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POCKET BELT CONVEYER AS THE LIKELY TRANSPORTER OF LOOSE SUBSTANCE

VISEĆI TRANSPORTERI SA ZATVORENOM TRAKOM KAO PRIKLADNI TRANSPORTERI ZA TRANSPORT RASTRESITIH MATERIJALA

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Abstract: *Pocket conveyer is one of the possible structural solutions of belt conveyer transport, where loose substance is conveyed in closed slot of the belt. The slot emerges (forms) by mutual bringing (approaching) of edges of the belt conveyer together, which have vulcanized lengthwise parts, Fig.1. The lengthwise parts serve for the leading of the belt conveyer and its hanging on a special construction with a number of supporting discs.*

Key words: *pocket belt conveyer, transportation, loose substance*

Apstrakt: *Viseći transporter sa zatvorenom trakom je jedno od mogućih strukturalnih rešenja kod trakastih transportera, gde se rastresiti materijali transportuju u zatvorenoj površini trake. Površina se formira međusobnim približavanjem ivica trake koje imaju vulkanizovane dužinske delove, slika 1. Dužinski delovi služe za vođenje trake i njeno vešanje na specijalne konstrukcije sa brojnim nosećim diskovima.*

ključne reči: *viseći transporter sa zatvorenom trakom, transport, rastresiti materijali*

1 ENTRY PREREQUISITES AND THE DESCRIPTION OF THE POCKET CONVEYER

The pocket conveyer enables to convey the material of the gradient higher by 5 – 10° 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.

The required transport amount (volume) Q [t.h^{-1}] is dependent on cross section S [m^2] of the conveyed loose substance, speed of the conveyer v [m.s^{-1}], loose weight (mass) of the conveyed material ρ_s [kg.m^{-3}] and filling coefficient k_φ.

1 PRISTUPNI PREDUSLOVI I OPIS TRASNPORTERA

Viseći transporteri sa zatvorenom trakom, za razliku od trakastih transportera uobičajene konstrukcije, omogućavaju transport materijala pri usponima većim za 5-10^0 u poređenju sa transporterima normalne konstrukcije Takođe, fleksibilnost kod visećih transportera sa zatvorenom trakom u horizontalnim lukovima i krivinama, i pri skretanjima, značajno je veća nego kod standardnih trakastih transportera koji su ograničeni manjom mogućnošću skretanja.

Zahtevani kapacitet transporta Q [t/h] zavisi od preseka S [m^2] transportovanog rastresitog materijala, brzine transportera v [m/s], zapreminske mase transportovanog materijala ρ_s [kg/m^3] i koeficijenta popunjenosti k_φ.

It is possible to determine the expression (formulation) of the cross transport section S 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 when its edges contact (join), as accurately as possible.

Moguće je utvrditi izraz za transportni presek (S oblast površine ograničene trakom visećeg transportera) numeričkim metodama, zato što matematički opis krive nije nedvosmisleno izražen.

Za numerički izraz preseka rastresitog materijala koji se transportuje visećim transporterom neophodno je izraziti oblik krive koji formira traka kada se ivice trake spoje.

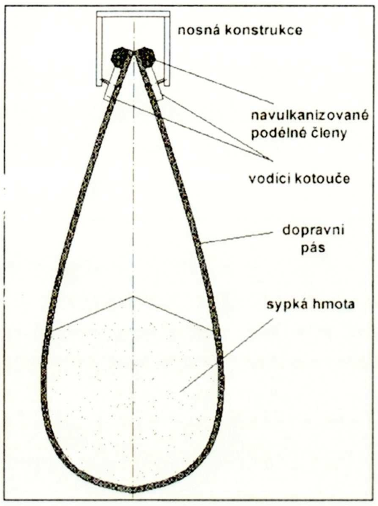

Figure 1 Cross section of the transport line of the pocket conveyer
slika 1 Presek transportne trake visećeg transportera sa zatvorenom trakom

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 of the belt in the cross direction with the purpose of computer analysis (evaluation) in the program ANSYS, followed by experimental verification on testing equipment. The belt 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, two types of models were examined:

1. model made as an anisotropic body – the model was made as a set of textile ply and top layers of the given dimensions
2. model made as an isotropic body – where the modulus of elasticity was expressed in cross direction of the belt as a whole.

Oblik krive koju će formirati traka visećeg transportera zavisi od poprečne čvrstoće trake. Poprečna čvrstoća trake transportera zavisi od tipa i konstrukcije transportera (broj i konstruktivni raspored tekstilnih uložaka transportne trake, vrsta i debljina gornjih i donjih obloga gume).

Zadatak je bio da se utvrdi modul elastičnosti E trake u poprečnom pravcu sa ciljem kompjuterske analize (ocene) u programu ANSYS, praćeno verifikacijom na opremi za testiranje. Traka se sastoji od konstrukcije, koja je sastavljena od tekstilnih uložaka i površinskih slojeva. U cilju određivanja modula elastičnosti u poprečnom pravcu trake, ispitivana su dva tipa uzoraka:

1. uzorak napravljen kao anizotropno telo – uzorak je napravljen kao komplet tekstilnih uložaka i gornjih obloga datih dimenzija,
2. uzorak napravljen kao anizotropno telo – gde je modul elastičnosti izražen u poprečnom pravcu trake.

Ad1) The examined (tested) belts 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 produces fabrics for belts in four sorts: - polyamide fabrics PA 6 – impregnated; polyester – polyamide fabrics (EP) – impregnated; fabrics for monoply belts SOLID WOVEN – unbleached (raw, grey) and fabrics for monoply 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.

On the rag tearing machine INOVA TSM 50 the tensile tests were made and the moduli 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 pick filling pick).

The standard [5] defines three sorts of rubber, see table 1, the standard [4] defines four sorts of rubber, see table 2, and the standard [6], see table 3, defines sorts of used top layers of the belts.

Two rubber samples were obtained, see Fig.3, used for belts of the firm STOMIL:

- sample Stomil Belchatow type 32PG, class 1, flammable
- sample Stomil Wolbrom type GTP, class 2, increased fire resistance

Ad2) 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 as a whole body. Samples of the belts 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 samples with textile ply defined in point 1.1 of the firms Stomil and Gumárny Púchov.

According to [2] the cross stiffness of the belt 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.

Ad1) Ispitivane trake firmi STOMIL i PUCHOV koriste konstrukcije napravljene od tekstilnih uložaka proizvedenih u fabrici Kordana a.s. Velka na Veličkou. Kordana proizvodi četiri tipa tkanine za trake: poliamidne tkanine PA 6 – impregnirane; poliester-poliamidne tkanine (EP) – impregnirane; tkanine za trake sa jednim uloškom – neizbeljene (izvorne, sive) i tkanine za transportne trake sa jednim uloškom SOLID WOVEN – impregnirane PVC-om.

Dobijeno je četiri tipa tkanina:

- dva tipa poliamidnih PA 6 – impregniranih: P 250/100 i P 400 Y/1
- poliester-poliamidne tkanine (EP) – impregnirane: EP 315A i EP 160

Na mašini za kidanje tkanine INOVA TSM 50 rađeni tu testovi na istezanje i utvrđeni su moduli elastičnosti za napred pomenute tipove tkanina. Primer opreme za testiranje i grafički prikaz ispitivanja na istezanje su predstavljeni na slici 2 (neophodno je naglasiti da su ispitivanja na istezanje urađena na pravcu tkanja tkanine.

Standard [5] definiše tri vrste gume, (tabela 1), standard [4] definiše četiri vrste gume, (tabela 2), a standard [6], tabela 3, definiše vrste korišćenih obloga gume.

Dobijena su dva uzorka gume, (slika 3), koji su korišćeni za trake firme STOMIL:

- uzorak Stomil Belchatov, tip 32PG, klasa 1, zapaljiv i
- uzorak Stomil Wolbrom, tip GTR, klasa 2, povećane optornosti na vatru.

Ad2) Drugi model razmatra traku kao izotropno telo, modul elastičnosti u poprečnom pravcu je određen eksperimentalnim merenjem savijanja pojedinačnih uzoraka trake kao celog tela. Uzorci trake dobijeni su od proizvođača čija je glavna fabrika u Češkoj Republici i njihove cene utiču na kupce. U tački 1.1 izražen je modul elastičnosti i poprečna krutost uzoraka trake sa tekstilnim uloškom firmi Stomil i Gumarny Puchov.

Prema [2] poprečna krutost trake je definisana njenom mogućnošću da se oblikuje u korito sopstvenim prilagođavanjem položaju valjaka. Zadatak ispitivanja je da se pronađe deformacija ispitivanog uzorka pomoću njegove težine kada je okačen na oba kraja, i da se meri ugib u njegovon srednjem delu.

Table 1 Physical properties of the rubber of belts
Tabela 1 Fizičke osobine gume kod traka

Stress	Belt type			Research method, see
	1	2	3	
a) tensile strength MPa (kG/cm^2) minimally	20 (200)	15 (150)	10 (100)	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 the temperature of 70°C for 144 hours				
Λ_{Rr}, %, maximum	15	20	25	PN-82/C-04216
$\Lambda_{\varepsilon r}$, %, maximum	25	30	35	PN-82/C-04216
In tables, it is defined 1kG/cm^2 = 0,1 MPa				

For the measuring is used 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.

Za merenje je korišćena oprema za ispitivanje prikazana na slici 4, koja se sastoji od dva dodatka, nosećih držača, jedan je fiksiran (čvrsto) a drugi je klizajući. Ispitivani uzorak je okačen na držače, širine najmanje 140 mm i najdalje 15 mm od kraja. Držač je na osovinama, ose osovine moraju biti u tački preseka ravni koja ide kroz sredinu ispitivanog tela sa ravni njegovih krajeva.

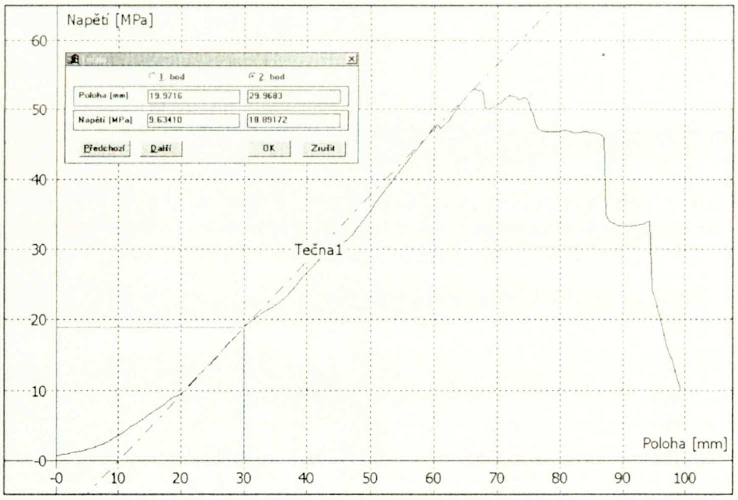

Figure 2 Tensile test of the given type of fabric of the carrier textile frame of the belt
slika 2 Ispitivanje na istezanje datog tipa tkanine noseće konstrukcije trake

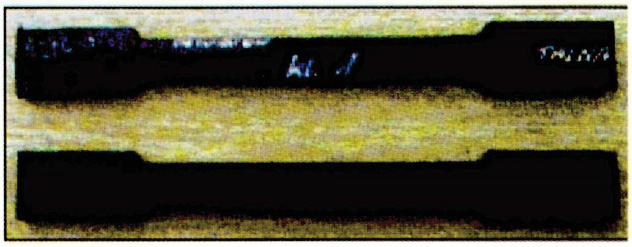

Figure 3 Samples of the rubber of top layers of the STOMIL belts
slika 3 Uzorak gume gornjih površinsih obloga traka STOMIL

Table 2 Strength to fracture, extension when pulling apart, abradability of the top layer
Tabela 2 Čvrstoća na lom, izduženje pri istezanju, abrazivnost površinskog omotača

Top layer	Strength to pulling apart N/mm^2; min.	Extension when pulling apart %; min.	Abradability mm^3 max.
W	18	400	90
X	25	450	120
Y	20	400	150
Z	15	350	250

Table 3 Usage of the belts in relation to operating conditions
Tabela 3 Upotreba traka pri operacionim uslovima

Type of the belt / label	Creation of the belt with top layers	Characterictics of the conveyed substance	Highest temperature of the conveyed substance °C	Characteristics of the working environment	Range of the environment temperatures °C	Highest speed of the belt $m.s^{-1}$
For general usage/Z	Rubber category A*)	Abrasive, angular, with high specific weight, big lumpiness (ores, quarry stone, overburden, surface coal)	+70	Dry or wet	-25 to +60	4,0 for belts type 160 to 400 6,3 for belts type 500 to 2000 9,0 for belts on packing machines
	Rubber category B	Mildly abrasive grained, loose (sand, gravel, ash, lime)	+70		-25 to +60	
	Rubber category AA*)	Very abrasive, medium to big lumpiness (ores, stone, agglomerate, overburden, surface coal, slag)	+70		-25 to +60	
	PVC	Mildly abrasive, grained, loose, partially lump, (sand, gravel, ash, lime)	+60		-20 up to +60	4,0
For underground usage/S	Rubber	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
	PVC		+70		+5 to +60	
Resistant to increased temperatures /T	Rubber category D	Hot materials, grained or loose(coke, clinker, agglomerates)	+125	Dry	-20 to +80	4,0
	Rubber category H		+150			

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 symetric top layers the orientation of the testing body is arbitrary).

Ispitivani uzorak je okačen na držače tako da su oba kraja u istoj ravni i gornja obloga je okrenuta naopako (za simetrične površinske obloge orjentacija ispitivanog uzorka je proizvoljna).

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** of the testing body.

It is calculated according to

$$y = A_2 - A_1 + \frac{s}{2}. \qquad (1)$$

Where $\mathbf{A_1}$ is the distance of the hanging point from the ground plane in mm; $\mathbf{A_2}$ distance of the lowest place on the belt surface from the ground plane in mm; **s** - total width of the belt in mm.

Cross stiffness of the belt (S_t) is calculated according to

$$S_t = \frac{K}{B}. \qquad (2)$$

Where **K** is the body deflection in mm; **B** belt width in mm.

Promenom klizećih dodataka, pozicija obešenih kablova je regulisana tako da su kablovi u verikalnom položaju (to je provereno viskom).

Ugib ispitivanog uzorka y [mm] je utvrđeno 5 minuta posle njegovog vešanja; to je razmak u vertikalnom pravcu između tačke vešanja (ose osovine držača) i najniže tačke savijanja, koja je u širini centra s ispitivanog tela.

Izračunato je prema:

$$y = A_2 - A_1 + \frac{s}{2}. \qquad (1)$$

gde je:
A_1 – razmak tačke vešanja i ravni podloge u mm,
A_2 – razmak najnižeg mesta na površini trake od ravni podloge i
s – ukupna širina trake u mm.

Poprečna krutost trake (S_t) je izračunata prema formuli:

$$S_t = \frac{K}{B}. \qquad (2)$$

gde je:
K – ugibi uzorka u mm i
B – širina trake u mm.

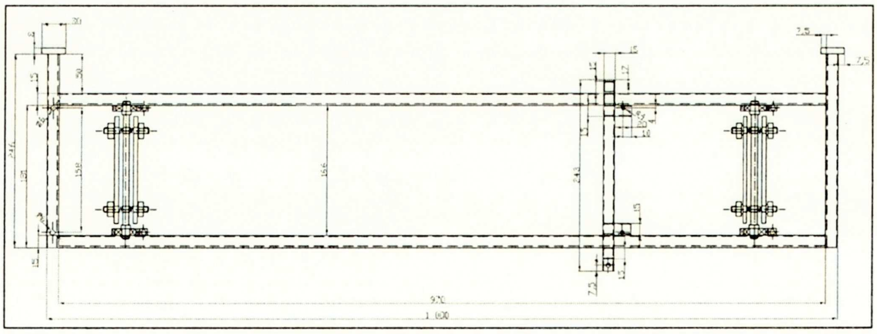

Figure 4 Testing equipment for the expression of the cross stiffness of the belt conveyer
slika 4 Oprema za ispitivanje za izražavanje poprečne krutosti trakastog tarnsportera

2 ILLUSTRATION OF THE DEFLECTION OF BELT AND EDGE CLAMPING FOR THE PURPOSES OF BELT POCKET CREATION

$Q = m \cdot g = q \cdot B \quad [N]$

$m = \frac{m_p}{B}$

$q = m \cdot g \qquad [N/m]$

2 ILUSTRACIJA SAVIJANJA TRAKE I SPAJANJA KRAJEVA U CILJU FORMIRANJA VISEĆEG TRANSPORTERA SA ZATVORENOM TRAKOM

$Q = m \cdot g = q \cdot B \quad [N]$

$m = \frac{m_p}{B}$

$q = m \cdot g \qquad [N/m]$

where:
m_p – weight 1 m belt [kg/m]
q – continuously distributed load, expressed from the weight of the belt [N/m]

$$Q = \int_B dQ = \int_B q(x).dx \qquad (3)$$

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

gde je:
m_p – težina 1 m trake [kg/m]
q – kontinualno raspoređeno opterećenje izraženo preko težine trake [N/m]

$$Q = \int_B dQ = \int_B q(x).dx \qquad (3)$$

Na slici 5 prikazana je traka širine B [m], debljine h [m] i dužine L [m]. Ako je debljina trake h značajno manja od širine B, moguće je posmatrati traku u ravni xy kao nosač opterećen sopstvenom težinom trake kao kontinualnim opterećenjem q. (slika 5.1).

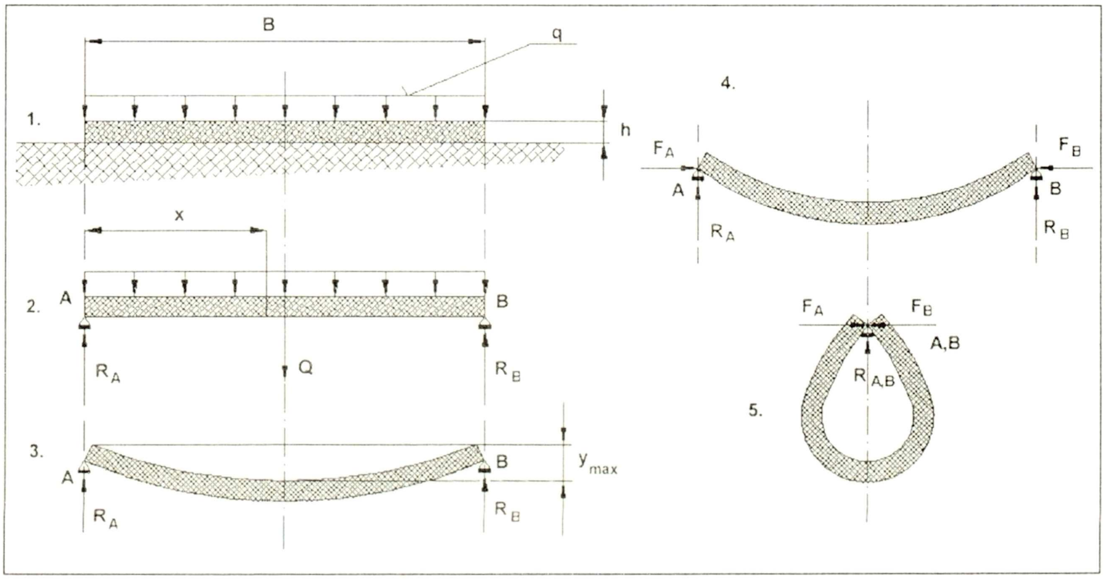

*Figure 5 Deflection of the belt, width **B**, influenced by its own weight (continuous transverse load **q**) and with the influence of axial load F_A, F_B.*
slika 5 Ugib trake širine B pod uticajem sopstvene težine (kontinualno transverzalno opterećenje q) i aksijalnog opterećenja F_A, F_B

The belt loaded by external power (force) **Q** (let us say by continuous load **q**) 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**, which is called bending moment M_0.

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** in the load centre of the particular belt element and reactions R_A a R_B will be introduced in the supports then we will get reactions R_A a R_B from the summary (cumulative) equation in the axis **y** in the support **A** and **B**:

$$R_A = R_B = \frac{Q}{2} = \frac{q.B}{2} \qquad (4)$$

Traka opterećena spoljašnjom silom Q (možemo reći kontinualnim opterećenjem q) se savija, ako rezultanta unutrašnjih sila u desnom delu ka njenoj longitudinalnoj osi (slika 6) formira par sila N, koja se zove moment savijanja M_0.

Veličina pokretnih sila i momenata savijanja će se utvrditi iz statičkog uslova ravnoteže, slika 5.2. Ako se kontinualno opterećenje zameni silom Q u centru opterećenja određenog elementa trake i uvedu se otpori oslonaca R_A i R_B tada ćemo dobiti reakcije R_A i R_B iz zbira (celokupnog) jednačine u osi y u osloncima A i B:

$$R_A = R_B = \frac{Q}{2} = \frac{q.B}{2} \qquad (4)$$

The size of the bending moment M_o is expressed in section **x** (Fig.5.2):

$$M_{0(x)} = R_A \cdot x - q \cdot x \cdot \frac{x}{2} = \frac{Q}{2} \cdot x - q \cdot \frac{x}{2} = = \frac{q \cdot B}{2} \cdot x - q \cdot \frac{x^2}{2} \quad (5)$$

Maximum bending moment M_{0max} interacts with the arm of force $\frac{B}{2} \Rightarrow$

$$M_{0\,max} = \frac{q \cdot B}{2} \cdot \frac{B}{2} - q \cdot \frac{1}{2} \cdot \left(\frac{B}{2}\right)^2 = = \frac{q \cdot B^2}{4} - \frac{q \cdot B^2}{8} = \frac{2 \cdot q \cdot B^2 - q \cdot B^2}{8} = \frac{q \cdot B^2}{8} \quad (6)$$

The size of the deflection y_{max} and the angle α_A and α_B will be determined from Schwedlerov theorem (formula), which shows the dependence between bending moment M_0, moving force **T** and continuous load **q** in the form of differential equation of the balance of the belt element [1].

Veličina momenta savijanja M_0 je izražena u delu x (slika 5.2):

$$M_{0(x)} = R_A \cdot x - q \cdot x \cdot \frac{x}{2} = \frac{Q}{2} \cdot x - q \cdot \frac{x}{2} = = \frac{q \cdot B}{2} \cdot x - q \cdot \frac{x^2}{2} \quad (5)$$

Maksimalni moment savijanja M_{0max} deluje sa krakom sile $\frac{B}{2} \Rightarrow$

$$M_{0\,max} = \frac{q \cdot B}{2} \cdot \frac{B}{2} - q \cdot \frac{1}{2} \cdot \left(\frac{B}{2}\right)^2 = = \frac{q \cdot B^2}{4} - \frac{q \cdot B^2}{8} = \frac{2 \cdot q \cdot B^2 - q \cdot B^2}{8} = \frac{q \cdot B^2}{8} \quad (6)$$

Veličina ugiba y_{max} i ugla α_A i α_B će biti određeni iz Švedlerove teoreme (formule), koja pokazuje zavisnost između momenta savijanja M_0, pokretne sile T i kontinualnog opterećenja q u obliku diferencijalne jednačine ravnoteže elementa trake [1].

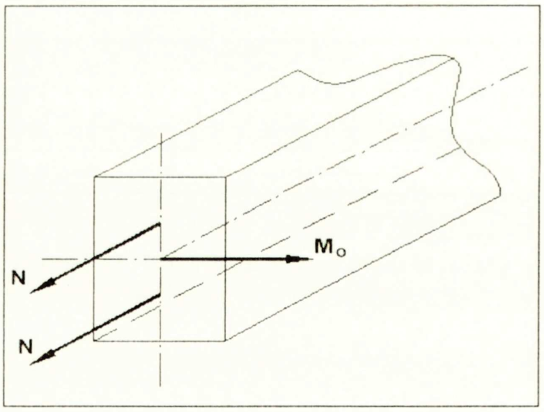

Figure 6 Resultant of internal forces in the right section to its longitudinal axis of the belt
slika 6 Rezultanta spoljašnjih sila u desnom delu longitudinalne ose trake

$$M_{0(x)} = \frac{q \cdot B}{2} \cdot x - q \cdot \frac{x^2}{4} \quad (7)$$

$$y''(x) = -\frac{1}{E \cdot J_z} \cdot M_{0(x)} = -\frac{1}{E \cdot J_z} \cdot \left(\frac{q \cdot B}{2} \cdot x - q \cdot \frac{x^2}{2}\right) \quad (8)$$

$$y'(x) = -\frac{1}{E \cdot J_z} \cdot \left(\frac{q \cdot B}{2} \cdot \frac{x^2}{2} - \frac{q}{2} \cdot \frac{x^3}{3}\right) = -\frac{1}{E \cdot J_z} \cdot \left(\frac{q \cdot B \cdot x^2}{4} - \frac{q \cdot x^3}{6}\right) + C_1$$

$$y(x) = -\frac{1}{E \cdot J_z} \cdot \left(\frac{q \cdot B}{4} \cdot \frac{x^3}{3} - \frac{q}{6} \cdot \frac{x^4}{4}\right) + C_1 \cdot x + C_2 = -\frac{1}{E \cdot J_z} \cdot \left(\frac{q \cdot B \cdot x^3}{12} - \frac{q \cdot x^4}{24}\right) + C_1 \cdot x + C_2 \quad (9)$$

Integration constants C_1 and C_2 will be determined from the marginal conditions, belt width **B** 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) = φ(b/2) = 0

From 1) it is clear that:

$$y(0) = -\frac{1}{E \cdot J_z} \cdot \left(\frac{q \cdot B \cdot 0^3}{12} - \frac{q \cdot 0^4}{24} \right) + C_1 \cdot 0 + C_2 = C_2$$

$$C_2 = 0 \tag{10}$$

From 2) it is clear that:

$$y(B) = 0 = -\frac{1}{E \cdot J_z} \cdot \left(\frac{q \cdot B \cdot B^3}{12} - \frac{q \cdot B^4}{24} \right) + C_1 \cdot B = -\frac{1}{E \cdot J_z} \cdot \left(\frac{q \cdot B^4}{12} - \frac{q \cdot B^4}{24} \right) + C_1 \cdot B = 0$$

$$C_1 = \frac{1}{E \cdot J_z} \cdot \frac{q \cdot B^3}{24} \tag{11}$$

From 3) it is clear that $C_1 = \frac{1}{E.J_z} \cdot \frac{q.B^3}{24}$, the correctness of the solution of condition 2) is justified.

Maximum deflection y_{max} is in the point **B/2** $\Rightarrow$

Integracione konstante C_1 i C_2 će biti utvrđene iz krajnjih uslova, širina trake se menja u intervalu <0, B>:

1.) Ugib u tački A jednak je 0 $\Rightarrow$ y(0)=0;
2.) Ugib u tački B jednak je 0 $\Rightarrow$ y(B)=0;
3.) Ugao u tački B/2 jednak je 0 $\Rightarrow$ y(B/2)= φ(b/2)=0.

Iz 1) jasno je da:

$$y(0) = -\frac{1}{E \cdot J_z} \cdot \left(\frac{q \cdot B \cdot 0^3}{12} - \frac{q \cdot 0^4}{24} \right) + C_1 \cdot 0 + C_2 = C_2$$

$$C_2 = 0 \tag{10}$$

Iz 2) jasno je da:

$$y(B) = 0 = -\frac{1}{E \cdot J_z} \cdot \left(\frac{q \cdot B \cdot B^3}{12} - \frac{q \cdot B^4}{24} \right) + C_1 \cdot B = -\frac{1}{E \cdot J_z} \cdot \left(\frac{q \cdot B^4}{12} - \frac{q \cdot B^4}{24} \right) + C_1 \cdot B = 0$$

$$C_1 = \frac{1}{E \cdot J_z} \cdot \frac{q \cdot B^3}{24} \tag{11}$$

Iz 3) jasno je da je $C_1 = \frac{1}{E \cdot J_z} \cdot \frac{q \cdot B^3}{24}$, tačnost rešenja iz uslova 2) je opravdana.

Maksimalni ugib y_{max} je u tački B/2 $\Rightarrow$

$$y_{max} = y\left(\frac{B}{2}\right) = -\frac{1}{E \cdot J_z} \cdot \left(\frac{q \cdot B}{12} \cdot \left(\frac{B}{2}\right)^3 - \frac{q}{24} \cdot \left(\frac{B}{2}\right)^4 \right) + C_1 \cdot \frac{B}{2} = -\frac{1}{E \cdot J_z} \cdot \left(\frac{q \cdot B^4}{96} - \frac{q \cdot B^4}{384} - \frac{q \cdot B^4}{48} \right) = \frac{5 \cdot q \cdot B^4}{384 \cdot E \cdot J_z}$$

$$y_{max} = -\frac{5 \cdot q \cdot B^4}{384 \cdot E \cdot J_z} = -\frac{5 \cdot q \cdot B^3}{384 \cdot E \cdot J_z} \tag{12}$$

Provided we know the modulus of elasticity **E** of the belt in cross direction and the quadratic moment of section J_z we can determine the deflection and angle of rotation of the belt. Modulus of elasticity **E** of the belt in cross direction is expressed experimentally for the given belt conveyer.

Quadratic moment of section J_z (Fig.8) is expressed as $J_z = \frac{h^3.l}{12}$.

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

Pretpostavimo da znamo modul elastičnosti E trake u poprečnom pravcu i kvadratni moment J_z, onda možemo odrediti ugib i ugao rotacije trake. Modul elastičnosti E trake u poprečnom pravcu je izražen eksperimentalno za dati trakasti transporter.

Kvadratni momenat dela J_z (slika 8) je izražen kao $J_z = \frac{h^3 \cdot l}{12}$.

Moduli elastičnosti od gore pomenute dve pretpostavke su upoređeni – izotropno i anizotropno telo – sa namerom da se uporede odstupanja ovih metoda.

The method of hanging up of the belt to its edges enables to determine the modulus of elasticity **E** in cross direction. However, in order to have the connection of the edges of the belt, and creation of the closed belt section, it is necessary to act on the edges of the belt by additional stress– axial thrust force **F**. The size of the axial thrust force **F** is dependent on the construction and cross stiffness $\mathbf{S}_t$ of the belt.

Program ANSYS enables to express the size of this additional stress– axial thrust force **F**.

Metoda vešanja ivica trake omogućava da se utvrdi modul elastičnosti E u poprečnom pravcu. Međutim, u cilju povezivanja ivica trake i kreiranja zatvorenog dela trake, neophodno je delovati na ivice trake dodatnim opterećenjem – aksijalnom silom potiskivanja F. Veličina aksijalne sile potiskivanja F zavisi od konstrukcije i poprečne krutosti trake S_t.

Program ANSYS omogućava da se objasni veličina dodatnog opterećenja - aksijalna sila potiskivanja F.

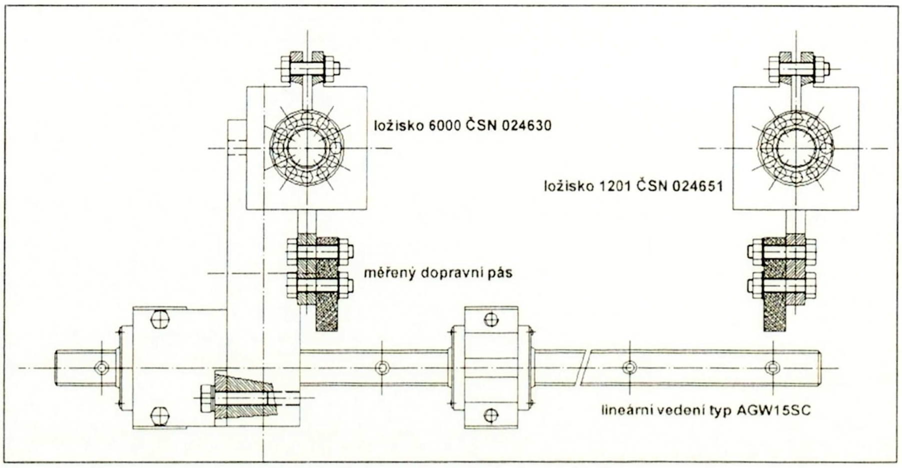

Figure 7 Expression of the cross section of the element of belt
slika 7 Objašnjenje poprečnog dela elementa trake

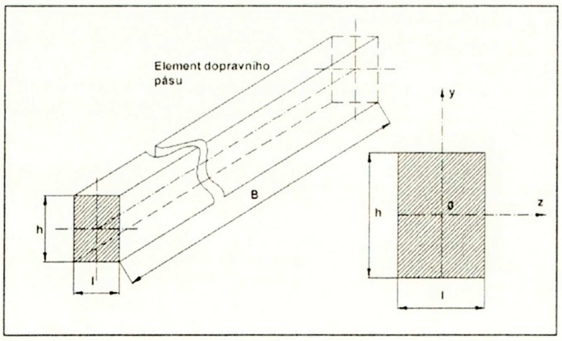

Figure 8 Quadratic moment of section J_z expressed from the dimension of the belt conveyer sample
slika 8 Kvadratni moment dela J_z izražen iz dimenzija uzorka trakastog transportera

On the measuring stand, see Fig.7, the real intensity of the axial thrust force **F** was measured by means of metric tensor weight reader with the compensation of the excentric load, accuracy rank 0,01%, identification **PW2G-2**, measuring range 0-72 kg, firm HBM (Hottinger Baldwin Messtechnik). 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 **y** is gradually measured in relation to the intensity of the acting force **F**. Mutual contact of edges of the belt is modelling the shape of the curve of the given type of the belt (with the given type and number of

Na postolju za merenje, (slika 7), stvarni intenzitet aksijalne sile potiskivanja F je izmeren pomoću tenzometričkog indikatora težine sa kompenzacijom ekscentričnog optrerećenja, tačnosti reda 0,01%, označen sa PW2G-2, merni opseg 0-72 kg, firme HBM (Hottinger Baldwin Messtechnik). Tenzometrički indikator je mehanički fiksiran za klizač dužinske trase AGW 15 SC. Klizanjem klizača, a prema tome i međusobnim približavanjem ivica, ugib trake y je postepeno meren u vezi sa intenzitetom delujuće sile F. Međusobni kontakt ivica trake dobija oblik krive datog tipa trake (sa datim tipom i brojem tekstilnih textile ply, thickness and kind of upper and bottom top layers). 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 in the program ANSYS, and thus determine the error of numerical expression of the cross plane of the pocket conveyer.

uložaka, debljinom i vrstom gornjih i donjih površinskih slojeva). Načinom konačnog upoređenja oblika krive dobijenog eksperimentalnim i teoretskim analizama, moguće je izraziti odstupanje oblika krive uzorka trake u programu ANSYS, a prema tome i utvrditi grešku numeričkog izražavanja poprečne ravni visećeg transportera.

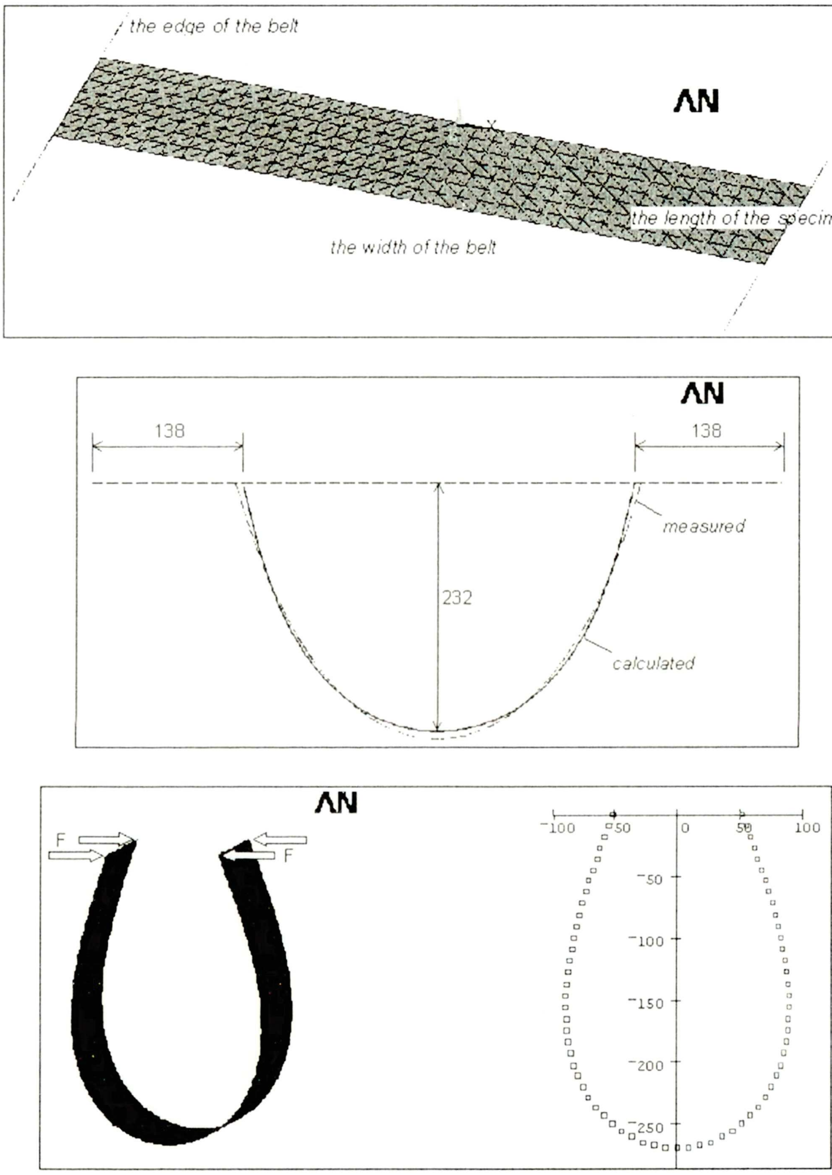

Figure 9 The curve shape of the the model belt in the program ANSYS
slika 9 Oblik krive uzorka trake u programu ANSYS

3 CONCLUSION

Pocket belt conveyer could have wider appliance in transportation of loose substance. Because of that, it is important to do the researches of the belt characteristics for used belts. The best results were obtained in combi researches, experimental and computer analyse.

3 ZAKLJUČAK

Viseći transporteri sa zatvorenom trakom mogu imati što širu primenu pri transportu rastresitih materijala. Zbog toga je veoma važno da se izvrše ispitivanja karakteristika traka koje se primenjuju. Najbolje rezultate daju kombinovana ispitivanja eksperimentalnim putem i primenom kompjuterske analize.

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