

BELT CONVEYOR DESIGN AND ANALYSIS

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Abstract: For handling of partial or continuous goods, belt conveyors are very efficient way. Belt conveyors are used in mining, iron and steel plants, thermal power plants, ore, coal, limestone, sinter transmission, automotive and the other sectors. There are several factors that have to be taken into consideration when a belt conveyor being designed. That means belt conveyor design process requires repetitive strength calculations. But analytical calculations are not capable of determine to entire stresses which occurred at whole body. During the design process, time can be saved with the assistance of Finite Element Method. In this study; as a result, it has been seen that, F.E.M is the most practical method which can be utilized during belt conveyor design process.

Keywords: BELT CONVEYOR, DESIGN, ANALYSIS, FINITE ELEMENT METHOD

1. Introduction

In this study; belt conveyor which is carrying lignite and has 2.5m/s carrying velocity and 50 meters horizontal length was investigated. (250t/h capacity)

For this purpose, conveyor drums, shafts and belt were chosen by tables. As a first step of projection, belt width was described as 1 meter with using of slope angle of lignite and capacity of belt conveyor. Then, belt mass was taken from table for values of lignite's density and belt width. For idlers, values of mass, diameter and width were taken from table for belt width. With this values, weight of conveyor's moving parts were calculated.

As a second step, necessity of engine power was calculated after the calculations. Then, type of the motor drive was chosen as drive from head. For this selection, friction forces were calculated for idlers and belt. Also, the value of take-up force was described with friction forces which were calculated and the take-up was projected to be connected to tail pulley. Belt deflection was calculated analytically.

As a final step of projection, carcass of belt conveyor and number of plies were described. Then, axle diameters of idlers and pulleys were determined with tables. [1, 2, 3, 4, 5, 6] Also, head drive pulley's width was determined too. Head drive pulley's rotation speed was calculated and the reducer was chosen from the catalogue. [7] The conveyor which was designed during this study is shown in the figure below.

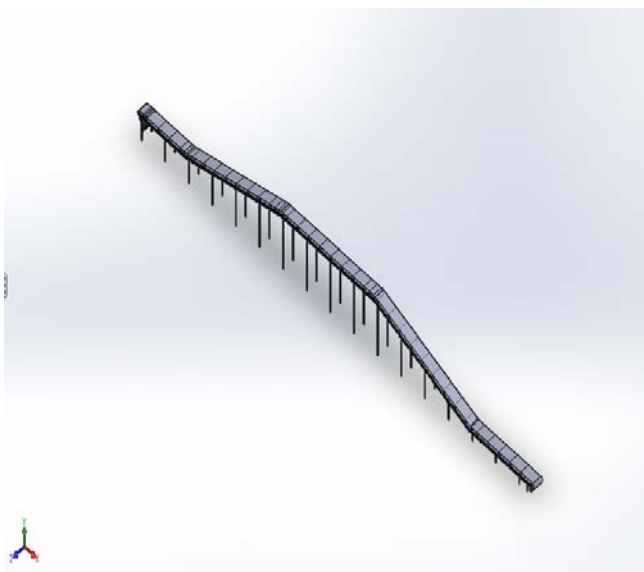


Fig. 1 Designed belt conveyor.

2. Analytical Analysis of the Belt Conveyor

Belt conveyor has been analysed analytically, before it was analysed with finite element method. Firstly the total deformation of the belt conveyor was checked. After that, basic conveyor elements and their dimensions have been defined. For analysis of belt conveyor there was not a formula to determine all types of stresses. So, determining of occurred stresses was difficult. Some empirical approaches were used to calculate stresses.

After all stresses were determined, shafts diameters were calculated for idlers and drums also bearings were chosen in accordance to idlers and drums diameters.[8]

Equation 1: Total deformation calculation formula.

$$f \leq \frac{L_T^2 (G_B + G)}{8T_1} \cong 17.5 \text{ mm}$$

$$L_T = 1400 \text{ mm}, G_B = 15 \text{ daN/m}, G = 27.8 \text{ daN/m}, T_1 = 900 \text{ daN}.$$

Equation 2: Stress calculation formula.

$$\sigma_{\max} = \frac{(M_e)_{\max}}{I_x} y_{\max}$$

Table 2: Values for stress calculation.

Part name	M_e [Nm]	I_x [mm ⁴]	y_{\max} [mm]	σ_{\max} [MPa]
Idler	114785	$\frac{\pi(133^4 - 125^4)}{64}$	$\frac{133}{2}$	2,26
Idler shaft	23485,40	$\frac{\pi \cdot 25^4}{64}$	$\frac{25}{2}$	15,31
Tail pulley	114711,19	$\frac{\pi(320^4 - 300^4)}{64}$	$\frac{320}{2}$	0,198
Tail pulley shaft	44205,04	$\frac{\pi \cdot 20^4}{64}$	$\frac{20}{2}$	56,29
Take-up pulley shaft	124078,10	$\frac{\pi \cdot 30^4}{64}$	$\frac{30}{2}$	46,8
Diversion pulley	127167,19	$\frac{\pi(320^4 - 300^4)}{64}$	$\frac{320}{2}$	0,174
Diversion pulley shaft	36180,07	$\frac{\pi \cdot 20^4}{64}$	$\frac{20}{2}$	46
Head drive pulley	210222,75	$\frac{\pi(400^4 - 380^4)}{64}$	$\frac{400}{2}$	0,180
Head drive pulley shaft	855000	$\frac{\pi \cdot 70^4}{64}$	$\frac{70}{2}$	26

3. Analysis of the Belt Conveyor with Finite Element Method

The next stage of the study includes the analysis of the belt conveyor with finite element method. To be able to analyze the belt conveyor by means of this method, firstly 3D solid model of the belt conveyor must be generated.[9]

3.1 Modelling of Belt Conveyor

For the design of the belt conveyor, usage of one pulley for tail, one for head, one for take-up and three for diversion was decided. Thicknesses of pulleys were determined for all of them as ten millimeters. Also, usage of sixty seven idlers was decided for the design. Forty six idlers of sixty seven were used to support of belt. Thicknesses of idlers were determined as four millimeters for every idler. With the tables, thickness of the belt was calculated eight millimeters.

For the chassis parts of the belt conveyor, U160 profiles were chosen for main frame, U120 profiles were chosen for supports which are thirty six, and for the connections between main frame parts, square section eighty millimeters profiles were chosen which are forty two.

In this study SolidWorks 3D design software has been used for modelling the belt conveyor. All the belt conveyor components were modelled one by one, and then they were combined.

3.2 Analysis of the Belt Conveyor Using ANSYS FEA Software

After the design of belt conveyor, there was a necessity for the analysis of belt conveyor to be sure about the conveyor's safety and capability for usage. For this purpose, finite element method which is one of the realistic approaches to analyze stress, strain, deflection etc. was chosen.

Designed belt conveyor model was transferred to ANSYS Workbench to analyze the belt conveyor. Static structural mode was opened to make linear and static analysis for the conveyor. Engineering data were given to analyze. Then model was being prepared. For the preparation of the model, materials specifications were assigned firstly. Then contacts were determined and contact types were assigned. After that, the model was divided into 804828 elements and 2640145 nodes for application of finite element method. At this point, belt was thought to be shell, and the others solid. Meshed model is shown in figure 2.

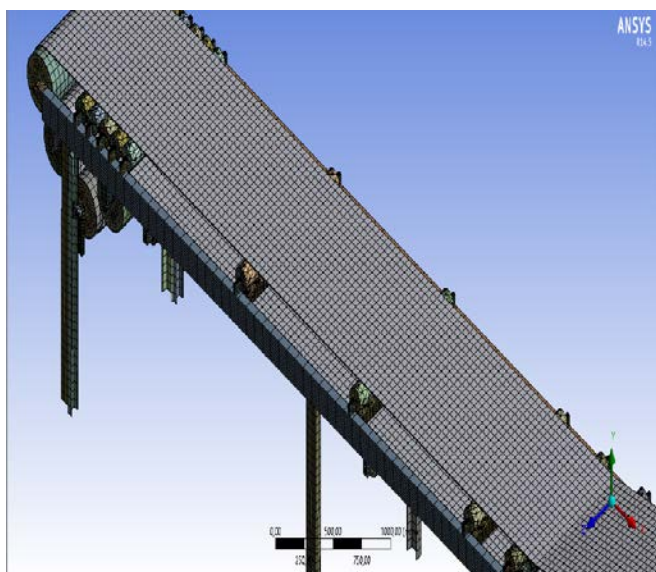


Fig. 2 Meshed model.

For finishing of the model preparation, all of the conditions were applied. Gravity were applied to all bodies, rotational velocity(120rpm) was applied to drive pulley shaft, weight of

lignite(13900N) was applied to belt, take-up force(7050N) was applied to take-up pulley and finally, fixed supports were applied to all supports' bottom faces. Belt conveyor model is shown in figure 3.

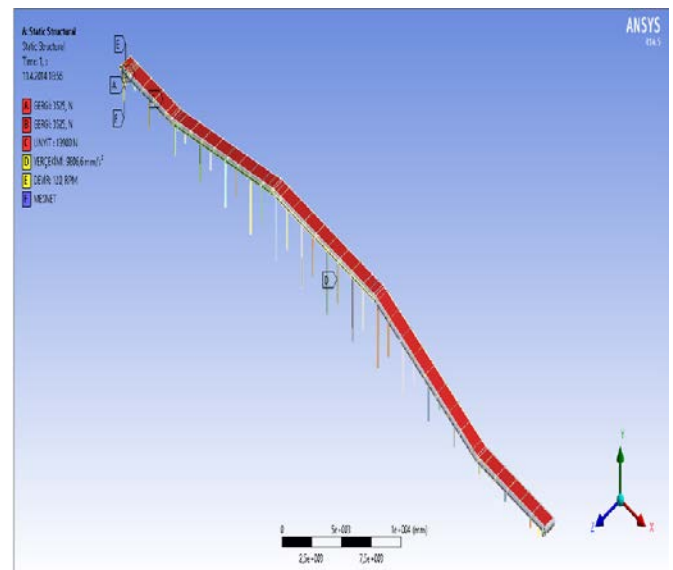


Fig. 3 Belt conveyor model.

4. Results

The software was run with these boundary conditions and the load combinations mentioned above. According to this analysis, we can see that maximum total deflection (Fig. 4) is smaller than 17.5 mm which is calculated analytically.

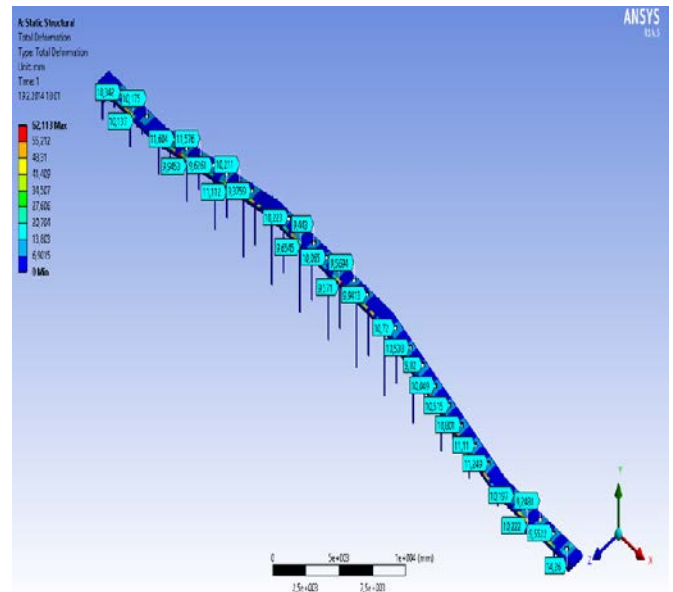


Fig. 4 Total deflection.

This result show us, if the analytical formula is customized for belt conveyor, results have proximity between analytical method and finite element method.

Unfortunately, at the belt conveyor topic, we have not any customized stress calculation for belt conveyor parts, only we have generalized stress calculation formula which comes from strength of materials approach.

Analytical approach results is shown in the table 1. For making a comparison between analytical approach and finite element method in this section, we need FEM results. So results are shown in Fig. [5-9]. From this results, we can see that some regions have stress concentrations which depend on design features. These

unpredictable stresses and hardnesses on calculation stage cause differences between analytical and FEM results.

Comparison between analytical approach and finite element method is shown table 2.

In accordance to these results, FEM is only way to determine all types of stresses which occur at belt conveyor parts.

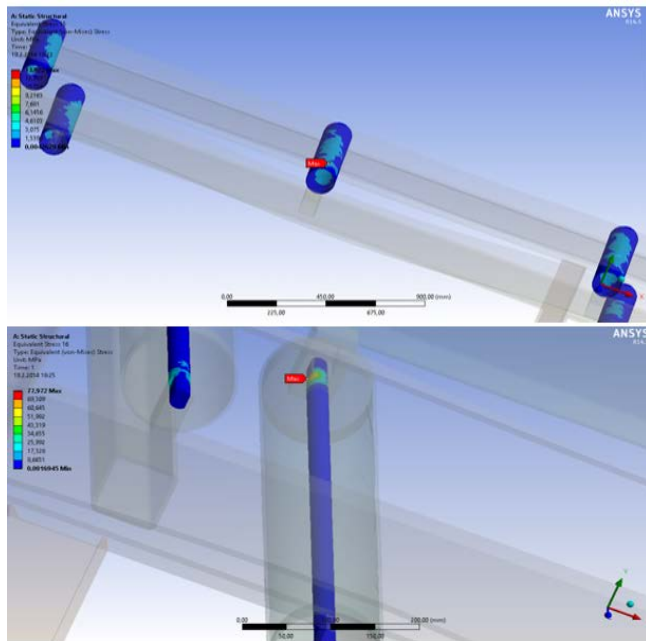


Fig. 5 Occurred stresses at idlers and idlers' shafts.

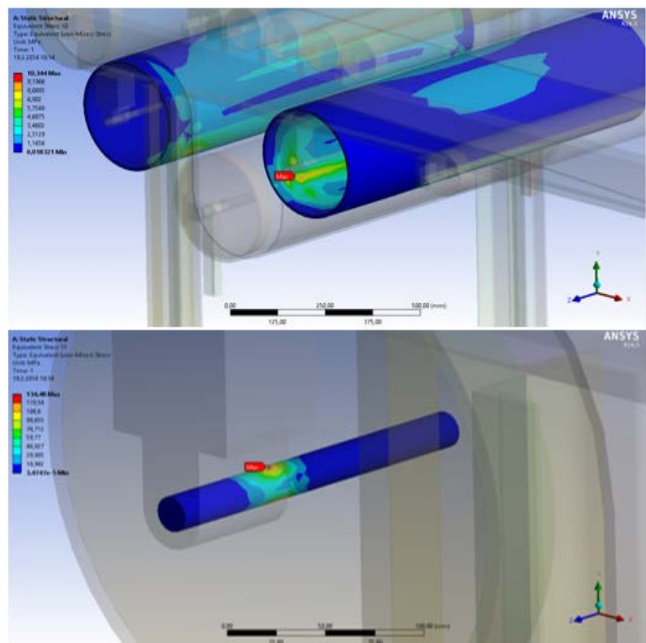


Fig. 6 Occurred stresses at diversion pulleys and diversion pulleys' shafts.

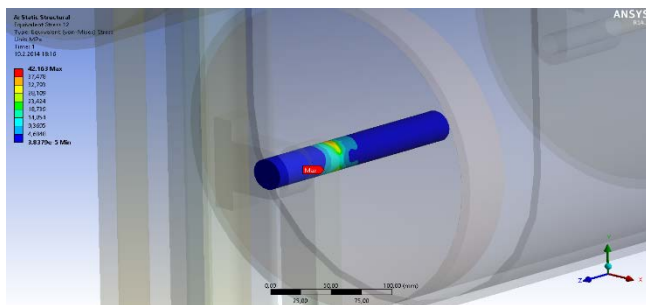


Fig. 7 Occurred stresses at take-up pulley's shaft.

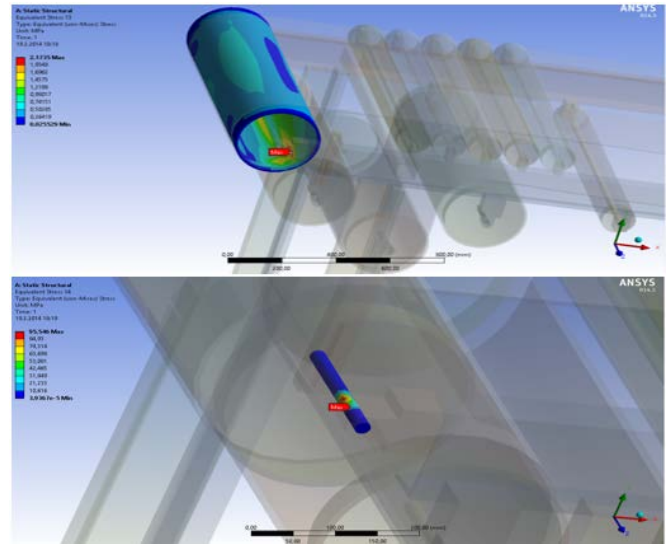


Fig. 8 Occurred stresses at tail pulley and tail pulley's shaft.

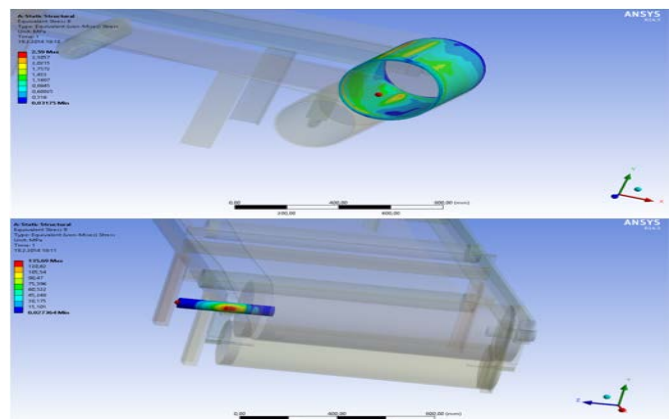


Fig. 9 Occurred stresses at head drive pulley and head drive pulley's shaft.

Table 2: Comparison between analytical approach and finite element method.

	Analytical Approach	Finite Element Method	
Part name	σ_{max} [MPa]	σ_{max} [MPa]	Difference (%)
Idler	2,26	13,822	83,6
Idler shaft	15,31	77,972	80,3
Tail pulley	0,198	2,1735	90,8
Tail pulley shaft	56,29	95,546	41
Take-up pulley shaft	46,8	42,163	-10,9
Diversion pulley	0,174	10,344	98,3
Diversion pulley shaft	46	134,48	65,7
Head drive pulley	0,180	2,59	93
Head drive pulley shaft	26	135,69	80,8

5. Conclusion

During the design process of belt conveyors or the similar structures, it is not enough only system's being safe in terms of strength. The design must fulfil the minimum safety conditions and should be light and cheap as well. Therefore, to be able to reach the optimum design, system should be modified and revised numerous times.[9]

Calculating the system with analytical approaches causes design process to take long and incorrect. In belt conveyor design process and the similar studies which require repetitive calculations, designers can save time by using finite element method. Constructor can change the model in computer environment and get the results of the new design via finite element method without wasting time. Also, this is the most practical and reliable way to reach the optimum design in terms of strength, weight and cost.[9]

6. References

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