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Optimizing Conveyor Belt Performance: Impact of Capacity Increase on System Efficiency and Structural Integrity Using Belt Analyst Software

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Abstract

This study investigates the effects of increasing conveyor belt capacity from 148.5 tons per hour (t/h) to 180 t/h on the overall system performance, employing both manual measurements and simulations using Belt Analyst software. The research aims to evaluate critical parameters such as effective pulling force, motor power requirements, structural load, and belt deflection, which are essential for determining the feasibility and impact of such an upgrade. The analysis reveals that with the capacity increase, the effective pulling force required rises to 14,072 N, while the motor power usage escalates to 15 kW. Concurrently, the structural load experiences a significant increase from 46.144 kg/m to 56.238 kg/m, and belt deflection intensifies from 22 mm to 27 mm. These findings suggest that increasing the conveyor belt capacity to 180 t/h, may lead to increased stress on the structure and belt, which could potentially affect the lifespan and performance of the conveyor system. Furthermore, while the conveyor system's performance enhances at the higher capacity, it also places additional stress on the system's components. The study further examines the implications of these changes, emphasizing the potential risks to the conveyor belt's structural integrity and the possible reduction in its lifespan due to the increased mechanical stress. It is highlighted that careful consideration and precise engineering adjustments are necessary when planning capacity enhancements to avoid adverse effects on the system's longevity and reliability.

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1. Introduction

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Conveyor belts have a very important role in the production process. Heavy industries like steel, fertilizer, chemical and cement etc. cannot function without the belt conveyors. In construction projects, the belt conveyors are used for handling. A conveyor system is a common piece of mechanical handling equipment that moves materials from one location to another. A conveyor system uses two pulleys that continuously loop over the material that rotates over them. A series of rollers along the path then supports the belt [1]. The performance of conveyor belts in bulk material handling is critical for optimizing production capacity across various industries. The use of advanced software tools, such as Belt Analyst, allows for detailed analysis and simulation of conveyor systems, which can lead to significant improvements in efficiency and reliability [2].

Knowledge of the physical, mainly mechanical, properties of conveyor belt rubbers belong to important preconditions of trouble-free operation of conveyor belt transportation. The mechanical nature of rubber materials used in belt transportation has, among others, an immediate effect on the friction between rubber layers of a conveyor belt and a driving drum and/or on the total power consumption. This knowledge is relevant not only in the case of new belts, where it helps their optimal selection concerning the nature and quantity of transported material, but also during monitoring the belt changes caused by operation [3].

One of the primary concerns in conveyor belt operations is the control of material flowability to prevent spillage, which can disrupt production and lead to environmental issues. emphasize the importance of modeling and simulation in managing coal flowability to mitigate spillage and enhance conveyor performance [4]. This aligns with the findings of Du et al., who advocate for the use of virtual prototyping to analyze the dynamic performance of belt conveyors, thereby reducing design cycles and development costs [5]. Such virtual modeling techniques enable engineers to identify potential issues in material transfer and optimize the design before physical implementation. Moreover, the capacity of a conveyor belt can be directly influenced by its geometrical configuration and the actual load it carries. Research indicates that maintaining the operational capacity of a conveyor belt below 80% is crucial for ensuring durability and performance [6]. This is supported by Guo & Wang, who discuss the advantages of belt conveyors in terms of conveying capacity and operational stability [7]. The integration of dynamic analysis tools, as highlighted by Feng et al., is essential for modernizing conveyor systems to handle larger loads and higher speeds effectively [8].

Dynamic modeling and simulation are also vital for understanding the mechanical properties of conveyor belts under various loading conditions. Sun's work on dynamic modeling illustrates how simulation software can be utilized to analyze the elastic modulus of steel cord conveyor belts, providing insights into their performance under stress [9]. This is further complemented by the findings of Li & Pang, who explore the dynamic characteristics of belt conveyors and the factors influencing their performance [10]. In addition to performance optimization, the detection and management of conveyor belt failures, such as longitudinal tears, are critical for maintaining operational efficiency. propose a multispectral visual detection method that enhances the identification of such failures, thereby reducing downtime and repair costs [11]. This is particularly relevant in coal mining operations, where conveyor belts are integral to production processes [11]. The implementation of such detection technologies can significantly contribute to the reliability and safety of conveyor systems.

The purpose of this study is to analyze the performance of the conveyor belt used to transport materials to find out the effective pulling force, the actual motor power used, belt tension also finds out the belt deflection, and loads on the structure of the conveyor belt due to increased capacity. Due to the need to increase production, an industry must consider the capabilities of the conveyor system they have.

Figure 1. Illustration conveyor belt. length 223 m, belt width 750 mm.

2. Materials and Methods

The plan to increase production requires raw material capacity to be transported by conveyor from 148.5 t/h to 180 t/h. The requirement of the conveyor are described as follows, with conveyor belt length 223 meter and belt width is 750 mm., displacement distance is 101 m, height difference is 19.4 m, using 3-roller-idler as carry idler, and 1-roller-idler as return idler, angle of repose 30˚, angle of surcharge 25˚, distance between idler 1.3 m, actual motor power used 22 kW, actual belt speed 0.9 m/s, maximum belt tension 29,302 N transported material is limestone with density 1,442 kg/m³.

2.1. Calculation

Calculations are made to find the value of effective tensile force and material weight if the capacity is increased from 148.5 tons per hour to 180 tons per hour.

Effective tensile force and material weight are calculated using equations (1) and (2), respectively [12].

$$F_e = W_m \times H + 0.04\,(2 \times W_b + W_m) \times L \quad (1)$$

$$W_m = \frac{Q}{V} \quad (2)$$

where:
F_e : effective tensile force (N)
W_m : material weight (Kg/m)
Q : capacity (t/h)
V : belt speed (fpm)
W_b : belt weight (Kg/m)
L : displacement distance (m)
H : altitude difference (m)

2.2. Belt Deflection Measurement

Belt deflection measurement is done manually by measuring the bending that occurs. Measurements were made at no-load conditions, with a capacity of 148.5 tons per hour and a capacity of 180 tons per hour.

2.3. Simulation

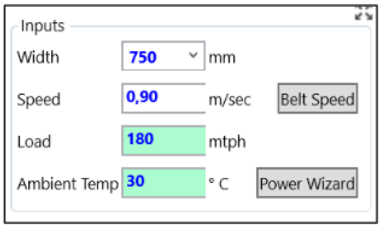
The simulation uses Belt Analyst 16 software to determine the structure's strength, dynamic load, belt tension, and motor power used. Calculations in this software are done automatically, if one parameter changes then the other parameters concerned will automatically change [13]. The steps needed to use this software are:

1. Input Data

Data entered are as follows:
Belt width of 750 mm, actual belt speed of 0.9 m/s, and capacity of 180 t/h.

Limestone material characteristics, with a surcharge angle of 25˚.

Required carry idler and return idler. Carry idlers with 3-rollers and an angle of 35˚, spacing is 1.3 meters long, the number of carry idlers needed is around 79 pieces. Return idler with 1-roller, spacing 3 meters long, the required number of return idlers is about 29 pieces.



Inputs

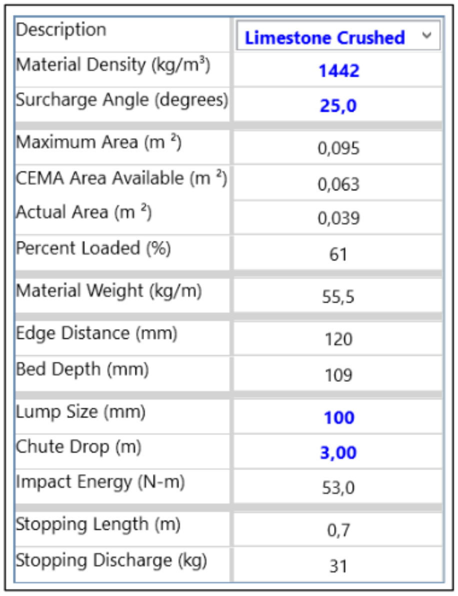
Width 750 mm

Speed 0,90 m/sec

Load 180 mtph

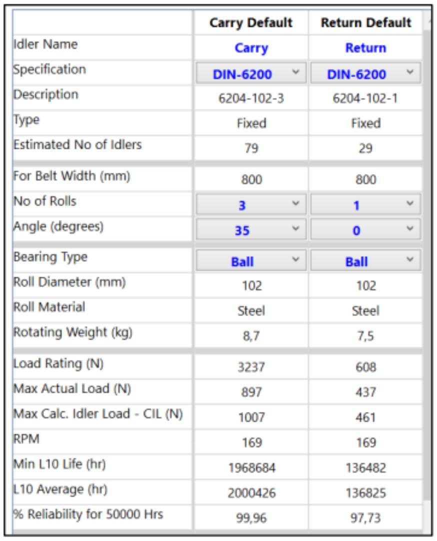
Ambient Temp 30 ° C

Figure 2. Specification data input to the software



Description	Limestone Crushed
Material Density (kg/m^3)	1442
Surcharge Angle (degrees)	25,0
Maximum Area (m ^{2})	0,095
CEMA Area Available (m ^{2})	0,063
Actual Area (m ^{2})	0,039
Percent Loaded (%)	61
Material Weight (kg/m)	55,5
Edge Distance (mm)	120
Bed Depth (mm)	109
Lump Size (mm)	100
Chute Drop (m)	3,00
Impact Energy (N-m)	53,0
Stopping Length (m)	0,7
Stopping Discharge (kg)	31

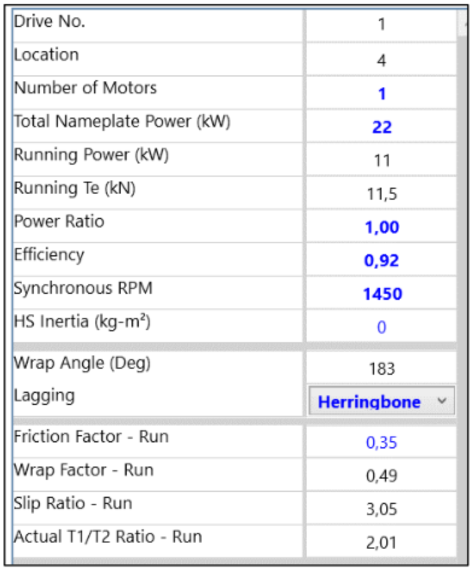
Figure 3. Material data input to the software



	Carry Default	Return Default
Idler Name	Carry	Return
Specification	DIN-6200	DIN-6200
Description	6204-102-3	6204-102-1
Type	Fixed	Fixed
Estimated No of Idlers	79	29
For Belt Width (mm)	800	800
No of Rolls	3	1
Angle (degrees)	35	0
Bearing Type	Ball	Ball
Roll Diameter (mm)	102	102
Roll Material	Steel	Steel
Rotating Weight (kg)	8,7	7,5
Load Rating (N)	3237	608
Max Actual Load (N)	897	437
Max Calc. Idler Load - CIL (N)	1007	461
RPM	169	169
Min L10 Life (hr)	1968684	136482
L10 Average (hr)	2000426	136825
% Reliability for 50000 Hrs	99,96	97,73

Figure 4. Idler's data input to the software

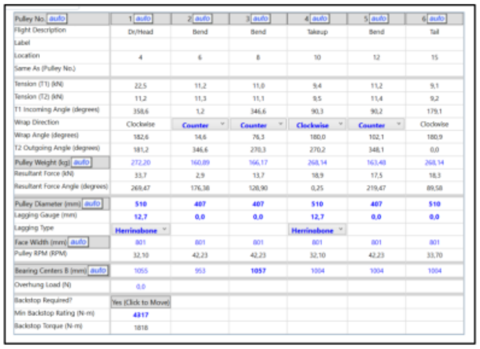
The motor power used is a motor with a power of 22 kW with an efficiency of 0.92.



Drive No.	1
Location	4
Number of Motors	1
Total Nameplate Power (kW)	22
Running Power (kW)	11
Running Te (kN)	11,5
Power Ratio	1,00
Efficiency	0,92
Synchronous RPM	1450
HS Inertia (kg-m²)	0
Wrap Angle (Deg)	183
Lagging	Herringbone
Friction Factor - Run	0,35
Wrap Factor - Run	0,49
Slip Ratio - Run	3,05
Actual T1/T2 Ratio - Run	2,01

Figure 5. Power motor used data input to the software.

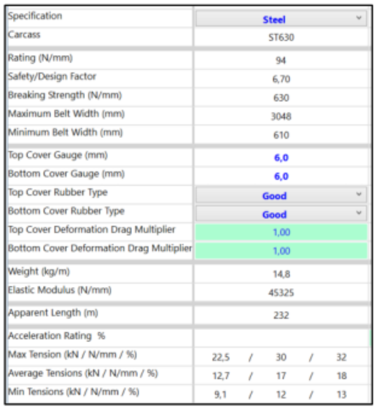
Pulleys used are drive/head pulley, tail pulley, bend pulley, and take-up pulley.



Pulley No. auto	1 auto	2 auto	3 auto	4 auto	5 auto	6 auto
Flight Description	Dr/Head	Bend	Bend	Takeup	Bend	Tail
Label						
Location	4	6	8	10	12	15
Same As (Pulley No.)						
Tension (T1) (kN)	22,5	11,2	11,0	9,4	11,2	9,1
Tension (T2) (kN)	11,2	11,3	11,1	9,5	11,4	9,2
T1 Incoming Angle (degrees)	358,6	1,2	346,6	90,3	90,2	179,1
Wrap Direction	Clockwise	Counter	Counter	Clockwise	Counter	Clockwise
Wrap Angle (degrees)	182,6	14,6	76,3	180,0	102,1	180,9
T2 Outgoing Angle (degrees)	181,2	346,6	270,3	270,2	348,1	0,0
Pulley Weight (kg) auto	272,20	160,89	166,17	268,14	163,48	268,14
Resultant Force (kN)	33,7	2,9	13,7	18,9	17,5	18,3
Resultant Force Angle (degrees)	269,47	176,38	128,90	0,25	219,47	89,58
Pulley Diameter (mm) auto	510	407	407	510	407	510
Lagging Gauge (mm)	12,7	0,0	0,0	12,7	0,0	0,0
Lagging Type	Herringbone			Herringbone		
Face Width (mm) auto	801	801	801	801	801	801
Pulley RPM (RPM)	32,10	42,23	42,23	32,10	42,23	33,70
Bearing Centers B (mm) auto	1055	953	1057	1004	1004	1004
Overhung Load (N)	0,0					
Backstop Required?	Yes (Click to Move)					
Min Backstop Rating (N-m)	4317					
Backstop Torque (N-m)	1818					

Figure 6. *Pulley data input to the software*

Belt used is a belt with carcass steel, and each cover has a width of 6.4 mm.



Specification	Steel
Carcass	ST630
Rating (N/mm)	94
Safety/Design Factor	6,70
Breaking Strength (N/mm)	630
Maximum Belt Width (mm)	3048
Minimum Belt Width (mm)	610
Top Cover Gauge (mm)	6,0
Bottom Cover Gauge (mm)	6,0
Top Cover Rubber Type	Good
Bottom Cover Rubber Type	Good
Top Cover Deformation Drag Multiplier	1,00
Bottom Cover Deformation Drag Multiplier	1,00
Weight (kg/m)	14,8
Elastic Modulus (N/mm)	45325
Apparent Length (m)	232
Acceleration Rating %	
Max Tension (kN / N/mm / %)	22,5 / 30 / 32
Average Tensions (kN / N/mm / %)	12,7 / 17 / 18
Min Tensions (kN / N/mm / %)	9,1 / 12 / 13

Figure 7. Belt data input to the software.

Draw the conveyor belt profile according to the actual situation.

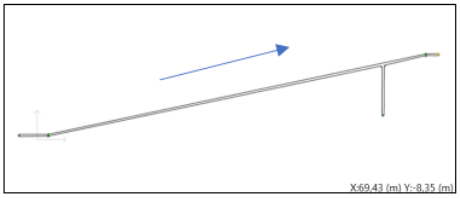


Figure 8. Conveyor belt profile, length is 223 meters, width is 750 mm, distance is 101 m, height difference is 19.4 m, angle of repose 30˚, angle of surcharge 25˚.

3. Results

3.1. Result of Calculations

Material weight (Wm):

Capacity 148.5 t/h

$$W_m = \frac{Q}{V}$$

$$W_m = \frac{148.5 \ \ t/h}{0.9 \ \ m/s}$$

$$W_m = \frac{41.25 \ \ kg/s}{0.9 \ \ m/s}$$

$$Wm = 45.833 \text{ kg/m}$$

Capacity 180 t/h

$$W_m = \frac{Q}{V}$$

$$W_m = \frac{180 \ \ t/h}{0.9 \ \ m/s}$$

$$W_m = \frac{50 \ \ kg/s}{0.9 \ \ m/s}$$

$Wm = 55.555$ kg/m

Effective tensile force (Fe)

Capacity 148.5 t/h

$$F_e = W_m \times H + (0{,}04\ (2 \times W_b + W_m) \times L)$$

$$F_e = 45.833 \times 19.4 + (0.04\ (2 \times 13 + 45.833) \times 101)$$

$$F_e = 1364.5 \text{ kg}$$

$$F_e = 13645 \text{ N}$$

Capacity 180 t/h

$$F_e = Wm \times H + (0{,}04\ (2 \times Wb + Wm) \times L)$$

$$F_e = 55{,}555 \times 19{,}4 + (0{,}04\ (2 \times 13 + 55{,}555) \times 101)$$

$$F_e = 1407.2 \text{ kg}$$

$$F_e = 14072 \text{ N}$$

3.2. Result of Belt Deflection Measurement

Belt deflection occurs in the carry idler with a distance of 1.3 meters between idlers. Belt deflection is measured in a static state, under no-load conditions the belt deflection is 8 mm, the deflection for a capacity of 148.5 t/h is 22 mm, for a capacity of 180 t/h the deflection reaches 27 mm.

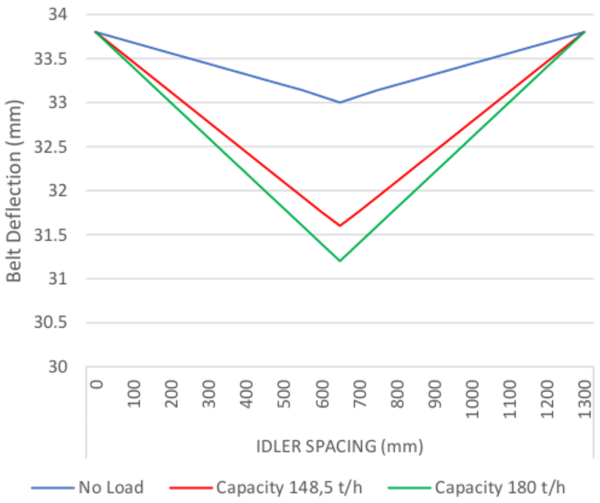


Figure 9. Belt deflection calculation result graphs.

3.3. Result of Simulation

Simulation for belt conveyor capacity of 180 t/h.

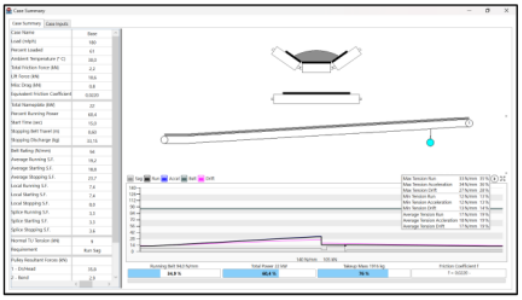
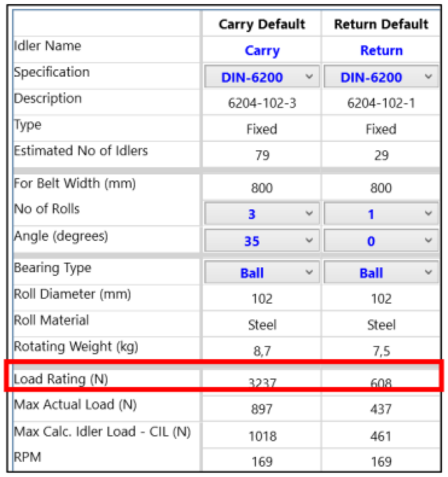


Figure 10. Result of conveyor belt strength simulation.

The result of the simulation uses Belt Analyst 16 software. The strength of the structure is determined based on the actual load on carrying idlers. The volume of material per meter at a capacity of 180 t/h is 555.55 N/m.

The strength of the structure is predicted to be able to withstand loads of up to 255,723 N because there are 79 carry idlers; every idler can withstand 3,237 N, if the capacity is increased, the structure is still able to withstand loads.



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Estimated No of Idlers	79	29
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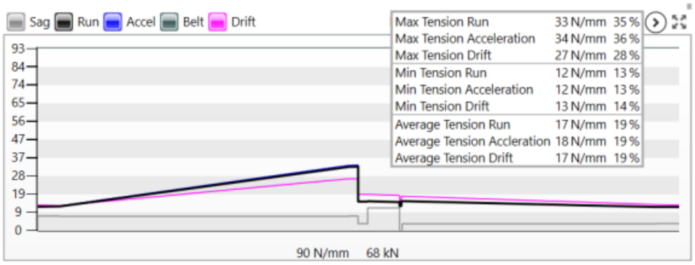
No of Rolls	3	1
Angle (degrees)	35	0
Bearing Type	Ball	Ball
Roll Diameter (mm)	102	102
Roll Material	Steel	Steel
Rotating Weight (kg)	8,7	7,5
Load Rating (N)	3237	608
Max Actual Load (N)	897	437
Max Calc. Idler Load - CIL (N)	1018	461
RPM	169	169

Figure 11. The Strength of the structure is safe, and the load rating is below the carry default.

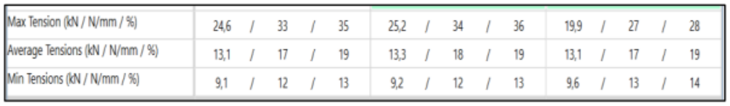
Dynamic load on the conveyor structure can be determined based on the result of tension. Maximum dynamic load is 34 N/mm, and minimum dynamic load is 12 N/mm.



Max Tension Run	33 N/mm	35 %
Max Tension Acceleration	34 N/mm	36 %
Max Tension Drift	27 N/mm	28 %
Min Tension Run	12 N/mm	13 %
Min Tension Acceleration	12 N/mm	13 %
Min Tension Drift	13 N/mm	14 %
Average Tension Run	17 N/mm	19 %
Average Tension Accleration	18 N/mm	19 %
Average Tension Drift	17 N/mm	19 %

Figure 12. Dynamic load on the conveyor belt structure.

Belt tension can be determined based on the simulation result below, with a maximum tension of 25.2 kN and minimum tension of 9.1 kN. The maximum tension the belt can withstand is 29.2 kN



Max Tension (kN / N/mm / %)	24,6 / 33 / 35	25,2 / 34 / 36	19,9 / 27 / 28
Average Tensions (kN / N/mm / %)	13,1 / 17 / 19	13,3 / 18 / 19	13,1 / 17 / 19
Min Tensions (kN / N/mm / %)	9,1 / 12 / 13	9,2 / 12 / 13	9,6 / 13 / 14

Figure 13. Belt tension is safe.

The simulation results explain that to transport materials with a capacity of 180 t/h, the required power is only 60.4% of 22 kW, namely 15KW.

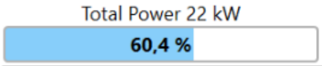


Figure 14. Power used after capacity increased is 60,4 % of total power

4. Conclusions

The results of the belt performance analysis explain that if the conveyor belt capacity is increased to 180 t/h, the effective pulling force that occurs is 14,072 N, the maximum belt tension is 25,200 N, the motor power used is 13.28 kW, there is an additional load on the structure from 45.833 kg/m to 55.555 kg/m, and there is an additional deflection from 22 mm to 27 mm.

The strength of the structure is safe and able to withstand loads of up to 255,723 N due to there are 79 carry idlers; every idler can withstand 3,237 N, and the capacity increase will consume 60,4 % of total power.

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