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Effect of Different Parameters on Swing Angle in Electrically Operated Overhead Travelling Crane

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Abstract - *In industries, material used for production, semi-finished product, etc. are required to be moved from one place to the other. It can be delicate, it can be too heavy to be handled by a human. A material handling system is used for this. Most widely and most commonly used system is an Electrically Operated Overhead Travelling (EOT) Crane. In this system, material to be moved is suspended with the help of rope with high load carrying capacity. While moving there occurs a swing of mass. This swing can be hazardous to other equipments in industry, people working there and also the material to be moved. Thus it is desired that swing angle should be as less as possible.*

For controlling this swing, it is required to be analyzed on which factors this swing depends more. For this purpose, using Lagrangian method, equation of motion of trolley and mass system is developed. And using MATLAB-Simulink model developed. Its, analysis is done by using values from Whiting crane handbook.

Key Words: **Material handling system, EOT Crane, MATLAB-Simulink, swing angle, Lagrangian method**

1. INTRODUCTION

In industries, movement of raw material, semi-finished or finished goods from one place to the other is done with the help of material handling equipments. For very heavy material movement, Electrically Operated Overhead Travelling (EOT) Cranes are used.

1.1 Introduction

Overhead tracks called girders have end trucks at their ends with wheels. Movement of these girders on runway beams is known as long travel. A trolley is a structure with wheels is driven on girder its movement on girder is called as cross travel. Trolley has two induction motors, one for hoisting mechanism and other for movement of trolley.

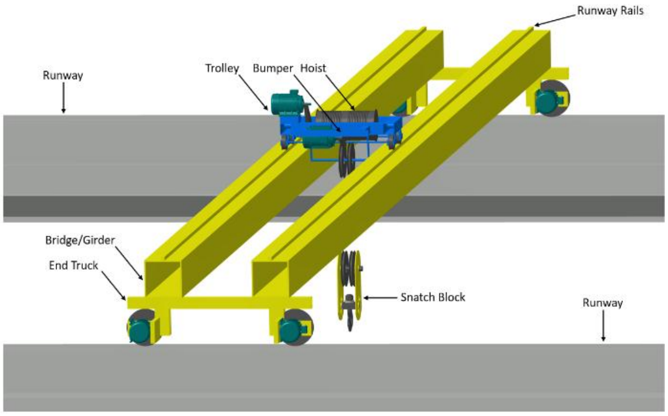


Fig – EOT Crane diagram [2]

1.2 Motivation

While moving the trolley, suspended mass swings due to trolley acceleration to achieve required speed. This swing can be hazardous to other equipments in industry, people working there and also the material to be moved. Also, because of excess swing, the payload may take more time to reach at desired position. Thus, this swing of payload has to be minimized. Swing reduction leads to optimal material handling operations.

2. MATHEMATICAL BACKGROUND

Trolley with mass to be moved can be represented using block diagram as follows.

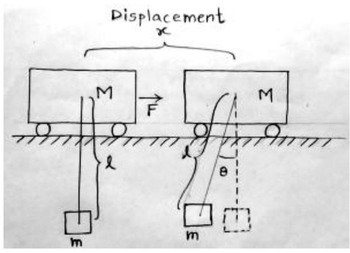


Fig - 1 Trolley and mass system block diagram

Here,

F = Force applied to trolley mass system

M = Mass of Trolley

m =Mass to be moved

l = Length

x = Displacement

θ = Swing angle theta

Using Lagrangian method, equations of motion of trolley and mass system are derived as follows [3];

$$F = (M + m)\ddot{x} - ml\ddot{\theta}\cos\theta + ml\dot{\theta}^2\sin\theta \ (1)$$

$$ml^2\ddot{\theta} - ml\ddot{x}\cos\theta + mgl\sin\theta = 0 \ (2)$$

As swing angle is minimum, cos θ can be reduced to 1and sin θ can be reduced to θ.

And,

$$\dot{\theta}^2 = 0$$

Thus, reducing and rearranging equations (1) and (2) we get;

$$\ddot{x} = \frac{F + ml\ddot{\theta}}{(M + m)}$$

$$\ddot{\theta} = \frac{\ddot{x} - g\theta}{l}$$

From these equations, MATLAB-Simulink block model is developed.

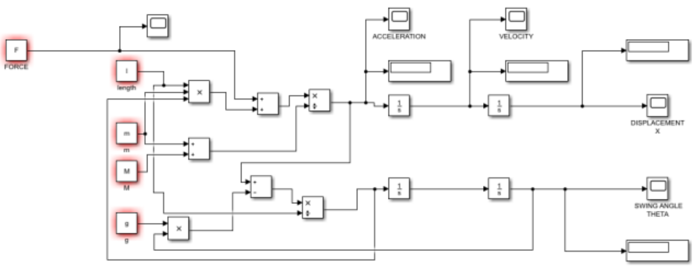


Figure 2 MATLAB-Simulink model of trolley and mass system

3. ANALYSIS

For analysis 5 ton to 30 ton EOT crane are considered. Mass of trolley will be as shown in table below. These values of masses are taken from Whiting crane handbook [4].

Table -1: Mass suspended and to be moved with mass of trolley

Mass suspended and to be moved (kg)	Mass of trolley (kg)
30000	11600
25000	11500
20000	9500
15000	8960
10000	7880
5000	5600

3.1 Analysis of trolley and mass system

For masses considered, values of different parameters are changed as shown in table below. In Whiting crane handbook, it is recommended that for better operation, acceleration of trolley should be around 0.3 m/sec².

Table -2: Swing angles obtained for different values in MATLAB-Simulink model

Mass suspended and to be moved (kg)	Total mass (kg)	Acceleration (m/sec²)	Force to be applied to trolley (N)	Length of rope (m)	Swing Angle (Radian)
30000	41600	0.3	12480	5	0.01
27000	38600	0.3	11580	5	0.01
24000	35600	0.3	10680	5	0.01
21000	32600	0.3	9780	5	0.01
18000	29600	0.3	8880	5	0.01
30000	41600	0.25	10400	5	0.0085
30000	41600	0.20	8320	5	0.007
30000	41600	0.15	6240	5	0.005
30000	41600	0.10	4160	5	0.0035
30000	41600	0.3	12480	6	0.0095
30000	41600	0.3	12480	7	0.009
30000	41600	0.3	12480	8	0.008
30000	41600	0.3	12480	9	0.0075

For analysis, friction between wheel and surface is considered in MATLAB-Simulink model. And force to be applied and its value is if 594 N as shown in figure 4 below.

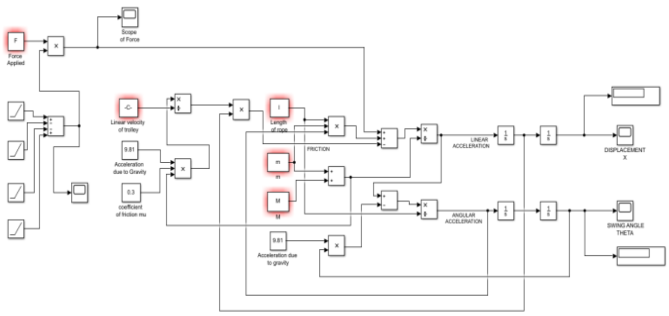


Fig – 3 MATLAB-Simulink model with friction considered

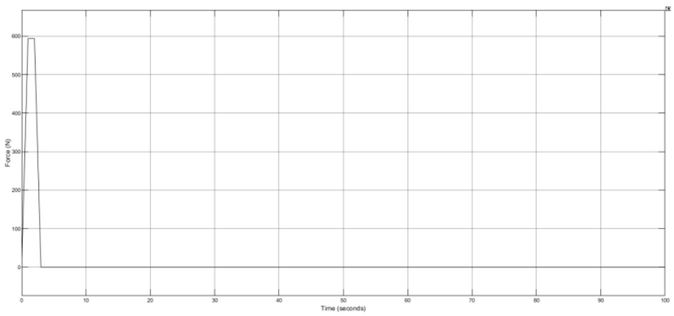


Fig – 4 Force applied

For variation in acceleration from 0.3 to 0.25 m/sec^2, swing angle variation is observed in figure below.

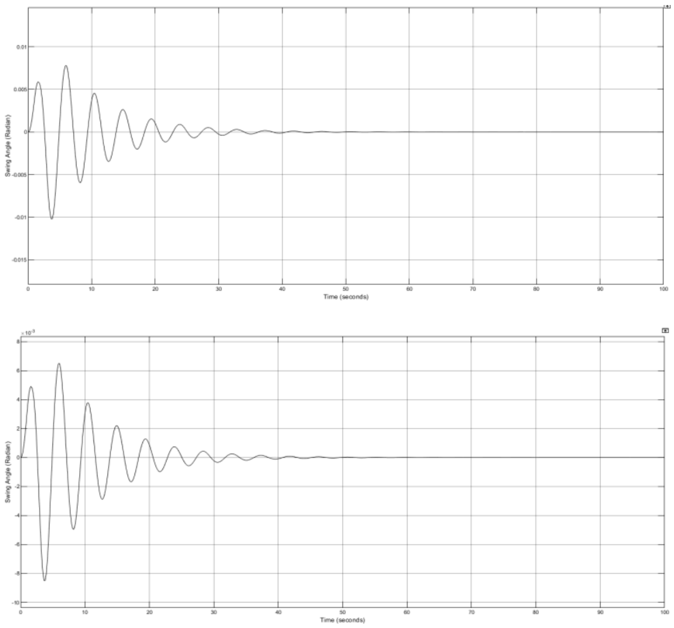
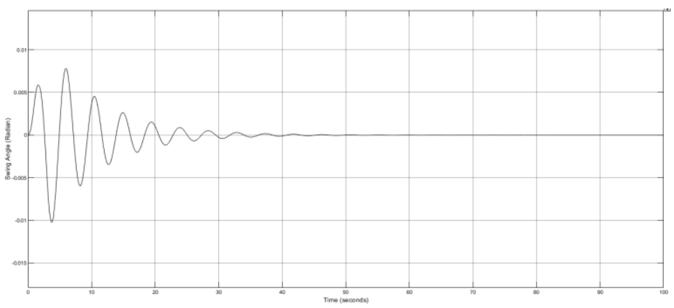


Fig – 5 Swing Angle for acceleration 0.3 and 0.25 m/sec^2

For variation in rope length from 5 m to 8 m, swing angle change is observed in MATLAB-Simulink output as shown in figure below.



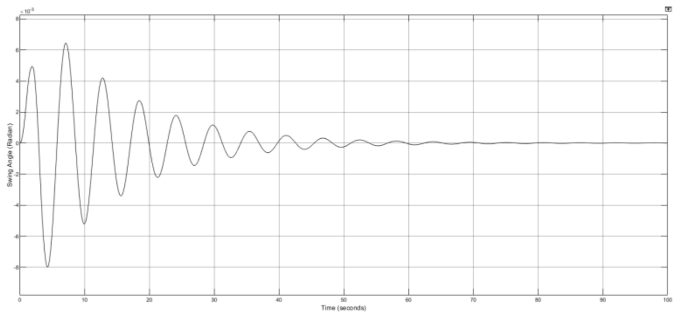
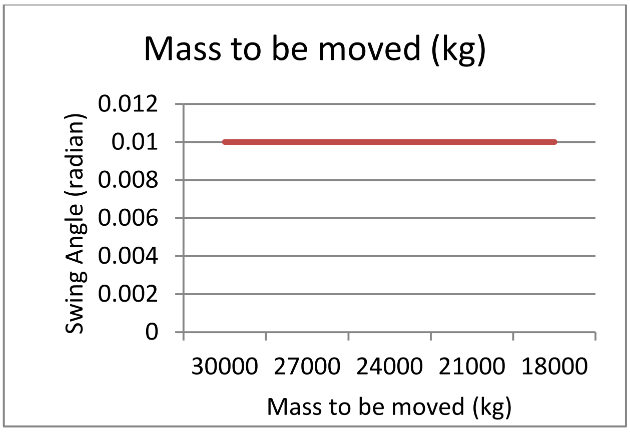
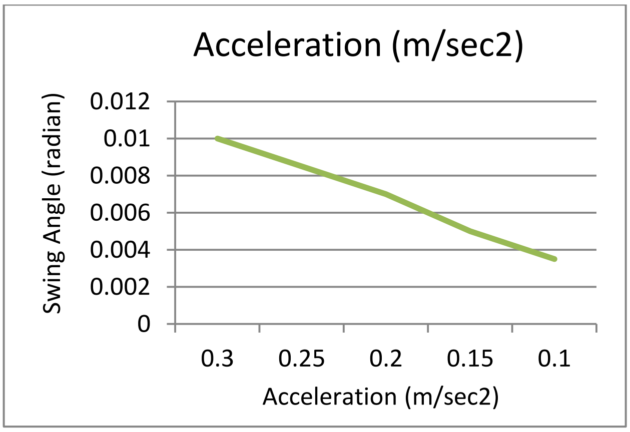


Fig - 6 Swing angle for 5 m and 8 m

Plotting graphs using readings in above table, for swing angle versus mass to be moved, swing angle versus acceleration and swing angle versus length of rope.





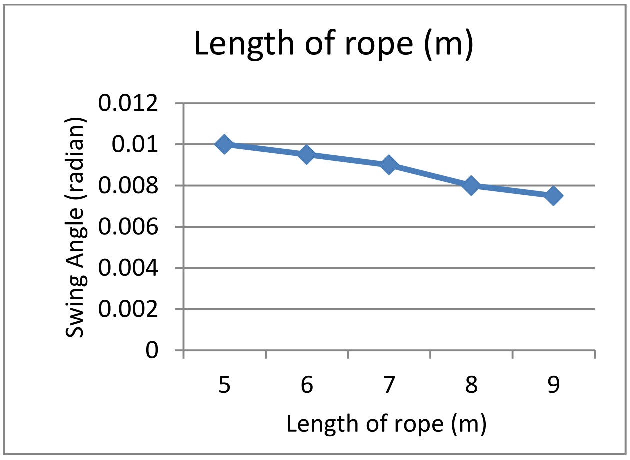


Fig -7: Graphs for mass, acceleration and length of rope versus swing angle

4. CONCLUSIONS

From graphs in above figure, it can be concluded that swing angle is mostly dependent on acceleration with which trolley is moved to reach desired speed. For 0.05 m/sec^2 reduction in acceleration swing angle is reduced by 0.0015 to 0.0020 radians. For increased rope length by 1 m, swing angle is reduced by around 0.0005 to 0.0010 radians. And effect of variation in mass is negligible on swing angle.

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