usually the pressure of pouring out amounts app. 0,05 *bar*.

**Effort of mixture expressed as pressure**
Values in meters of slurry column can be expressed in the form of pressure according to formula as follows:

$$P_r = H \cdot g \cdot \rho_m \cdot H_r, \qquad (5)$$

where $H$ is total effort, $g$ is standard gravity, $H_r$ factor is corrective factor for effort and $\rho_m$ is specific weight of slurry [4].

**Checking of wall thickness**
A checking of wall thickness can be done for slurry long-distance pipeline on the basis of the following characteristics:

- p [bar] of overpressure; t [°C]; $D_o$ = [*mm*]; $D_i$ = [*mm*].

Pipeline material is St 37.4 according to DIN, i.e. P235TR2 according to standard EN 10216-1 / EN 10217-1. From the table of mechanical properties of material, a minimum value of tensile strength amounts to $R_m$ = 350 $N/mm^2$. According to EN 13480-3:2002 (E) for flat pipes it is of value (if condition $D_o/D_i \leq 1{,}7$ is satisfied) [5]:

$$e = \frac{p_c * D_o}{2f * z + p_c} \,, \qquad (6)$$

$$e_{ord} = e + C_o + C_1 + C_2 \,, \qquad (7)$$

If it applies $D_o/D_i > 1{,}7$ than it is:

 

$$e = \frac{D_o}{2}\left[1 - \sqrt{\frac{f * z - p_c}{f * z + p_c}}\right], \quad (8)$$

where are:

e – minimum wall thickness without tolerances and deviations, $D_o$ – outside diameter, $D_i$ – inside diameter, $p_c$ – calculation pressure; $p_c$ = 32,3 bar, f – calculation tension, $f_{min}$ – minimum value of calculation tension, $f_{\min} = \left[\frac{R_{eHt}}{1{,}5}\, ili\, \frac{R_{p0,2t}}{1{,}5}; \frac{R_m}{2{,}4}\right]$, z – coefficient of connection, for seamless pipes z = 1, $e_{ord}$ – required wall thickness, $C_0$ – addition due to corrosion; $C_0 = 1mm$, $C_1$ – allowed deviation of material dimensions; $C_1 = \frac{12{,}5}{100 - 12{,}5} * e\,[mm]$, $C_2$ – addition due to decrease of thickness during manufacturing process (for flat pipes $C_2 = 0$).

## 3. CONCLUSION

Long distance pipelines come out of fly ash silo and follow the existing route of hydraulic transport up to depot. Each transport line starts from conditioner and consists of centrifugal slurry pumps, long distance steel pipelines and pipeline distributions around the depot. Considering that velocity of slurry is relatively small and based on experiences from similar plants, more significant influence of abrasion is not expected, but pipes are selected with reinforced wall thickness and pipe elbows are with big radius. Considering operational lifetime of pipeline, which should be 20 years and because of abrasion impacts on pipeline, it is adopted approximately double value for wall thickness. Distribution and discharge pipelines, made of PEHD material, will be installed in sticks about ten meters long with flange adapters and flanges at ends. This is hydraulic transport and disposal with afterwards self solidification disposal material. This technology completely used fly ash and bottom ash characteristic and all negative influence on production are eliminated (like instability of disposal material, redundance of water used like transport medium and pollute water and air). Hydraulic transport of fly ash and bottom ash like dense slurry (in ratio 1:1) have next advantages: simple operation of facility, less of investments, minimum consumption of electricity required for transport, satisfy ecological standards, and simple service and minimum costs.

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