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# Controlled Engagement and Disengagement of Air Transport Rack (ATR) Chassis using Ball Screw Mechanism

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***Abstract* - An avionic tray used in aircrafts for supporting avionic box consists of few components such as base plate, side plates and back plate. The trays are mounted at front and back ends of the cross beams provided in the aircraft. The avionic equipment box which is a long air transport rack chassis is mounted on the tray. The rear part of the avionic equipment box having four ARINC 600 series of connector pins which is to be mating with the corresponding connector pins on the rear part of the tray. The rear portion of the tray cannot be viewed, hence the connections are blind mating. Insertion and extraction of avionic chassis connector pins on the tray connector pins are done manually. By manual insertion and extraction the connector pins get damaged as there is no control over the applied force and due to the misalignment of the connector pins. To overcome this problem a ball screw mechanism has been designed which controls the applied force and avoids the misalignment problem.**

***Keywords: Avionic Tray, Avionic Equipment Box, Ball Screw, ARINC600 Connector, Ball screw calculation and design, Analysis of rear plate.***

## I. INTRODUCTION

### A. *Avionic Tray*

The avionic trays are usually made in standard ATR (aircraft tray racking) widths to accommodate various sizes of instruments. The bottom section of tray has an opening for air plenum chamber. Air is usually continuously evacuated from plenum chamber. The rear part of the tray includes 4 ARINC 600 series of connectors which in turn are connected with the permanent aircraft wiring harnesses.

### B. *Avionic Equipment Box*

The avionic equipment box which is a one long ATR (Air Transport Rack) chassis is to be mounted on avionic tray. Radios, inertial navigation systems, radar systems etc., are mounted in ATR chassis. The rear part of the chassis includes electrical connector pins which mate with the tray connectors to electrically interface the chassis circuits with the aircraft wiring. The ATR chassis are remains in connected with the ARINC 600 connector for long time. This chassis is extracted form connector pins only for maintenance purpose or during replacement.

### C. *Ball Screw Mechanism*

A ball screw is a mechanical linear actuator that translates rotational motion into linear motion. It consists of screw, nut and balls. The balls are moving between the screw and nut. The screw and the nut have semi-circular thread profiles. As the screw is rotated, the balls advance in the grooves in the nut and the screw. They are collected at the end of the nut and returned back. There is no heat generation due to negligible friction. The ball screw has many characteristics such as high mechanical efficiency, low wear, high precision, long life and low pollution. The most important advantage of ball screw is high positioning accuracy. Due to its specific features, ball screw is used in aircraft, missiles, automobile power steering, machine tools, robots, and in precision assembly equipment. It can also be applied in the drive of the computer disk drive starter, the adjustment of the aircraft wings, and medical X-ray examination.

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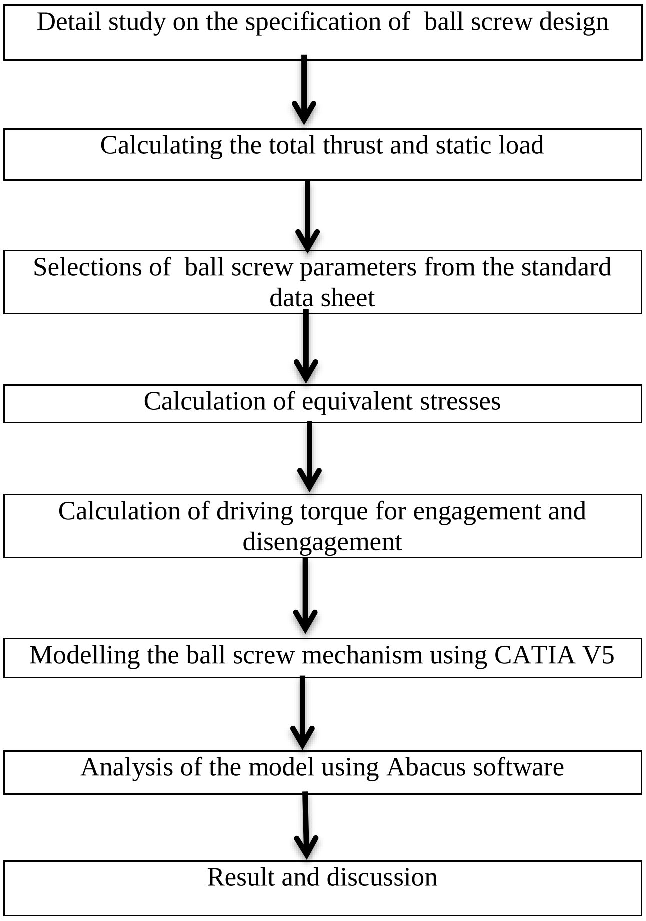
## II. METHODOLOGY




The methodology in this work involves the calculation of ball screw parameters. The model is designed using CATIAV5 R20. Analysis is done by using Abacus software.

## III. BALL SCREW CALCULATION

### A. Nomenclature

$d_s$: Shaft Diameter.
$d_b$: Ball diameter.
$d_c$: Ball circle diameter.
*l:* lead.
$F_a$: Thrust Force.
$F_f$: Frictional Force.
$F_b$: Blind Mating Force.
T: Driving Torque [Nm].
η: Efficiency.
$C_{oa}$: Static load rating.
$f_s$: Factor of safety.

### B. Specifications

1. Weight of the box = 28 kg * 9.81 = 274.68 N.
2. Force required to overcome the
   Friction = 0.2 * 274.68 = 54.936 N.
3. Blind mating force = 45 to 55 lbs.
4. Numbers of connectors = 4.
5. Converting lbs force to Newton's force.
   1 lbs = 4.4483 N.
   Then Blind Mating Force = 50 lbs * 4.4483
   = 222.415 N.
6. 4 numbers of connectors are used then Blind Mating Force become,= 222.415 * 4 = 889.66 N.

### C. Calculations

1. Total thrust force,

$$F_a = F_f + F_b \quad \text{.......... (1)}$$

$$F_a = 54.936 + 889.66.$$

$$F_a = 944.596 \text{ N}.$$

2. Static Load Rating:

$$C_{oa} \geq f_s F_a \quad \text{.......... (2)}$$

Taking Factor of Safety, (FOS) = 1.6.

$$C_{oa} = 1.6 * 944.596$$

$$C_{oa} = 1511.35 \text{ N}$$

3. From the standard product datasheet for Ball Screw for $C_{oa}$ = 1600 N

Table1: standard ball screw data sheet.

| Ball nut model number | Shaft nominal diameter | lead | Ball size | BCD | Root dia | Static load rating $C_{oa}$ |
|---|---|---|---|---|---|---|
| FBS 0602 A | 6 | 2 | 1 | 6.2 | 5.1 | 1200/590 |
| FBS 0602 B | 6 | 2 | 1 | 6.2 | 5.1 | 1600/800 |
| FBS 0602.5A | 6 | 2.5 | 1 | 6.2 | 5.1 | 1200/590 |

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From the table 1 the fallowing parameters are noted.

i. Material = Steel.

ii. Shaft Diameter, $d_s$ = 6mm.

iii. Lead, $l$ = 2mm.

iv. Ball Size, $d_b$ = 1mm.

v. Ball Circle Diameter, $d_c$ = 6.2mm.

vi. Root diameter, $d_r$ = 5.1mm.

4. Equivalent stress,

$$\sigma_{eq} = \frac{4F_a}{\pi d_s^2} * \sqrt{1 + \frac{12l^2}{\pi^2 d_s^2 \eta^2}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

$$\sigma_{eq} = \frac{4 * 944.53}{\pi * 0.006^2} * \sqrt{1 + \frac{12 * 0.002^2}{\mu^2 * 0.006^2 * 0.9^2}}$$

$$\sigma_{eq} = 36.08 \text{ Mpa}$$

5. Driving Torque to Obtain Thrust:

$$T = \frac{F_a l}{2\pi\eta} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

$$T = \frac{944.53 * 0.002}{2\pi * 0.9}$$

$$T = 0.334 \text{ N} - \text{m}$$

## IV. DESIGN CONSIDERATIONS

### A. Dimension of Tray

The base plate of the tray has 290mm width, 544mm depth and 2.54mm of thickness. The back plate of the tray has 286mm width and 229mm depth. The back plate has provision to place the connector which has 150mm depth and 47mm width. The side plate of the tray has 544mm width, 232mm depth and 2.5mm thickness.

### B. Dimension of Avionic Chassis

The avionic chassis is mounted on the tray which is also called as electronic equipment box or black box. The avionic chassis is having a width of 278mm, depth of 547mm and height of 231mm.

### C. Dimension of Connectors

The plug having a height of 117.23mm, depth of 25.4mm and width 35.61mm. The receptacle having a height 188.8mm, 35.63mm width and depth 25.4mm.

### D. Material selection

Here we selected Aluminium 6061 T6 material for Inserter/Extractor arrangement. This material has tensile yield strength of 276 Mpa, modulus of elasticity is 68.9 Gpa and poisson’s ratio is 0.33. For tray we selected Aluminium 7075 T6 material. This material has tensile yield strength of 503 Mpa, modulus of elasticity is 71.1 Gpa and poisson’s ratio is 0.33. Hardened Steel with Black Chrome Plating is selected for screw.

## V. MODEL OF TRAY AND BALL SCREW

### A. Parts and Assembly of Tray

The tray parts and assembly CATIA model is as shown in figure 1. It consists of rear plate, base plate and side plate. The rear plate has provision to place the four electrical connector pins. The base plate has provision for placing the air plenum chamber.

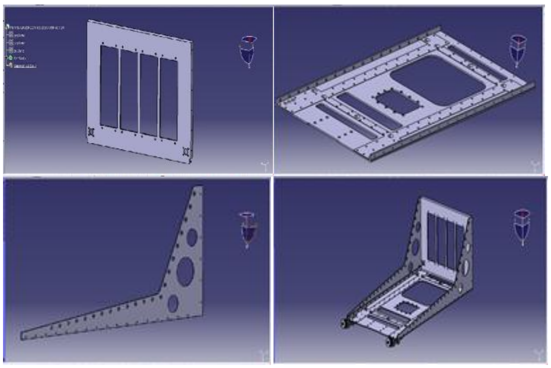

Figure 1: Parts and Assembly of Tray Model.

### B. Part and Assembly of Ball Screw

The ball screw parts and assemble CATIA model is shown in figure 2. It consists of moving block, fixed block, and screw & nut. The ball screw assembly is fixed at the bottom of the base plate tray. The avionic box is placed above the moving block of the ball screw arrangement. As the screw rotates the moving block move forward and backward this in turns rotates the avionic box. This results in the insertion and extraction of avionic box connector pins on the corresponding tray connector pins.

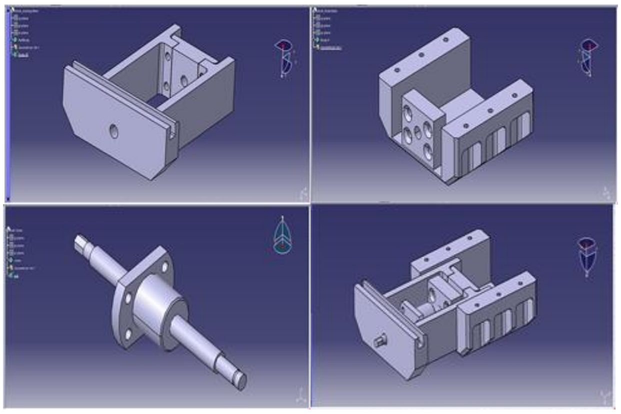

Figure 2: Parts and Assembly of Ball Screw Model.

## VI. ANALYSIS OF MODEL

The analysis is carried out for the rear plate of the tray. As the ball screw rotates, the force is applied on the avionic box to engage the connector pins of box with the tray pins, the force which in turns transfers to the rear plate of the tray. Hence the rear plate of the tray affected by the force. The stress produced by the applied force is analysed by using Abacus software and the induced stress is compared with the yield stress.

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*A. Steps Adopted for Analysis*

i. Importing the CATIA model file of rear plate to Abacus software.
ii. Meshing the model.
iii. Feeding the material property of the material such as young's modulus and poissons ratio.
iv. Creating the reference point i.e. CG for connector 1, 2, 3 and 4.
v. Creating the kinematic coupling for connecting CG of connectors and mounting holes of connectors.
vi. Defining the loads on the CG of the connectors.
vii. Defining the boundary condition to back plate.
viii. Running the model in software.
ix. Checking the von miss stresses and discussing the result.

*B. Result Analysis*

Figure 3 shows the analysis model and result of analysis. The maximum stress produced on the rear plate is 116.77 Mpa.

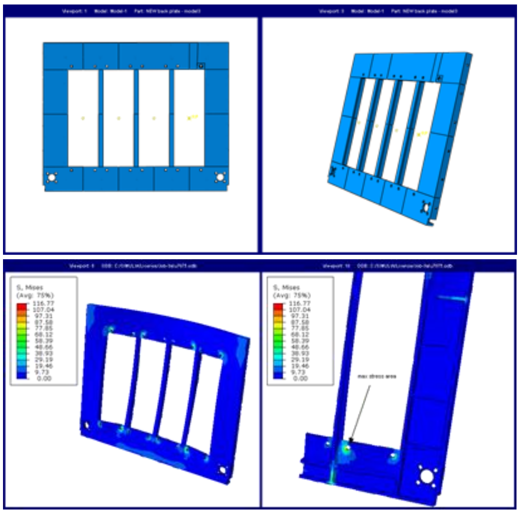

Figure 3: Analysis Model and Result.

## VII. RESULT AND DISCUSSION

*A. Results*

Table 2: Design Calculation Result.

| Sl.No | Parameters | Results |
|---|---|---|
| 01 | Total thrust force, Fa | 944.596 N |
| 02 | Static Load Rating, $C_{oa}$ | 1511.35 N |
| 03 | Shaft Diameter, $d_s$ | 6 mm |
| 04 | Lead, $l$ | 2 mm |
| 05 | Ball Size, $d_b$ | 1 mm |
| 06 | Ball Circle Diameter, $d_c$ | 6.2 mm |
| 07 | Root diameter, $d_r$ | 5.1 mm |
| 08 | Equivalent stress, $\sigma_{eq}$ | 36.08 Mpa |
| 09 | Factor of Safety, $f_s$ | 1.693 |
| 10 | Driving Torque to Obtain Thrust, T | 0.334 N-m |

Table 3: Analysis Result

| Sl.No | Parameters | Result |
|---|---|---|
| 01 | Von miss stress | 116.77 Mpa |
| 02 | Factor of safety | 4 |

*B.Discussion*

The stress produced on the tray rear plate is 116.77Mpa. The yield strength of the material is 503 Mpa. The factor of safety of the material is 4. From the above result we conclude that the stress produced on the tray back plate are below yield stress hence it is found to be safe. From the factor of safety we state that the material is four times greater than the stress produced on the tray back plate. Finally the aluminium 7075 T6 material is safe and can be used for aircraft tray.

## VIII. CONCLUSION

The ball screw mechanism for avionic tray has a controlled engagement and disengagement on electronic chassis. The ball screw mechanism avoids the damage of electrical connector pins as it applies the limited force required for engagement and disengagement of avionic chassis on the tray connector pins and also it avoids the misalignment problem. Ball screw mechanism has many advantages such as high mechanical efficiency, high precision, low wear, low tear, long life, Low starting torque and smooth running.

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