Stream Lined Emission Particles Handling For Civil Engineering Purposes

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Abstract. Exploitation of conveyor belts for building purposes has large meaning and order scientific potential, that are competently solve the situation in terms of engineering structure. Pocket conveyer is one of the possible structural solutions of belt conveyer transport, where loose substance is conveyed in closed slot of the belt conveyer. The slot emerges (forms) by mutual bringing (approaching) of edges of the belt conveyer together, which have vulcanized lengthwise parts. The lengthwise parts serve for the leading of the belt conveyer and its hanging on a special construction with a number of supporting discs.

1. Introduction

The pocket conveyer, Fig. 1, enables to convey the material of the gradient bigger by 5 ÷ 10 deg in comparison to the belt conveyer of ordinary construction. Also, transport in horizontal arcs, bends, curves is enabled, significantly smaller than standard belt conveyers due to lower flexural rigidity (bend stiffness) of the belt of the pocket conveyer.

Figure 1. Cross section of the transport line of the pocket conveyer

The required transport amount (volume) $Q$ [t.h⁻¹] is dependent on cross section $S$ [m²] of the conveyed loose substance, speed of the conveyer $v$ [m. s⁻¹] loose charge (mass) of the conveyed material $\rho_{s}$ [kg. m⁻³] and filling coefficient $k_{\phi}$ [-].
2. Entry prerequisites and the description of the pocket conveyer

It is possible to determine the expression (formulation) of the cross transport section $S \text{ [m}^2\text{]}$ area volume limited by the belt of the pocket conveyer) by numerical methods, because mathematical description of the curve of drop shape is not unambiguously expressed.

For the numerical expression of the cross sectional area of the conveyed loose substance by the pocket conveyer, it is therefore necessary to express the curve’s shape, which is formed by the belt conveyer when its edges contact (join), as accurately as possible. The shape of the curve which will be created by the belt of the pocket conveyer is dependent on cross rigidity of the belt conveyer. The cross rigidity of the belt conveyer is dependent on the type and construction of the belt conveyer (number and constructional arrangement of the supporting textile ply of the belt conveyer, sort and thickness of the upper and lower top rubber layer).

The task was to determine the modulus of elasticity $E \text{ [Pa]}$ of the belt conveyer in the cross direction with the purpose of computer analysis (evaluation) in the program ANSYS, followed by experimental verification on testing equipment. The belt conveyer as a whole consists of the frame, which is a set of textile ply and top layers. In order to determine the modulus of elasticity in cross direction of the belt conveyer, two types of models were examined:

I. model made as an anisotropic body - the model was made as a set of textile ply and top layers of the given dimensions,

II. model made as an isotropic body - where the modulus of elasticity was expressed in cross direction of the belt conveyer as a whole.

1. The examined (tested) belt conveyers of the firms STOMIL and Gumárny PÚCHOV use frames made of textile ply produced in the factory (plant) Kordárna a.s. Velká nad Veličkou. Kordárna a.s. produces fabrics for belt conveyers in four sorts:

- polyamide fabrics PA 6 - impregnated;
- polyester - polyamide fabrics (EP) - impregnated;
- fabrics for one ply belt conveyers SOLID WOVEN - unbleached (raw, grey);
- fabrics for one ply belt conveyers SOLID WOVEN - impregnated PVC.

Four types of fabrics were obtained:
- two types of polyamide PA 6 - impregnated: P 250/100 and P 400 Y/1;
- polyester - polyamide fabrics (EP) - impregnated: EP 315A and EP 160.

![Figure 2. Tensile test of the given type of fabric of the carrier textile frame of the belt conveyer](image)
On the rag tearing machine INOVA TSM 50 the tensile tests were made and the module of elasticity were determined for the above mentioned types of fabrics, the example of testing equipment and the graphical layout of the tensile test is shown in Fig. 2 (it is necessary to mention that the tensile tests were done in the direction of filling pick.

The standard [5] defines three sorts of rubber, see table 1, the standard defines four sorts of rubber, see table 2, and the standard [4], see table 3, defines sorts of used top layers of the belt conveyers.

**Table 1** Physical properties of the rubber of belt conveyers

| Stress                                      | Belt type | Research method, see |
|---------------------------------------------|-----------|----------------------|
| a) tensile strength MPa (kG/cm²) minimally  | 1 2 3     | PN-82/C-04205        |
| b) extension in instant of rupture %, the least | 400 350 300 | PN-82/C-04205        |
| c) Accelerated thermal ageing of rubber at temperature of 70°C for 144 hours | 15 20 25 | PN-82/C-04216        |
| \( \Delta R_r, \% \), maximum               | 25 30 35  | PN-82/C-04216        |

In tables, it is defined 1kG/cm² = 0.1 MPa

**Table 2** Strength to fracture, extension when pulling apart, abradability of the top layer

| Top layer | Strength to pulling apart N/mm², min. | Extension when pulling apart %, min. | Abradability mm³ max. |
|-----------|---------------------------------------|-------------------------------------|-----------------------|
| W         | 18                                    | 400                                 | 90                    |
| X         | 25                                    | 450                                 | 120                   |
| Y         | 20                                    | 400                                 | 150                   |
| Z         | 15                                    | 350                                 | 250                   |

Two rubber samples were obtained, see Fig. 3, used for belt conveyers of the firm STOMIL:
- sample Stomil Belchatow type 32PG, class 1, flammable;
- sample Stomil Wolbrom type GTP, class 2, increased fire resistance.

**Figure 3.** Samples of the rubber of top layers of the belt conveyers STOMIL

2. The second model considers the belt as an isotropic body, the modulus of elasticity in cross direction was determined from experimentally measured deflection of individual samples of the belt conveyer as a whole body. Samples of the belt conveyers were obtained from the producers whose head agency is in the Czech Republic and their prices indicate (set) purchasing solvency of the end customers. The modulus of elasticity was expressed and the cross stiffness of belt conveyer samples with textile ply defined in point 1 of the firms Stomil and Gumáry Púchov.

According to [2] the cross stiffness of the belt conveyer is defined as its ability to take the shape of trough in cross section, made up of self-aligning idler. The core of the test is to find out the
deformation (distortion) of the testing body by its own weight when being hung up on both ends, and to measure the deflection in its middle part.

For the measuring we use testing equipment Fig. 4, which consists of a couple of attachments, carrying holders, one is fixed (strong), the other one is sliding. The testing body is clamped in holders, width at least 140 mm and the furthest 15 mm from its end. The holder is in pivots, pivot axis must be in the point of intersection of the plane which goes through the thickness centre of the testing body with the plane reversed by its edge.

**Table 3 Usage of the belt conveyers in relation to operating conditions**

| Type of the belt conveyer/label | Creation of the belt conveyer with top layers | Characteristics of the conveyed substance | Highest temperature of the conveyed substance °C | Characteristic of the conveyed substance | Range of the working environment °C | Highest speed of the belt conveyer m.s⁻¹ |
|---------------------------------|-----------------------------------------------|-------------------------------------------|-----------------------------------------------|--------------------------------------|------------------------------------|--------------------------------------|
| For general usage/Z             |                                               | Abrasive, angular, with high specific weight, big lumpiness (ores, quarry stone, overburden, surface coal) | +70                                           | Dry or wet                            | -25 to +60                         | 4.0 for belt conveyers type 160 to 400 |
| Rubber category A¹              |                                               |                                            |                                               |                                      |                                    |                                      |
| Rubber category B               | Mildly abrasive, grained, loose (sand, gravel, ash, lime) | +70                                           |                                            | Dry or wet                            | -25 to +60                         | 6.3 for belt conveyers type 500 to 2000 |
| Rubber category AA²             | Very abrasive, medium to big lumpiness (ores, stone, agglomerate, overburden, surface coal, slag) | +70                                           |                                            |                                      | -25 to +60                         | 9.0 for belt conveyers on packing machines?? |
| PVC                             | Mildly abrasive, grained, loose, partially lump, (sand, gravel, ash, lime) | +60                                           |                                            |                                      | -20 up to +60                       | 4.0                                  |
| For underground usage/S         |                                               | Mildly abrasive (grinding) and abrasive, grained (granular), loose, partially lump, angular (coal, gangue, waste rock and ore - underground mining) | +70                                           | With the risk of explosion of flammable powders (dust) and gases; fire risk | 0 up to +70                         | 4.0                                  |
| Rubber                          |                                               |                                            |                                               |                                      |                                    |                                      |
| PVC                             |                                               |                                            |                                               |                                      |                                    |                                      |
| Resistant to increased temperatures/T |                                               | Hot materials, grained or loose(coke, clinker, agglomerates) | +125                                           | Dry                                 | -20 to +80                         | 4.0                                  |
| Rubber category D               |                                               |                                            |                                               |                                      |                                    |                                      |
| Rubber category H               |                                               |                                            |                                               |                                      |                                    |                                      |
The testing body is clamped in holders in such a way that both its ends are in the same plane and the upper top layer is turned upside down (for symmetrical top layers the orientation of the testing body is arbitrary).

By shifting of the sliding attachment, the position of suspension cables is adjusted in such a way that the cables are in vertical position (it is checked by plumb).

Deflection of the testing body $y$ [mm] is determined 5 minutes after its hanging up; it is a distance in vertical direction between the suspension point (pivot axis of the holder) and the lowest deflection point, which is in the width centre $s$ [mm] of the testing body.

It is calculated according to

$$ y = A_2 - A_1 + \frac{s}{2} $$

Where

- $A_1$ - is the distance of the hanging point from the ground plane in mm;
- $A_2$ - distance of the lowest place on the belt surface from the ground plane in mm;
- $s$ - total width of the belt conveyer in mm.

Cross stiffness of the belt conveyer is calculated according to

$$ S_t = \frac{K}{B}; $$

mark $K$ - is the body deflection in mm;

$B$ - belt width in mm.

Figure 4. Testing equipment for the expression of the cross stiffness of the belt conveyer
3. Illustration of the deflection of belt conveyor and edge clamping for the purposes of belt pocket creation

\[ Q = m \cdot g = q \cdot B \text{ [N]}; \quad m = \frac{m_p}{B} \cdot g = m \cdot g \text{ [N.m\(^{-1}\)]} \]  

mark \( m_p \) - weight (mass) 1 m belt conveyor [kg.m\(^{-1}\)];
q - continuously distributed load, expressed from the weight of the belt conveyor [N.m\(^{-1}\)].

\[ Q = \int_B^B dQ = \int_B^B q(x) \, dx \]  

In Fig. 5 a belt conveyor, width \( B \) [m], is shown, height \( h \) [m] and length \( L \) [m]. If the belt thickness \( h \) [mm] is significantly smaller than its width \( B \) [mm], it is possible to consider the belt in the plane \( xy \) as a beam loaded by continuously distributed load \( q \) [N/m] from its own weight of the belt (Fig. 5.1).

The belt conveyor loaded by external power (force) \( Q \) [N] (let us say by continuous load \( q \) [N(m)]) is bending stressed, if the resultant of the internal forces in the right section to its longitudinal axis (Fig. 6) create couple of forces \( N \) [N], which is called bending moment \( M_0 \) [N.m].

![Figure 5. Deflection of the belt conveyor, width B [m], influenced by its own weight (continuous transverse load q [N/m]) and with the influence of axial load FA [N], FB [N]](image)

The size of moving forces and bending moments will be determined from the static condition of balance, Fig. 5.2. If the continuous load \( q \) is substituted by the force \( Q \) [N] in the load centre of the particular belt element and reactions \( R_A \) [N] a \( R_B \) [N] will be introduced in the supports then we will get reactions \( R_A \) [N] a \( R_B \) [N] from the summary (cumulative) equation in the axis \( y \) in the support A and B:

\[ R_A = R_B = \frac{Q}{2} = \frac{q \cdot B}{2} \]  

The size of the bending moment \( M_0 \) [N.m] is expressed in section \( x \) (Fig.5.2):

\[ M_0(x) = R_A \cdot x - q \cdot x \cdot \frac{x}{2} = \frac{Q}{2} \cdot x - q \cdot \frac{x^2}{2} = \frac{q \cdot B}{2} \cdot x - q \cdot \frac{x^2}{2} \]  

Maximum bending \( M_{0\text{max}} \) [N.m] moment interacts with the arm of force \( B/2 \) [m] ⇒

\[ M_{0\text{max}} = \frac{q \cdot B \cdot B}{2 \cdot 2} - q \cdot \frac{1}{2} \left( \frac{B}{2} \right)^2 = \frac{q \cdot B^2}{4} - \frac{q \cdot B^2}{8} = \frac{2 \cdot q \cdot B^2 - q \cdot B^2}{8} = \frac{q \cdot B^2}{8} \]  

The size of the deflection \( y_{\text{max}} \) [m] and the angle \( \alpha_A \) [deg] and \( \alpha_B \) [deg] will be determined from Schwedler theorem, which shows the dependence between bending moment \( M_0 \) [N.m], moving force
T [N] and continuous load q [N/m] in the form of differential equation of the balance of the belt element [1].

\[ Mo(x) = \frac{qB}{2}x - q\frac{x^2}{2} \]  

(8)

\[ y''(x) = -\frac{1}{EJ_z}M_o(x) = -\frac{1}{EJ_z}\left(\frac{qB}{2}x - q\frac{x^2}{2}\right) \]  

(9)

\[ y'(x) = -\frac{1}{EJ_z}\left(\frac{qB}{4}x^3 - q\frac{x^4}{6}\right) + C_1 \]  

(10)

\[ y(x) = -\frac{1}{EJ_z}\left(\frac{qB}{4}x^3 - q\frac{x^4}{6}\right) + C_1x + C_2 = -\frac{1}{EJ_z}\left(\frac{qB}{12}x^4 - q\frac{x^5}{24}\right) + C_1x + C_2 \]  

(11)

Integration constants C_1 and C_2 will be determined from the marginal conditions, belt width B [m] changes in the interval <0, B>:
1. deflection in point A equals zero \( \Rightarrow y(0) = 0; \)
2. deflection in point B equals zero \( \Rightarrow y(B) = 0; \)
3. angle in point B/2 equals zero \( \Rightarrow y'(B/2) = \varphi(b/2) = 0. \)

![Figure 6](image)

**Figure 6.** Resultant of internal forces in the right section to its longitudinal axis of the belt conveyor.

From 1) it is clear that:

\[ y(0) = 0 = -\frac{1}{EJ_z}\left(\frac{qB}{12}0^3 - 0\frac{0^4}{24}\right) + C_1.0 + C_2 = C_2 \Rightarrow C_2 = 0 \]  

(12)

From 2) it is clear that:

\[ y(B) = 0 = -\frac{1}{EJ_z}\left(\frac{qB}{12}B^3 - 0\frac{B^4}{24}\right) + C_1.B = -\frac{1}{EJ_z}\left(\frac{qB}{12}B^4 - q\frac{B^4}{24}\right) + C_1.B \Rightarrow \]  

\[ = -\frac{1}{EJ_z}\left(\frac{qB^4}{12} - q\frac{B^4}{24}\right) + C_1.B = 0 \Rightarrow C_1 = \frac{1}{EJ_z}\frac{qB^3}{24} \]  

(13)

From 3) it is clear that: \( C_1 = \frac{1}{EJ_z}\frac{qB^3}{24}, \) the correctness of the solution of condition 2) is justified.

Maximum deflection \( y_{\text{max}} \) [m] is in the point B/2 [m]:

\[ y_{\text{max}} = y\left(\frac{B}{2}\right) = -\frac{1}{EJ_z}\left(\frac{qB}{12}\left(\frac{B}{2}\right)^3 - q\frac{B^4}{24}\right) + C_1\frac{B}{2} = -\frac{1}{EJ_z}\left(\frac{qB^4}{96} - q\frac{B^4}{384} - q\frac{B^4}{48}\right) = \frac{5qB^4}{384.EJ_z} \]
Provided we know the modulus of elasticity $E$ [Pa] of the belt conveyer in cross direction and the quadratic moment of section $J_z$ [m$^4$], we can determine the deflection and angle of rotation of the belt conveyer. Modulus of elasticity $E$ [Pa] of the belt conveyer in cross direction is expressed experimentally for the given belt conveyer. Quadratic moment of section $J_z$ [m$^4$] (Fig. 8) is expressed as $J_z = \frac{h^3 I}{12}$.

The modulus of elasticity of the two above mentioned assumptions were compared - isotropic and anisotropic body - with the intention to compare deviations of these methods.

The method of hanging up of the belt conveyer to its edges enables to determine the modulus of elasticity $E$ [Pa] in cross direction. However, in order to have the connection of the edges of the belt conveyer, and creation of the closed conveyer belt section, it is necessary to act on the edges of the belt conveyer by additional stress - axial thrust force $F$ [N]. The size of the axial thrust force $F$ [N] is dependent on the construction and cross stiffness $S_t$ of the belt conveyer.
The tensometric reader was mechanically fixed to the slider of the linear line AGW 15 SC. By sliding the slider and thus by mutual approaching of edges, the deflection of the belt conveyer y [m] is gradually measured in relation to the intensity of the acting force F [N]. Mutual contact of edges of the belt conveyer is modelling the shape of the curve of the given type of the belt conveyer (with the given type and number of textile ply, thickness and kind of upper and bottom top layer).

4. Conclusions
By means of final comparison of the shape of the curve gained by experiment and theoretical analysis, it is possible to express the deviation of the curve shape of the model belt conveyer in the program ANSYS, and thus determine the error of numerical expression of the cross plane of the pocket conveyer.

References
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