Dynamic Analysis of the Belt Conveyor System for Detergent Industry

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DOI: 10.29322/IJSRP.8.10.2018.p8279
http://dx.doi.org/10.29322/IJSRP.8.10.2018.p8279

Abstract- This research focus on the dynamic analysis for inclined belt conveyor system. The aim of research is to improve the reliability and design level. This analysis is done by using Belt Analyst V18.1.6.0 software. This research presents an approach to estimate the velocity time of inclined belt conveyor. The simulations with finite element model are carried out to analyze the belt dynamic behaviors such as pulley resultant force, belt power, tension in transient operation. Further simulations are carried out to get the optimum velocity time for starting and stopping process. The maximum pulley resultant force is 1.4kN, the maximum belt power is 0.4kW and the maximum belt tension is 1.1kN for starting and stopping process. The maximum velocity for starting is 1.09m/sec and for stopping of the process 1.46m/sec by using Belt Analyst V18.1.6.0. The maximum velocity in running condition of belt conveyor system is 1m/sec by using theoretical calculation.

Index Terms- Belt conveyor, Transient operation, Belt power, Pulley resultant force, Belt velocity

I. Introduction

Belt conveyor is widely used in all kinds of industry fields, such as electric power, coal, mine, metallurgy, chemical, port, architecture and food supplies [1]. It is one of the most important devices to transport bulk material of long distance [9]. For detergent industry, the inclined flat belt conveyor is used when the detergent bags are transported from the semi-finished product shop to packing machines shop. Figure 1 shows inclined flat belt conveyor system from E-Lan detergent industry in Mandalay Industrial Zone.

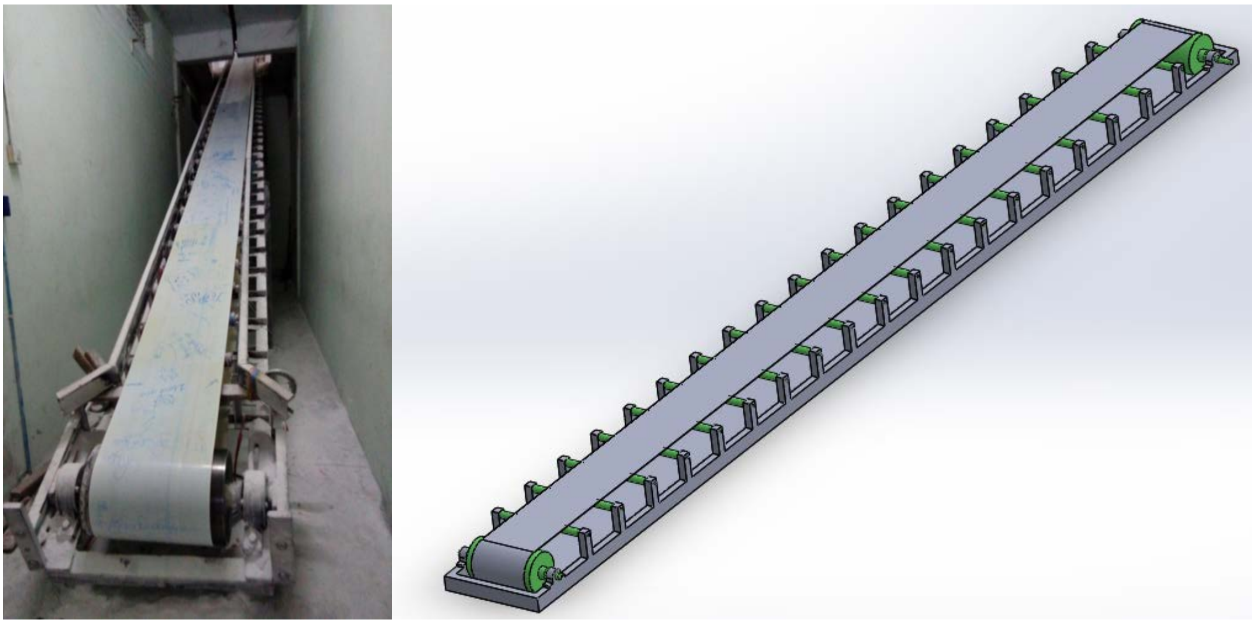

Fig. 1 The inclined flat belt conveyor

Many research institutions, engineers and technicians did a lot of deep researches on design theory, calculation methods, system control methods, design standards and design analysis system [11]. The traditional design of belt conveyor was thought more about static properties than dynamic properties. Otherwise, if only thinking static properties when designing, choosing type and using, some serious problems will happen, such as unstable starting-up or failure starting, sharp rising belt tension, belt skidding, running deviation, irrational system design, too high safe factor and so on. The recent researches on dynamic properties of conveyor are introduced. The main research of conveyor dynamics is analysis [11].

The dynamic behavior of conveyors has not been an issue of interest until a few decades ago [7]. However, as a general issue, dynamic behavior of axially moving continua is first examined in late 19th century [7]. This subject hasn't met a general interest until 1960s [7]. Scientists and engineers accelerated their research on analytical solutions for axially moving strings as they are the simplest form. From 1960s to 1970s, the solution techniques, scenarios and models have been improved [7]. From 1970s, various beam models have been introduced [7]. In parallel to emerging capabilities of computers, in 1984 first FE (finite element) model of a belt conveyor is applied [7]. The use of FE models expanded the research of belt conveyor dynamic behavior research. As an advantage of FEM (finite element methods) planar and web methods have been introduced lately [7].

Dynamic analysis is used to verify the maximum and minimum loads on all belt conveyor components during all possible transient conditions of stopping and starting [13]. It is also used to develop and test the control algorithms necessary to safely and reliability stop and start the load [13]. Proper dynamic analysis requires a time based, FEA solver which considers the elasticity of the belting and all the masses which make us the conveyance system [13].

There are three types of basic dynamic analysis real eigenvalue analysis, linear frequency response analysis, linear transient response analysis [12].

Real eigenvalue analysis is used to determine the basic dynamic characteristics of a structure [12]. The results of an eigenvalue analysis indicate the frequencies and shapes at which a structure naturally tends to vibrate. Although the results of an eigenvalue analysis are not based on a specific loading, they can be used to predict the effects of applying various dynamic loads [12].

Frequency response analysis is an efficient method for finding the steady-state response to sinusoidal excitation. In frequency response analysis, the loading is a sine wave for which the frequency, amplitude, and phase are specified. Frequency response analysis is limited to linear elastic structures [12].

Transient response analysis is the most general method of computing the response to time-varying loads. The loading in a transient analysis can be of an arbitrary nature, but is explicitly defined (i.e., known) at every point in time. The time-varying (transient) loading can also include nonlinear effects that are a function of displacement or velocity. Transient response analysis is most commonly applied to structures with linear elastic behavior [12].

II. SPECIFICATION DATA

The specification data are surveyed from E-Lan detergent industry in Mandalay Industrial Zone. To analyse the inclination flat belt conveyor system of detergent industry, the following data must be known.

TABLE I
SPECIFICATION DATA OF CONVEYOR SYSTEM

No	Description	Symbol	Value	Unit
1.	Capacity	C	40	ton/hr
2.	Belt width	B	500	mm
3.	Belt thickness	t	4	mm
4.	Length between centers	L	9	m
5.	Vertical height of the conveyor	H	4.5	m
6.	Conveyor inclination angle	α	30	Deg
7.	Arc of contact	θ	180	Deg
8.	Belt tension before the drive pulley	F_1	1370	N
9.	Belt tension after the drive pulley	F_2	456	N
10.	Drive force of pulley in steady operating condition	F_d	913.8	N
11.	Average mass per unit length due to rotating rolls	m_{roll}	1.27	kg/m
12.	Mass of belt per unit length	m_{belt}	2.8	kg/m
13.	Average mass of specified bulk materials	m_{bulk}	5.9	kg/m
14.	Coefficient of friction between belt and drive pulley	μ	0.35	-
15.	Artificial friction coefficient	f	0.018	-
16.	Safety factors in transient operation	S_A	5.4	-

17.	safety factor in steady operating condition	S_B	8	-

III. THEROTICAL CALCULATION OF THE BELT SPEED

The belt speed is important because the wrong speed ratio will cause the material to pile up inside the screen or bounce of the belts. To analyse the belt velocity of starting and stopping process for inclined belt conveyor system by using Belt Analyst V 18.1.6.0, the belt velocity from theoretical equations derives out [2].
The belt velocity equals,

$$v(t) = -\frac{\pi}{2}\frac{\Delta V}{T_a}\cos\frac{\pi t^2}{2T_a} \quad (1)$$

The required minimum acceleration time [2],

$$T_{a,min} = C_p \times \frac{\Delta V}{a_{max}} \quad (2)$$

With regard to risks of both breaking and slipping, the permitted acceleration a_{max} in transient operation equals [2],

$$a_{max} = \min\{a_{max,break}, a_{max,slip}\} \quad (3)$$

The permitted maximum acceleration honoring the belt tension rating and safety factor [2],

$$a_{max,break} = \left[\frac{F_{2A}}{L(m_{roll} + 2m_{belt} + m_{bulk})} + Cfg\right]\frac{S_B - S_A}{S_A} \quad (4)$$

The permitted acceleration which honors the ratio between the belt tension before and after drive pulley [2],

$$a_{max,slip} = \left[\frac{(e^{\mu\alpha} - 1)F_{2A}}{L(m_{roll} + 2m_{belt} + m_{bulk})} - Cfg\right] \quad (5)$$

The belt tension after the drive pulley in transient operation [2],

$$F_1 = F_2 + F_d \quad (6)$$

The maximum extra drive force of pulley in transient operation [2],

$$F_{ac,max} = (F_2 + F_d)\frac{S_B - S_A}{S_A} \quad (7)$$

In transient operation, the peripheral driving forces on the drive pulley(s) equal [2],

$$F_{dA} = F_d + F_{ac} \quad (8)$$

The permitted belt tension in transient operation [2]:

$$F_{1A,max} = \frac{F_1 S_B}{S_A} \quad (9)$$

The belt tension after the drive pulley in transient operation equals [2],

$$F_{1A} = F_{2A} + F_{dA} \quad (10)$$

IV. DYNAMIC ANALYSIS OF BELT CONVEYOR

Belt conveyor system is analyzed by using Belt Analyst V18.1.6.0 software. Belt Analyst is the belt conveyor design software that was first created in 1996. It was developed by conveyor engineers as a consulting tool in order to design and analyze the most difficult belt conveyor applications. The list of successfully built applications is huge. This is not just design software, but a real engineering tool [13]. There are five analyze in this software;

1. Feeder analyst
2. Lagging analyst
3. Horizontal curve analyst
4. Dynamic analyst
5. Idler analyst.

For inclined belt conveyor for detergent industry, dynamic analyst is used. Dynamic analysis is used to verify the maximum and minimum loads on all belt conveyor components during all possible transient conditions of starting and stopping

[13]. It is also used to develop and test the control algorithms necessary to safely and reliability stop and start the loads [13]. Proper dynamic analysis requires a time based, FEA solver which considered the elasticity of the belting and all the masses which makes us the conveyance system [13].

The input data for the dynamic analysis of inclined belt conveyor system is types of conveyed material, types of belt, types of idlers, types of pulley and drives. The table shows the input data for the dynamic analysis. Pulley resultant force, belt power, tension and velocity according to the time for this research are shown in followings;

TABLE II
INPUT DATA FOR THE DYNAMIC ANALYSIS OF BELT CONVEYOR SYSTEM

1.	General	Belt width (mm) Belt speed (m/sec) Load (ton/hr)	500 1.65 40
2.	Material	Description Material density (kg/m^3) Lump size (mm) Chute drop height (m)	Soap powder 961 400 9
3.	Profile	Horizontal length (m) Vertical lift (m)	9 4.5
4.	Belt	Specification Belt weight (kg/m) Top cover gauge (mm) Bottom cover gauge (mm)	Fabric-ISO 2.8 1 1
5.	Idlers	No of idlers Roll diameter (mm) Roll material Rotating weight (kg) Bearing tight Idler to belt friction factor	22 60 Steel 11.4 Roller
6.	Pulleys	No of pulley Wrap direction Wrap angle (degree) Pulley diameter (mm) Face width (mm) Shaft diameter (mm) Shaft length (mm) Bearing type	2 Clockwise 180 330 600 55 1197 Ball
7.	Drives	Power ratio Efficiency Wrap angle (Degree) Synchronous RPM	1 0.95 180 95

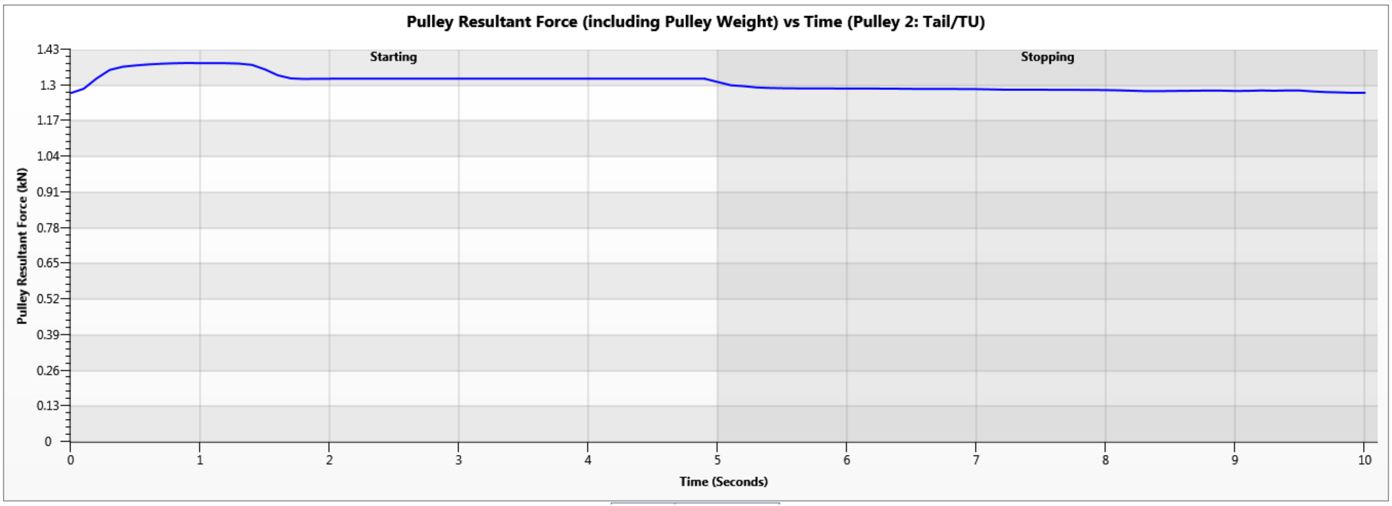

Fig. 2 The relation between pulley resultant force and time

Figure 2 shows the relation between pulley resultant force and time. The maximum pulley resultant force is 1.4kN for starting and stopping process.

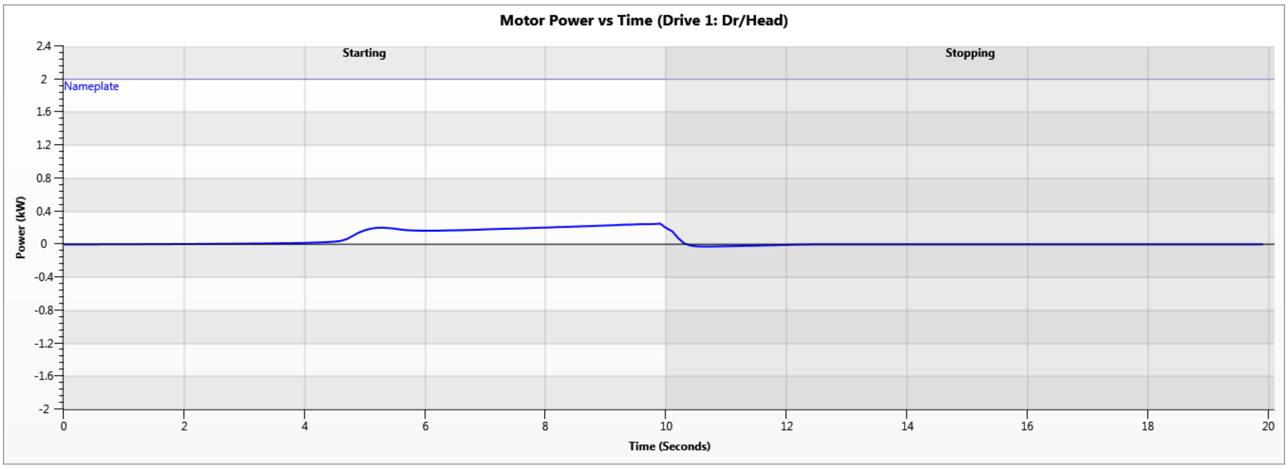

Fig. 3 The relation between belt power and time

Figure 3 shows the relation between belt power and time. The maximum belt power is 0.4kW and minimum power is zero for starting and stopping.

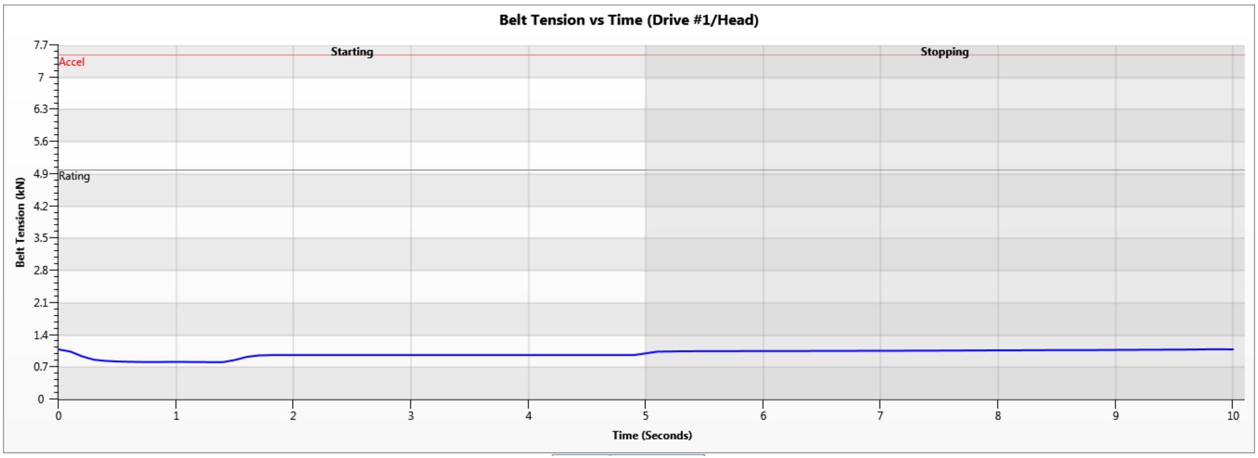

Fig. 4 The relation between belt tension and time

Figure 4 shows the relation between belt tension and time. The maximum belt tension is 1.1kN and the minimum belt tension is 0.8kN for starting and stopping process.

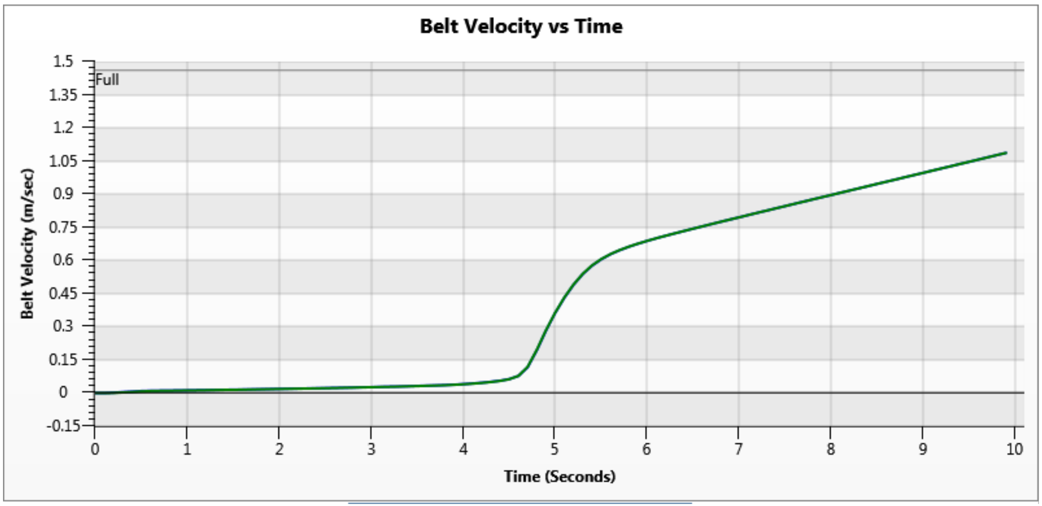

Fig. 5 The relation between belt velocity and time for starting process

Figure 5 shows the relation between belt velocity and time. The maximum belt velocity is 1.09m/sec and minimum belt velocity is zero for starting process.

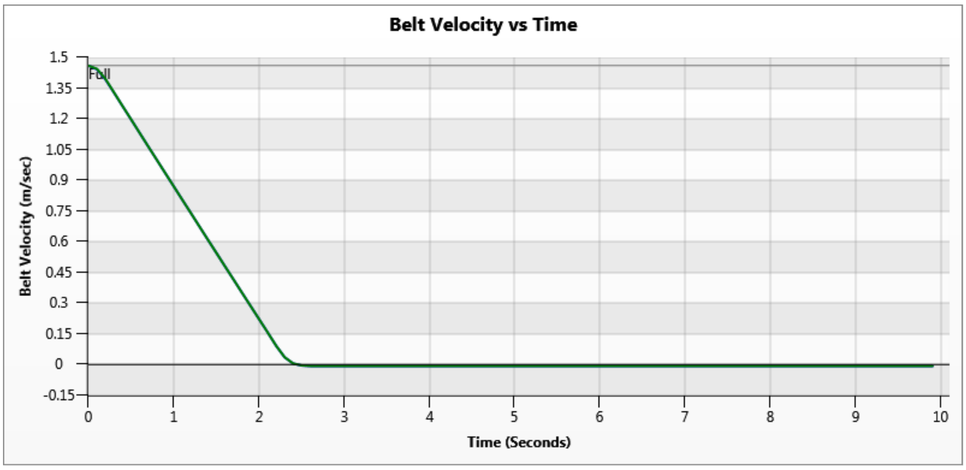

Fig. 6 The relation between belt velocity and time for stopping process

Figure 6 shows the relation between belt velocity and time. The maximum belt velocity is 1.46m/sec and minimum belt velocity is -0.01m/sec for stopping process.

V. COMPARISON BETWEEN SIMULATION AND THEORETICAL RESULT FOR BELT CONVEYOR SYSTEM

Figure 7 and 8 are shown the velocity results to compare the theoretical and simulation results. The stopping condition means that before the belt velocity reaches till 0 m/sec from running condition. In stopping condition, the ten seconds are chosen to express the belt velocity how to reach the zero condition.

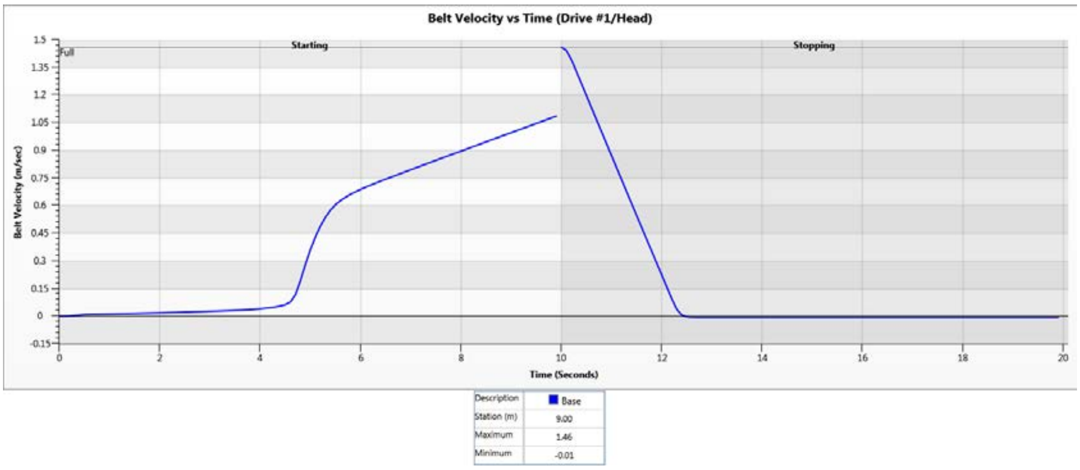

Fig. 7 The relation between belt velocity and time for starting and stopping from Belt Analyst

Figure 7 shows the velocity in starting condition during 10 seconds and in stopping condition during 10 seconds. The starting condition means that the belt starts the velocity 0 m/sec to running condition. The ten seconds are chosen to show the velocity changes in starting condition. The maximum belt velocity for starting and stopping process is 1.46m/sec from Belt Analyst software.

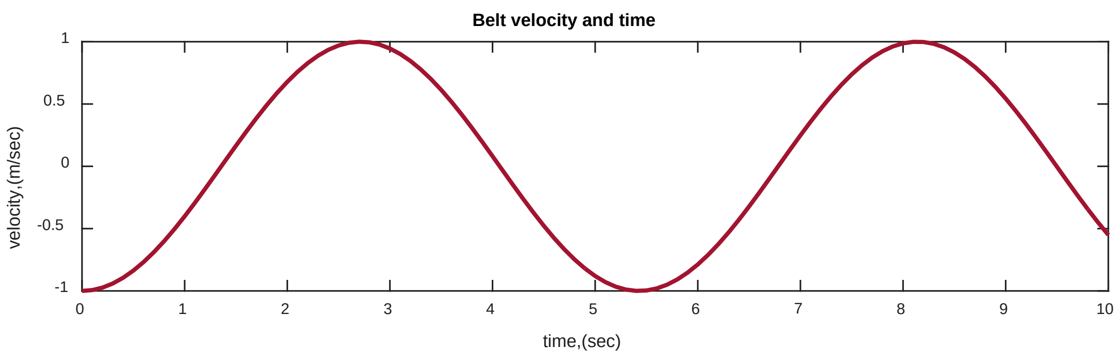

Fig. 8 The relation between belt velocity and time for starting and stopping from Belt Analyst

Figure 8 shows the velocity in running condition of the flat belt conveyor system during ten seconds by using theoretical calculations. The maximum velocity in running condition for inclined belt conveyor system is 1m/sec from Matlab software.

DISCUSSION AND CONCLUSION

This paper presents dynamic analyst for inclined belt conveyor system. Pulley resultant force, power, tension and belt velocity for starting and stopping according the time are expressed. In transient operation, the maximum pulley resultant force is 1.4kN, the maximum belt power is 1kW and the maximum belt tension is 1.1kN. The maximum velocity for starting is 1.09m/sec and for stopping of the process 1.46m/sec by using Belt Analyst V18.1.6.0. The maximum velocity in running condition of belt conveyor system is 1m/sec by using theoretical calculation. Taking polyvinyl chloride (PVC) an example look for solving dynamic to verify the reliability of theory the result showed it objectively reflected the actual work of conveyor belt.

APPENDIX

TABLE III
PROFILE COEFFICIENT WITH VARIOUS ACCELERATION PROFILES

Acceleration profile	Rectangular	Sinusoid	Deltoid	Parabolic
Coefficient (C_p)	1	$\frac{\pi}{2}$	2	1.5

TABLE IV
SECONDARY RESISTANCE COEFFICIENT

Length(m)	3	4	5	6	8	10	13	16	20
Secondary resistance coefficient (C)	9.0	7.6	6.6	5.9	5.1	4.5	4.0	3.6	3.0

ACKNOWLEDGMENT

The First of all, the author wishes to express her deep gratitude to Dr. Sint Soe, Rector ,Mandalay Technology University, for his kindness and valuable permission to summit the paper for the Doctor of Philosophy of Engineering Degree.

The author is particularly intended to Dr. Htay Htay Win, Professor and Head of Mechanical Engineering Department, Mandalay Technological University, for her immeasurable help throughout the research.

Moreover, the author would like to express heartfelt gratitude to his supervisor Dr. Ei Ei Htwe, Professor, Department of Mandalay Technological University, for her supervision, support, guidance and encouragement throughout this study.

Special appreciation is extended to his co-supervisior Dr. Maw Maw Htay, Lecturer, Department of Mandalay Technological University, for her supervision, support, guidance and encouragement throughout this study.

Finally, the author is deeply greatful to her parents and her sister for their noble support, encouragement, and guidance throughout her entire life. The heading of the Acknowledgment section and the References section must not be numbered.

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