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Stress Analysis of Belt Conveyor Roller Tube

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Abstract – Material transmission plays a crucial role in the industrial sector's economic landscape, and belt conveyors have emerged as highly efficient systems for continuous material transportation. These conveyors utilize rubber belts that facilitate the horizontal or inclined movement of materials. The primary objective is to transport materials from the loading point to the unloading point. This study focuses on the analysis of belt conveyors, specifically examining the utilization of reels and the significance of selecting suitable belt speeds. By employing advanced simulation software such as Ansys, the behavior of the reel under specific conditions was analyzed, and exaggerated images were utilized to visualize reel deformations. The findings indicate that the most significant deformation occurs at the center of the roller, while the highest stress values are concentrated near the bearings. To ensure efficient material transportation, it is imperative to understand and optimize the performance of belt conveyors. The selection of appropriate reels, belt speeds, and materials is crucial to maintain smooth operations and extend the system's service life. The insights gained from this research can guide decision-making processes, allowing industries to enhance efficiency and minimize maintenance costs. In conclusion, the selection of suitable components and a comprehensive understanding of reel behavior are key factors in improving belt conveyor systems. By employing advanced simulation tools and implementing effective strategies, industries can optimize material transportation processes, increase productivity, and minimize operational disruptions. Continuous improvement in design and maintenance practices will lead to streamlined operations and improved performance of belt conveyors.

Keywords – Roller, Belt Conveyor, Bearing, Stress Analysis, Deformation

I. Introduction

Material transmission is one of the most influential factors on the business economy in the industry today. Belt conveyors form the most efficient system in continuous material transmission among many application areas. Belt conveyors are manufactured in two types, fixed and mobile. All construction methods of fixed belt conveyors are in such a way that they remain fixed during use. Features such as the accessible high carrying capacity, the ability to carry loads over long distances, the curved transport path, simple design, lightweight structure, reliable operation have made the belt conveyors the most used transport machine. The conveyed material can be wet or dry or in granular form [1].

In rubber band transmission systems, an endless moving band transports the material horizontally or inclined upwards or downwards. The task of the belt is to transport the material to be conveyed from the loading place to the unloading place. In order to fulfill this task, the belt is placed on a suitable machine construction. In this system, there is a drive drum connected with the drive system and a direction change (tail) drum connected to the tensioning system. The steel construction carries the conveyor rollers carrying the upper belt line and the return rollers carrying the lower belt line [1].

The history of belt conveyors goes back nearly 200 years from our time. In our time, belt conveyors are used to transport a wide variety of materials in large capacities and long distances, and it can be said that the final limits in belt conveyor design have not yet been reached. The first belt conveyors made in America were used for grain transportation, and at the end of the 19th century, belt conveyors were used for the transportation of coal and ores [4].

The first conveyors had no rollers, the belt slid on wooden or sheet metal slides; then straight and concave pulleys, and in the last years of the 19th century triple pulley groups emerged. After the emergence of roller bearing groups, we see that belt conveyors are widely used in the transport of bulk material in large capacities and long distances [4].

Belt conveyors are used in many areas such as loading, unloading, stocking and taking from stock as well as material transmission. Commonly in coal and mines; in mineral processing and enrichment facilities; in stone crushing, screening and washing plants; sand and mold grinding works in foundries; ore, coal, grain etc. in ports. in loading and unloading of materials; Belt conveyors are mostly used in the paper, sugar industry and grain silos [2].

The conveyor belt, despite being the most expensive part of a conveyor system, is often the least durable. It undergoes a complex state of stress due to the loading effect, characterized by varying sizes and distinctive nature. Several common types of belt damage include surface and edge wear, impact-induced striking, tearing, and peeling caused by large ore particles. Additionally, the belt core experiences fatigue from alternating bending around idlers, leading to decreased intensity and aging due to environmental factors. Calculations suggest that conveyor belt expenses account for half of the total equipment cost. Therefore, selecting a suitable belt based on the operating conditions, as well as implementing effective maintenance and management practices, are crucial for extending the belt's service life, improving conveyor efficiency, and reducing manufacturing costs [3].

Conveyor belts can be categorized into two types: rubber belts and plastic belts. Rubber belts are typically suitable for temperatures ranging from -10°C to +40°C, with the material temperature not exceeding +50°C to maintain elasticity. If the temperature drops too low, the belt becomes stiff and prone to cracking. For temperatures above +90°C, a fireproof belt should be used, while a cold-proof belt is recommended for temperatures between -15°C and -55°C [3].

Rollers serve as support devices for the conveyor belt and cargo. They move in sync with the belt to reduce running resistance. The quality of idlers greatly impacts the lifespan of the conveyor belt, and maintenance costs for idlers often constitute a significant portion of operating costs. Therefore, idlers should possess a reasonable structure, durability, low steering resistance, reliability, and prevent dust or coal dust from entering the bearings. These features help minimize running resistance, save energy, and extend the service life of the conveyor [3].

Working conditions and bandwidth are factors that determine the diameter of the pulley. The reel diameter varies depending on the diameter of the pipe it is made. Taking the pulley diameter larger is beneficial in terms of belt life since it will increase the radius of curvature of the belt. On the other hand, costs increase with the increase in diameter [1].

II. Materials and Method

In this study, there is dry clay to be carried by flat belt conveyor which have a standart rubber belt with woven carcass. The total length of the conveyor is not important. The goal is carrying (%100 caliber 65 mm) clay on standart rubber belt with 1 m/s speed, and finding out what happens to the roller's tube. First of all belt width has to be found. So carried material's angle of reposes are needed. As it seen clay has 20° dynamic repose angle in Table 1 [5].

Table 1. Angle of Repose [5]

	Malzemenin akma özelliği				
	Çok akıcı	Akıcı	Orta akıcı		Zor akıcı
Şekil	5°	10°	20°	25°	30°
Dinamik şev açısı	5°	10°	20°	25°	30°
Doğal şev açısı	0° - 20°	20° - 30°	30° - 35°	35° - 40°	40° den fazla
Örnek malzeme	Kuru silika kumu, çimento, ıslak beton	Bakliyat ve tahıl taneleri	Antrasit kömürü, kil, pamuk tohumu	Bitümlü kömür, taş, maden cevheri	Ağaç talaşı, tavlanmış döküm kumu, küspe

For specific dynamic repose angle there is this special chart so this is the reason why choosed clay. Material is thinned fully to 65 mm granul size. The belt width is determined as shown in Table 2. B=400 mm.

Table 2. Belt Width [5]

Cetvel 6.21 Malzeme büyüklüğüne bağlı olarak bant genişliği (20° dinamik şev açısı için)

Bant genişliği (mm)	Malzeme içindeki parça yüzdesine göre en az parça boyutları (mm)					
	%5	%10	%20	%80	%90	%100 kalibreli
350	120	100	80	65	60	50
400	150	150	100	75	75	65
450	180	150	130	90	90	75
500	200	180	150	100	100	90
650	270	220	220	140	140	120
750	330	280	280	180	180	160
800	350	290	290	190	180	160
1000	460	390	390	260	230	210
1200	600	500	500	350	300	270
1400	730	660	620	380	330	330
1500	750	700	700	400	360	360

For B=400 mm and material's density is 1.2 t/m^3 so belt weight per meter is 4.2 daN in Table 3.

Table 3. Belt Weight [5]

Cetvel 6.6 Yaklaşık bant ağırlıkları: G_B (daN/m)

Bant Genişliği (mm)	Malzemenin Yığma Özgül Ağırlığı (t/m^3)		
	0.45-1.20	1.20-2.00	2.00-3.20
300	3.1	3.8	3.9
350	3.7	4.5	4.6
400	4.2	5.2	5.3
450	4.6	6.0	6.1
500	5.2	6.7	6.8
550	5.7	7.6	8.0
600	6.2	8.5	9.2
650	6.6	9.0	9.8
700	7.3	9.5	10.6
750	7.8	10.3	11.6
800	12.0	12.5	15.0
900	13.4	14.0	17.0
1000	15.0	16.0	19.2
1400	22.5	25.5	29.2
1600	27.6	30.3	33.5
1800	30.0	36.0	38.0
2000	33.0	40.0	42.0

The length between idle pulleys is determined from Table 4 as LT =1500 mm.

Table 4. Length Between Rollers [5]

Cetvel 6.9 Taşıyıcı ve dönüş makara grupları arasında öngörülen aralıklar (mm)

Bant Genişliği (mm)	L_T (mm) Malzemenin özgül ağırlığı (t/m^3)						Dönüş Makarası L_D (mm)
	0.5	0.8	1.2	1.6	2.0	2.4	
300-400	1600	1500	1500	1500	1400	1400	3000
450-550	1600	1500	1400	1400	1400	1400	3000
600-700	1500	1500	1400	1400	1200	1200	3000
750-850	1500	1400	1200	1200	1000	1000	3000
900	1400	1400	1200	1200	1000	1000	3000
1000	1400	1400	1200	1000	1000	900	2700
1200	1200	1200	1000	1000	900	900	2700
1400	1200	1200	1000	1000	900	900	2700
1600-1800	1200	1000	1000	900	900	900	2500
2000	1200	1000	1000	900	900	900	2500

Not: 1. Yükleme bölgesinde makara aralığı yarı yarıya azaltılmalıdır.
2. Ağır çalışma şartlarında bu aralıklar % 25 oranında azaltılabilir.

Then the weight of the belt per pulley is:

G_B = (4.2 daN/m)*(1.5 m)

G_B = 63 N

The clay has a bulk density between 0.96-1.20, so 1.20 is used [5]. Then materials volume must be calculated , so section area needed. And it is A=0.0056 m^2 as the Table 5 shows.

$G_M = \gamma\ A\ L_T\ g$

G_M = (1200 kg/m^3) (0.0056 m^2) (1.5 m) (9.81 m/s^2)

G_M = 99 N

Total Force: F = G_B + G_M = 162 N

So at the end we obtained the forces act on 1 roller. This forces and roller's own weight due to gravity are added to Ansys.

Table 5. Section Area [5]

Cetvel 6.23 Düz bantlı konveyörlerde malzeme kesit alanı (m^2) (v=1 m/s için)

Bant Genişlikleri (mm)	Dinamik Şev Açıları: β					
	5°	10°	15°	20°	25°	30°
400	0.0012	0.0028	0.0042	0.0056	0.0071	0.0087
500	0.0023	0.0047	0.0070	0.0094	0.0119	0.0145
650	0.0042	0.0083	0.0126	0.0169	0.0214	0.0259
800	0.0065	0.0131	0.0197	0.0265	0.0335	0.0406
1000	0.0105	0.0210	0.0318	0.0427	0.0539	0.0654
1200	0.0154	0.0310	0.0467	0.0627	0.0791	0.0961
1400	0.0213	0.0427	0.0644	0.0866	0.1092	0.1326
1600	0.0281	0.0564	0.1085	0.1112	0.1442	0.1750
1800	0.0364	0.0720	0.1457	0.1457	0.1839	0.2233
2000	0.0445	0.0894	0.1811	0.1811	0.2285	0.2774
2200	0.0542	0.1088	0.2203	0.2203	0.2779	0.3374
2400	0.0648	0.1300	0.2633	0.2633	0.3322	0.4033
2600	0.0763	0.1531	0.3101	0.3101	0.3913	0.4750
2800	0.0888	0.1782	0.3608	0.3608	0.4552	0.5526
3000	0.1022	0.2050	0.4158	0.4158	0.5240	0.6361

The speed of belt is chosen below the shown value because of safety (1 m/s). Since the pulley is rotating , it's angular velocity (w) must be found.

Linear velocity (v) at outher surface of the pulley (when r = r_{max}) is equal to belt's velocity, so:

v = w . r

(1 m/s) /(75 x 10^{-3} m) = w

w = 13.333 rad / s

Engineering Data was seen in Fig. 1.

Outline of Schematic B2: Engineering Data

	A	B	C	D	E
1	Contents of Engineering Data			Source	Description
2	Material				
3	Structural Steel			General_Mater	Fatigue Data at zero mean stress comes from 1998 ASME BPV Code, Section 8, Div 2, Table 5 -110.1
*	Click here to add a new material				

Properties of Outline Row 3: Structural Steel

	A	B	C	D	E
1	Property	Value	Unit		
2	Material Field Variables	Table			
3	Density	7850	kg m^-3		
4	Isotropic Secant Coefficient of Thermal Expansion				
6	Isotropic Elasticity				
7	Derive from	Young's Modulus...			
8	Young's Modulus	2E+11	Pa		
9	Poisson's Ratio	0,3			
10	Bulk Modulus	1,6667E+11	Pa		
11	Shear Modulus	7,6923E+10	Pa		
12	Strain-Life Parameters				
20	Tensile Yield Strength	2,5E+08	Pa		
21	Compressive Yield Strength	2,5E+08	Pa		
22	Tensile Ultimate Strength	4,6E+08	Pa		
23	Compressive Ultimate Strength	0	Pa		

Fig. 1 Engineering Data

The model cylinder has t=15 mm of thickness. Mesh and element size were seen in Fig. 2 and Fig. 3, respectively.

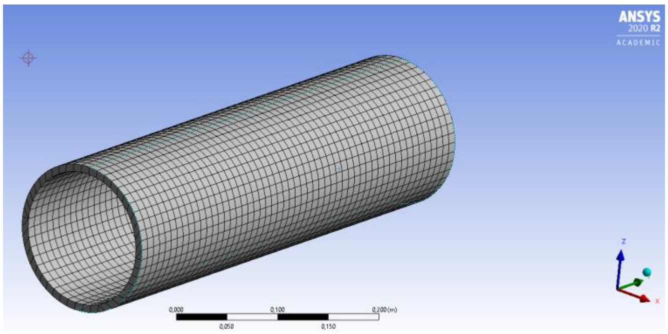

Fig. 2 Mesh

Details of "Mesh"

Display	
Display Style	Use Geometry Setting
Defaults	
Physics Preference	Mechanical
Solver Preference	Mechanical APDL
Element Order	Program Controlled
Element Size	1,e-002 m

Fig. 3 Element Size

III. Results and Discussion

Supports are frictionless and mirrored. Supports and roller rotation were seen in Fig. 4 and Fig. 5, respectively.

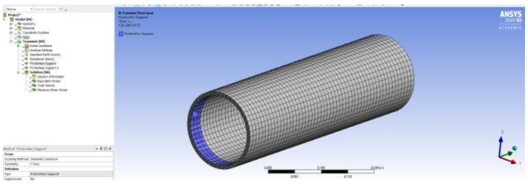

Fig. 4 Support

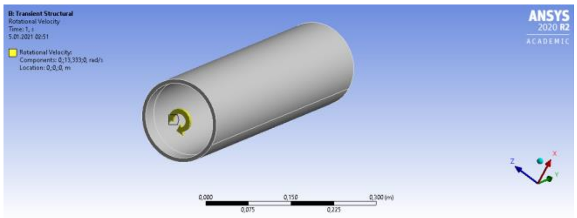

Fig. 5 Roller Rotation

Max. equivalent (von-Mises) stress was obtained as 12.687 MPa (Fig. 6).

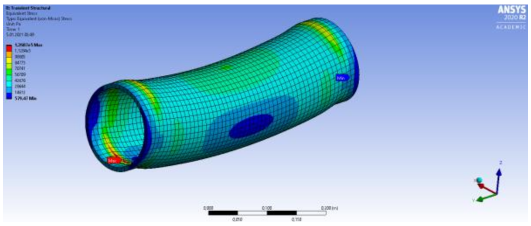

Fig. 6 Equivalent (von-Mises) Stress

Maximum shear stress was obtained as 73.192 MPa (Fig. 7).

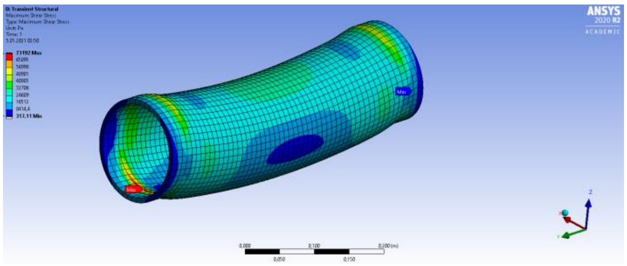

Fig. 7 Maximum Shear Stress

Total deformation was obtained as 0.00014559 mm (Fig. 8).

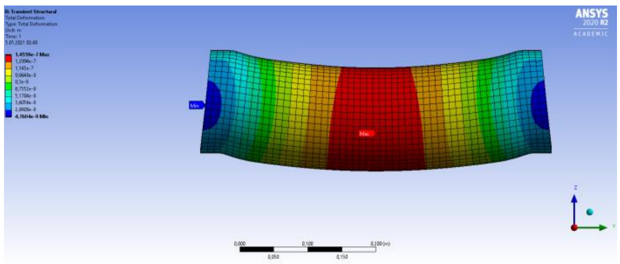

Fig. 8 Total deformation

IV. Conclusion

As expected, the highest deformation is at the middle of the roller, the highest stress value was located near the bearings.

- Max. equivalent (von-Mises) stress was obtained as 12.687 MPa.
- Maximum shear stress was obtained as 73.192 MPa.

- Total deformation was obtained as 0.00014559 mm.

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