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Design of Lead Screw Mechanism for Powder Coating Process

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Abstract

This paper proposes a theoretical design of a detailed assembly to automate the powder coating process. Most hospital furniture manufacturing industries employ workers to powder coat various parts of the furniture. Manual operations require a lot of time, money, manpower, apart from health hazards on the side of worker. In order to enhance existing process so as to improve productivity and save working capital, it becomes crucial to automate the mechanical operations using mechanism to move the mechanical tool and control the motion using controllers. This paper gives emphasis on the design of the mechanism for the powder coating which incorporates two lead screws for horizontal and vertical motion of powder gun. In this research, design and modelling is obtained using Creo for lead screws.
Keywords: Lead Screws, Powder Coating

I. Introduction

This design is concerned with the motion of powder spray gun along horizontal and vertical axis along the coating booth. Lead screw mechanism comprises
- Lead screw, lead screw nut assembly.
- Lead screw supporting structure, lead screw driving motor, coupling and bearing.
- Lead screw supporting structure holds lead screw and base nut and guide way for motion of nut.
- A base plate to provide vertical support to the nut.

II. Design of lead screw mechanism

The whole assembly consists of following parts:
- Lead screw
- Bearing.
- Lead screw nut
- Motor
- Coupling
- Selection of Lead Screw

A. *Vertical Lead Screw*

1) *Selection of Lead Screw*

In lead screw selection process we find out pitch and lead of lead screw, material selection for screw and nut, outer or major diameter, minor diameter, pitch diameter, pitch, lead, type of thread. The lengths for vertical and horizontal lead screw are 1500mm and 1800mm respectively.

Material for screw is steel (C 40) [1] Material for nut is phosphorus bronze. We select bronze nut because of high wear resistance. [2]

The most appropriate diameter for the vertical lead screw was 14mm as nominal diameter [3]. Other diameter were calculated from the empirical equations as:

a) Corresponding core diameter

d_c= (d-p)=14-2=12mm. d_c=12mm

b) Corresponding mean diameter

d_m=(d-0.5p)=(14-0.5*2)=13mm. d_m=13mm

Corresponding pitch was selected as 2mm [4]. Lead =2mm, considering single start lead screw.

Trapezoidal threads were selected which provide the following advantages:

- Machining with a multi-point cutting tool is an economic operation compared with machining with a single- point cutting tool. Therefore, trapezoidal threads are economical to manufacture.
- A trapezoidal thread has more thickness at the core diameter than a square thread. Therefore, a screw with trapezoidal threads is stronger than an equivalent screw with square threads.

2) Selection of Motor & Nut

The best suited motor which reconciles with the conditions had 0.18 KW of power and 2720 RPM [5].Corresponding torque generated= 632 N-mm.

Lead=2mm, Length of envelope of powder coat= 14mm [6]

- No of revolutions for one complete vertical spray= 1500/2=750 revolutions
- Time required for one complete vertical spray
- It requires 60 seconds for completing 2720 rounds, therefore time required for 750 revolutions will be (750 ×60)÷2720 = 17 seconds
- Total time for one vertical spray =17+2=19 sec (2 sec for shifting right on horizontal lead screw)
- No of shifts required for complete coating

Since it takes 1 shift for covering 14 mm length, number of shifts

Required for complete length will be 1800/14=130 shifts.

- Total time for complete powder coating

For 1 shift it requires 19 sec, therefore for 130 shifts time required will be 40 mins.

PZ 8000 nut manufactured by PIC industries was selected as it reconciled with the requirements [7].

3) Design of Coupling

Using empirical relations the dimensions of coupling were found to be

d_h= 24mm, L_h = 18mm, D= 36mm, t= 6mm, t1=3mm, d_r=18mm, D_o= 54mm, d= 12mm [7]Type equation here.(a) Hub Design

S_{ys}=0.577×S_{yt}=> 0.577×200 = 115.4 Mpa. Considering FOS=3, we get,

T = 38.46 MPa.

By applying the torsional shear stress equation, we get,

T = 0.24 MPa. Hence, the hub is safe in torsion.

a) Flange Design

Checking for shear, we get,

632= 0.5×3.14×24×24×6×T => T= 0.11 MPa. Hence, the flange is safe in shear.

b) Bolt Design

T=96.16 Mpa. Assuming bolt diameter to be 4mm. Taking N=3 (for d<40 mm) [8]

c) Key Design

T=96.16 MPa.

σ_c=Syc/fos=1.5Syt/fos=(1.5×500)/3=250MPa.For12mm<d<17mm, b=h=5 mm[9].Checking for shear and compressive stresses, T=1.17 MPa and σ_c =2.34 MPa. Hence, the key is safe in shear and compression.

4) Selection of bearing

Knowing the internal diameter and considering no thrust load SKF 6201 bearing was selected having 14 mm inner diameter and 32mm outer diameter respectively [10].

B. Horizontal Lead Screw

1) Mean Diameter using Flexural Equation

The bending equation is given by,

M/I=σ/y=E/R

Assuming diameter of lead screw to be 25mm in order to consider self-weight.

- Volume of lead screw= (3.14×25×25×1800)/4=883572mm^3
- Material is 40C8, Density=7.85×10^{-6} kg/mm^3.
- Mass of lead screw=M= (7.85×10^{-6}×883572)= 7 kg
- Weight of Lead Screw=M×g=7×9.81=70N.
- UDL for self-weight:

Weight for 1800mm length lead screw is 70N, therefore for 1 mm length lead screw weight will be 0.0389N/mm.

The maximum bending moment is obtained from the shear force and bending moment diagram in Fig 1

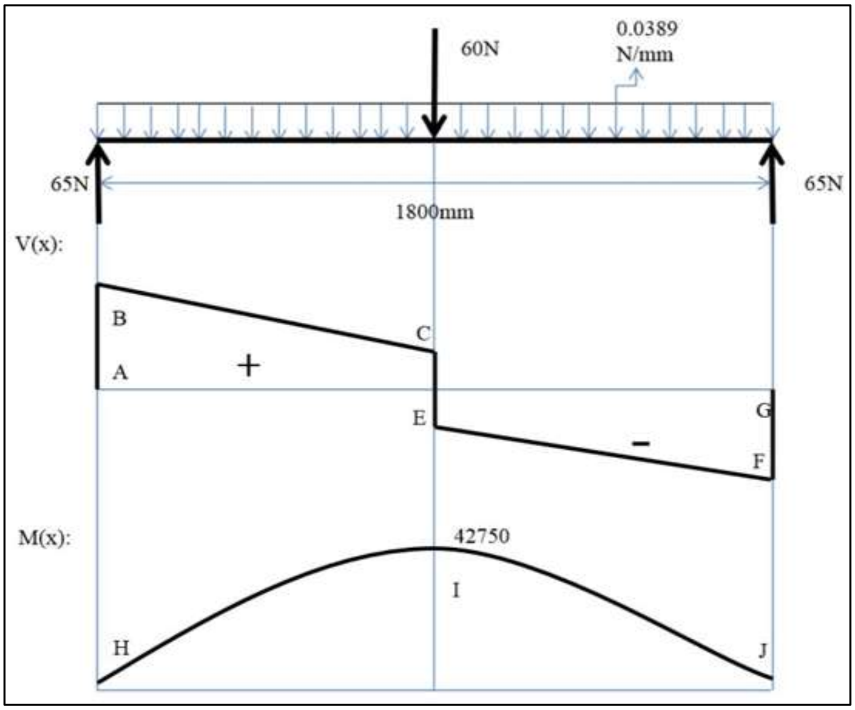

Fig. 1: SFD & BMD for Horizontal Lead Screw

a) SFD calculations

- Point B: V=65N.
- Point C: V_f- V_i= -(900×0.0389)=>V_f- 65= -35=>V_f= 30N.
- Point E: V=30 - 60= -30N.
- Point F: V_f- V_i= -(900×0.0389)=>V_f- (- 30)= -35=>V_f= -65N.

b) BMD calculations

- Point I: M_f - M_i= (900×30)+(0.5×35×900)=> M_f - 0= 42750=> M_f = 42750 N-mm.
- Point J: M_f - M_i= -(900×30)-(0.5×35×900)=> M_f - 42750= -42750=> M_f = 0 N-mm

c) Applying Flexural Equation:

(320/2) = (42750×d×64)/(2×3.14×d ^{4}), we get
d= 18 mm. Corresponding,
Mean Diameter of Horizontal Lead Screw= 17 mm
Nominal Diameter selected: d=18mm
Corresponding core diameter:
d_c= (d-p)=18-2=16mm. d_c=16mm
Type of threads: TRAPEZOIDAL
Corresponding pitch=2mm & lead=2mm. [11]

2) Mean Diameter using Torsional Equation

Torsional equation is given by,
T/J=σ/R=GΘ/L
T= 0.577×Syt=0.577×580=334 MPa. Considering FOS=3,
T=111 MPa, T=24527 N-mm
d_m^3= (16×24527)/(111×3.14)= 10mm.
d_m= 10mm.
But this diameter cannot be selected because vertical LS diameter is more than this diameter.

3) Selection of Motor and Nut

The best suited motor reconciles with the conditions had 5.5 KW of power and 2840 RPM [12].Corresponding torque generated= 24527 N-mm.

Block nut model MTSBHL was selected Fig 2 with nominal diameter 18 mm and pitch 2mm [13].

Fig. 2: Block Nut Model MTSBHL

4) Selection of bearing

Knowing the internal diameter and considering no thrust load SKF 6004 bearing was selected having 16 mm inner diameter and 44 mm outer diameter respectively [14].

5) Design of Coupling

Using empirical relations the dimensions of coupling were found to be d_h= 32mm, L_h = 24mm, D= 48mm, t= 8mm, t1=4mm, d_r=24mm

Stresses generated and critical stresses were calculated in the same manner as that of vertical coupling and all elements were found safe.

6) The Main Assembly

The main components were drafted in CREO. Required models are shown in below figures.

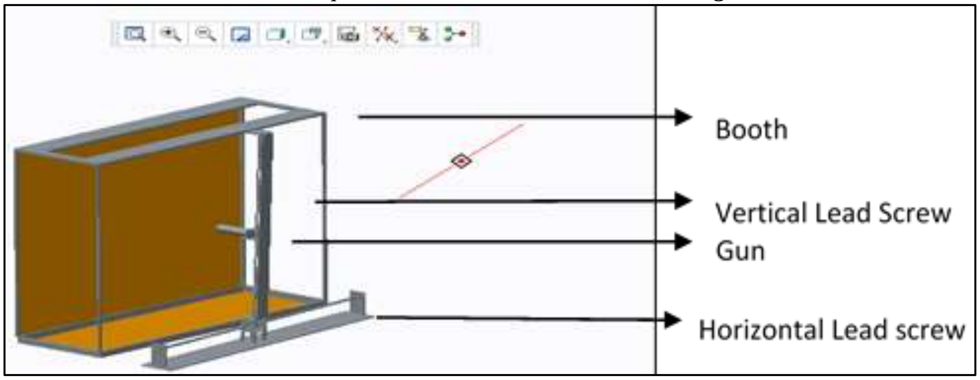

Fig. 3: Main Assembly alongside Booth

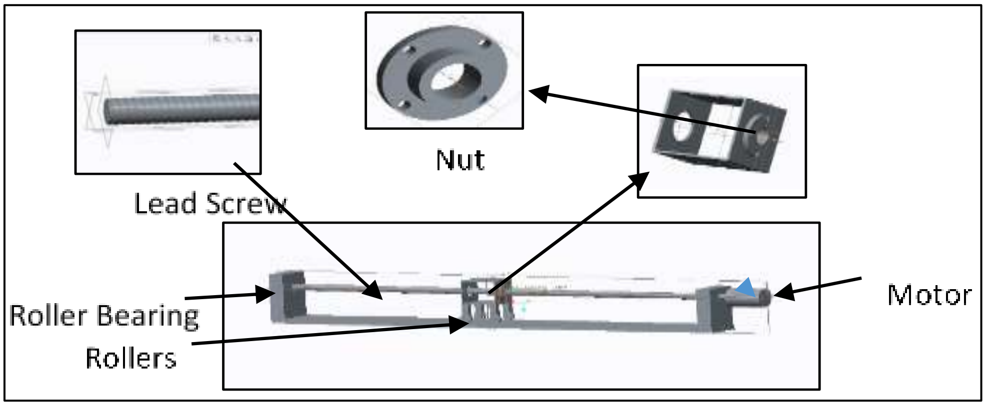

Fig. 4: Horizontal Lead Screw Assembly

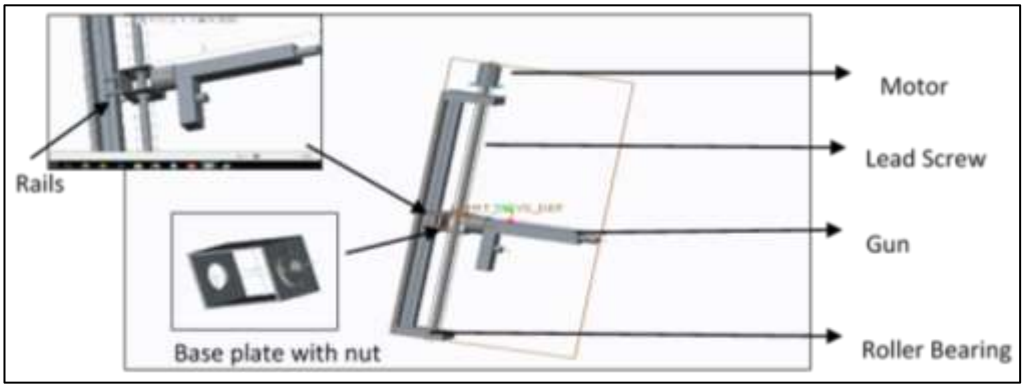

Fig. 5: Vertical Lead Screw Assembly

III. CONCLUSION

The design of lead screw mechanism was successfully analyzed and drafted using CREO Parametric. Shear stresses, Compressive stresses were determined to check for critical failure of the components. Concepts of Mechanics of Materials were implemented to obtain various parameters for the design of lead screws.

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