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Design and Analysis of Air Film Transporter

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Abstract:- ***Material handling equipment are widely use in industry to handle the heavy process equipment like boiler, end shield. End shield is the component of nuclear reactor, which provides support to lattice tube and use for shielding the nuclear reactors. For that reason special type of material handling equipments are uses. Air film transporter is one of the materials handling equipment use for the movement of end shield in dust free enclosure. It is designed because of its feature like easily movable heavy loads and positional accuracy in movement.***

The present work includes Design and Analysis of 100MT air film transporter. The components of air film transporter like base frame and drive unit are designed for various loading conditions. Also the selection of air casters, have been carried out.

Keywords:- Air film transporter, Design and Stress Analysis

1. INTRODUCTION

Movement of the heavy nuclear reactor components like End shield is very critical task; because of heavy weight care should be taken care during the movement. Many of the precaution and safety rules should be considered and followed during the movement. To move the End shield from one place to another within the plant various material handling equipments are use like, cranes, low bed wagons, automated guided vehicles and air film transporter. Terry [7] has given the selection of proper material handling equipments is based on various factors. Specifically air film transporter is chosen as a material handling equipment due to the following advantages; the direct floor loading is not acting, high positional accuracy can be achieved, compact in size compare to other material handling equipments.

1.1 WORKING PRINCIPLE

Air film transporter is works on the principle of air cushion. So, it is also called as air cushion transporter. It works similar like a hovercraft. Here, the air coming out from the air caster attached at the bottom of the transporter base and makes a thin film of air. It plays an important role to reduce the friction between the floor and the transporter base. Then drive unit moves the job at required destination. Now unload the job with supporting devices and remove the transporter. For better understanding the working of the air film transporter is divided into following three steps.

Step-1 Prior to inflation, the load is solidly supported on landing pads. These pads protect the Air caster's torus bag from being crushed when load is at rest.

Step-2 When Air is applied to the Air-caster, the torus bag inflates, creating a seal against the floor surface and raising the load.

Step-3 When the pressure within the chamber is sufficient to offset the load's weight, air slowly and evenly escapes between the floor and transporter base and make thin film, which gives nearly friction less movement.

1.2 ASSEMBLY OF AIR FILM TRANSPORTER

- Transporter base
- Air casters
- Drive unit

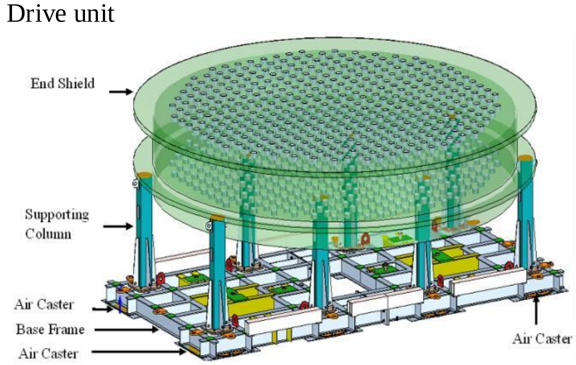


Figure 1.1 Air film transporters with job. [1]

2. *DESIGN OF AIR FILM TRANSPORTER*

DESIGN PARAMETERS

Weight – 150MT

Diameter- 8.1 meter

Job Height- 1.29 meters

Job placement height- 2.1 meter

MATERIAL

IS 2062 (Grade B) [2]

Ultimate Tensile Stress - 410 MPa

Yield Stress - 240 MPa

Young's modulus - 210 GPa

Permissible bending stress - 144 MPa [3]

Permissible shear stress - 94 MPa (IS 800:1984) [3]

Permissible axial stress - 141 MPa

(Tensile/compressive) (IS 800:1984)

2.1. DESIGN CALCULATION

Considering both fixture and end shield,
Load acting on columns, 18.17 MT

DESIGN OF COLUMN [4]

Length of column = 1725 mm
Moment of inertia I = 92.32 x 10^6 mm^4

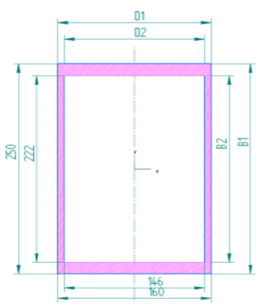


Figure 2.1 Cross-Section of column

Deflection, δ_{max} = 0.25 mm
Stress, σ_{max} = 101.8 MPa

2.1 ANALYSIS RESULTS OF TRANSPORTER

Analysis of the transporter base has been carried out for two different loading conditions**.** [5]

1) When the load is rested on the base frame and support provided by the plurality of the air casters.
2) When the load is rested on the base frame and support provided by eight numbers of jacks applied at the box section. Which are use to adjust the proper location of the air caster during the movement of the air film transporter.

ANALYSIS OF ASSEMBLY FOR CONDITION-1

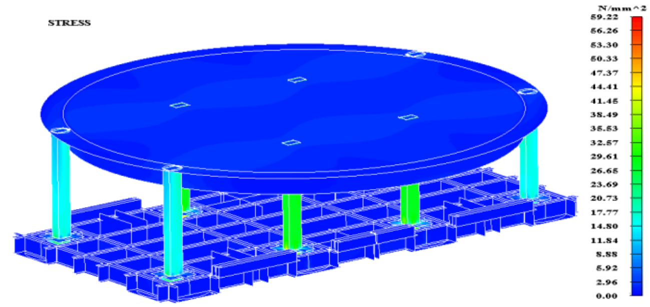


Figure 2.3 Stress produces in transporter base

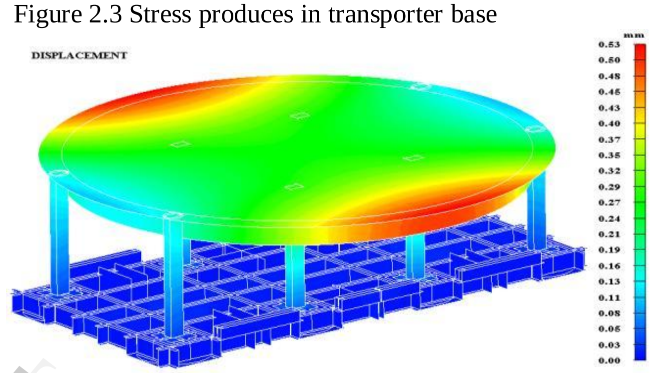


Figure 2.3 Deflection produces in transporter base

ANALYSIS OF ASSEMBLY FOR CONDITION-2

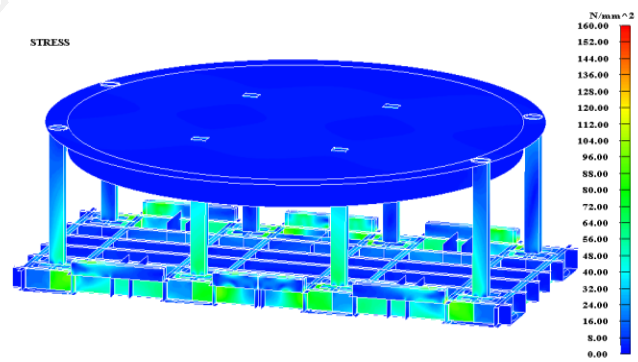


Figure 2.4 Stress produces in transporter base

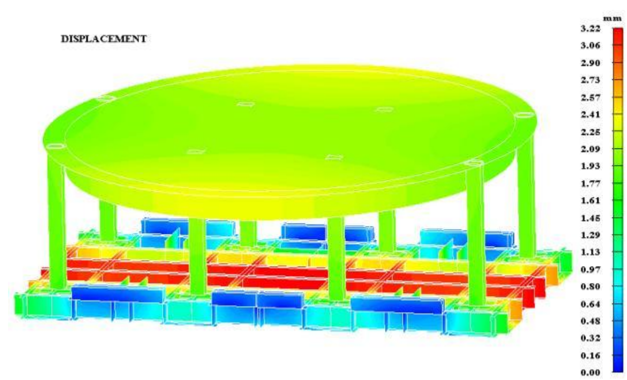


Figure 2.5 Deflection produces in transporter base

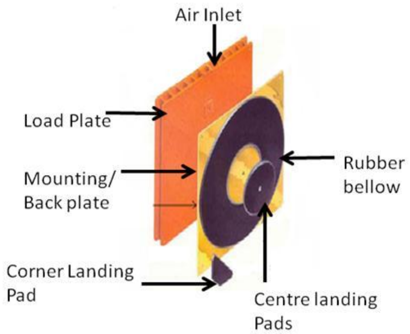
3. SELECTION OF AIR CASTER

Air caster is the pneumatic lifting device. It uses a continuous, regulated flow of air to create an air film between an inflated caster element and the floor surface. The thin film of air created between the air caster and the floor surface allows the load to lift and float, virtually friction-free and omni-directional movement is achieved.

3.1 CONSTRUCTION OF AIR CASTER.

Figure shows the construction of air caster and it consists following parts: [8]

- Circular rubber tours
- Landing pad
- Back plat
- Compressor



3.2 SELECTION PROCEDURE

Selection of air caster depends on following factors:

1. Load carrying capacity of the caster
2. Working floor condition
3. Mounting specification

Required load carrying capacity of the each caster:
P = 19.8 MT
Floor condition: Smooth epoxy painted
Slide mounting casters.

By considering above all parameters, Selection of the air caster is carried out from air caster corporation catalogue.

3.3 SPECIFICATIONS OF AIR CASTER

Make : Air Float Corporation, USA.
Module : Load Modules No: B19 – 0048-5 (Heavy Duty)

Material	: Urethane
Skid Size	: 1220 x 1220 mm
Air Bearing Diameter	: 1200 mm
Air Flow	: 1.1 – 1.5 m^3/ min
Air Pressure	: 70PSI (5kg/cm^2)
Lifting capacity	: 45,000 lbs. (20.25 MT approx.)
Air Line Requirement	: 20 MM (ID)
Weight of the caster	: 215 kg
Air bearing Lift	: 31.7 mm

4. DRIVE UNIT

The heavy job movement with help of the air film transporter is become easier and possible with help of the combine effect of the air caster and the drive unit. Drive unit consists of an air or electric motor that drives the air film transporter with an adjustable speed by means of a driving wheel. Drive unit having various steering and turning options are possible for the movement of the transporter.
Here, the drive unit is divided in to two mechanisms according to its working. 1) Mechanism for straight motion. 2) Mechanism for turning motion.
In the air film transporter drive unit doest carry any direct job load, because of the complete job load is carried out by the plurality of the air casters. Hence drive unit carry only load provided to maintain the contact with floor.

<u>DESIGN PARAMETERS</u>

Job Weight – 150MT
Velocity of the straight motion: V = 10 m/min
Velocity of the turning motion: V = 1.8 m/min
Here, due to the air film generation the friction between the base and the floor should be negligible.
So, the motion of the transporter is resist by the air, rolling action of wheel and bearing.

4.1 DESGIN OF STRAIGHT MECHANISM

1) Power and Torque calculation [6]
Total forces, which resist the straight motion of the transporter are, air resistance (F_a) = 1560N, rolling resistance (F_r) 211.2N & Bearing resistance (F_b) = 4N
Hence, Total resistive force $F = F_a + F_r + F_b$
Total Torque $T = F \times R_{wheel} = 90$ Nm
Total Power $P = T \times V/ R_{wheel} = 300$ Watt

2) Selection of gear box and motor
Input data: T = 45 Nm , P = 150 watt
Required gear ration i = 36
Based on above parameters, Selection of the planetary gear box is carried out from oriental motor catalogue.
Designation: - BH I 6 2 ST 36
From the above required power and torque the

3phase induction motor has been selected and the specification of the motor are, power 200 watt , current 1.1 Amp, torque 1.23 Nm and Tsated/Trated =1.25 and weight = 8 kg.

3) Selection of Driving wheel

Driving wheel is use for the movement of the transporter. The selection of driving wheel is depends on the following factors, load acting, material of wheel, working environment.
Load acting on the driving wheel is 1000N
The material of the driving wheel is taken as a 75D poly urethane, because it will not damage the floor and it having highest wear and tear resistance compare to other polyurethane material.
Selected wheel parameters are,

- Wheel Diameter: 100 mm
- Wheel Width: 100 mm
- Load carrying capacity: 1500 N
- Weight of the wheel: 4.5 kg
- Bore diameter: 31 mm

4) Design of pulley and belt

Belts are the cheapest utility for power transmission between shafts that may not be axially aligned. Power transmission is achieved by specially designed belts and pulleys. They run smoothly and with little noise, and cushion motor and bearings against load changes, belts are less strength than gears or chains.

Input Parameters

Maximum rpm provided by motor shaft = 42 Rpm
Require power transmission 150 watt
Required rpm at wheel shaft = 32 rpm
Transmission ratio (i) = 1.31
V-Pulleys are design for a type cross section belt.

Table- 4.1 Dimension of the transmission pulleys[11]

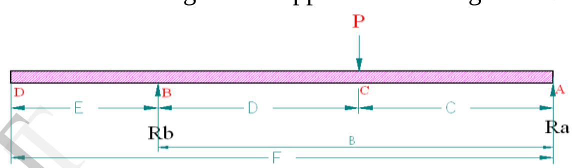
Sr. No.	Description	Motor shaft pulley	Wheel shaft pulley
1	Outside dia.	55 mm	72 mm
2	Pitch circle dia.	48 mm	63 mm
3	Center hole	18 mm	25 mm
4	Width	20 mm	20 mm

Belts are selected based on power transmission capability, cross section and required length.
P = 0.1 to 3.5 KW [11]
Cross section Type A

Wedge angle β = 17˚
Material: Fabrics leather
Density δ = 1000 kg/m3
Allowable tensile strength σt = 2.5 Mpa
Required length of the belt (L) = 620 mm

5) Design of shaft

Shaft is the rotational machine element which is used to transmit power. The power is delivered to the shaft by some tangential force and the twisting moment setup within the shaft permissible limit. It is mounted in the two bearing and it supports the driving wheel.



Load P acting on the shaft is1000N
Twisting moment acting on the shaft 58590 Nmm
Selected, Material of the shaft is selected is C40
By considering the combine twisting and bending of the shaft required diameter of the shaft is 13.5 mm
By considering the higher safety the selected diameter is (d) = 25 mm. [9]

6) Bearing Selection

Bearing require shaft to mounted the inside diameter and housing to support the outer casing.
As per the required loading condition the selection of the straight roller bearing is carried out from the SKF manufactures catalogue.
Bearing number: NUP 2205 ECP [10] Static load carrying capacity (C_o) = 34 KN Dynamic load carrying capacity (C) =34.1 KN

Just like every mechanical element, the bearings are selected based on the criterion of expected life from the bearing
L = (1,000,000 / 60 x n) x (C/P) ^10/3
L = = 2093.17 Hours

4.2 DESGIN OF TURNING MECHANISM

Turning mechanism use for turn the transporter. It consist the following components, gear and pinion, gearbox and motor, bearing, spring.

1) Power and Torque calculation

Total torque, which resist the turning motion of the transporter are, load resistance (T_l) = 150Nm, rolling resistance (Tr) 0.312Nm & Bearing resistance (Tb) = 0.09Nm

Hence, Total resistive torque (T) = $T_a + T_r + T_b$

Total Torque T = 150.2 Nm

Total Power P = T x V/ R_{wheel} = 277.82 Watt

2) Selection of gear box and motor

Input data: T = 75 Nm , P = 138 watt

Required gear ration i = 115.38

Based on above parameters, Selection of the planetary gear box is carried out from oriental motor catalogue.

Designation: - BH I 6 2 ST 90

From the above required power and torque the 3phase induction motor has been selected and the specification of the motor are, power 200 watt , current 1.1 Amp, torque 2.2 Nm and Tsated/Trated =1.25 and weight = 7.5 kg.

3) Design of spur gear and pinion

Input Parameters

Geared motor rpm= 16

Required drive rpm = 13

Required transmission ratio = 1.23

Required power transmission = 138 watt

Required torque transmission = 75 Nm

Assumption

No of teeth in pinion Z1 = 36

Pressure angle Ø = 20 ˚ Full depth

Module of teeth m = 4 mm

Standard gear ratio i = 1.25

By taking the above parameters the design of the spur gear and pinion pair is carried out and dimension of the gear and pinion are mention in table 4.2.

Table- 4.2 Dimension of the gear and pinion [11]

	Gear	Pinion
No of teeth (Z)	45	36
Module (m)	4 mm	4 mm
Face width (b)	16 mm	16 mm
Gear Ratio(i)	1.25	1.25
Bottom clearance, c	1 mm	1 mm
Pitch circle diameter, d	180 mm	144 mm
Tip diameter, d_a	184 mm	148 mm
Root diameter, d_f	175 mm	139 mm

3) Bearing Selection

As per the required loading condition the selection of the straight roller bearing is carried out from the SKF manufactures catalogue.

Bearing number: 32210 [10]

Static load carrying capacity (C_o) = 122N

Dynamic load carrying capacity (C) =100 KN

Life of bearing, L = 5860.10 Hours

4) Spring Design

Spring provides the sufficient amount of force on drive unit to maintain continuous contact with floor. These spring are to be designed for the total amount of force provided by spring must be higher than the total pulling force required, then only the wheel will not slip.

Input Parameters

Load acting on spring = 700 N

Assume Spring Index C = 10

Deflection of the spring (δ) = 100 mm

Minimum outside diameter (Di) = 60mm

Mean diameter (Do) = Di + d

Material Selection:

Carbon steel C55 Cold Drawn [11]

Tensile Stress (σu) =1138 MPa

Allowable shear Stress (τs) = 420 MPa

Young's Modulus (E) = 210 GPa,

Modulus of rigidity (G) = 80 GPa,

Hardness number, HRC = 55

Density ρ = 7850 kg/m^3

Now by considering the Whal's factor, calculate the mean diameter of the spring.[9]

Whal's factor.

$$K = \frac{4C-1}{4C-4} + \frac{0.615}{C}$$

K = 1.1415

Now calculate required wire diameter of spring

$$\tau = \frac{K x 8 x P x C}{\pi x d^2}$$

d = 6.8 mm ~ 7 mm

Mean diameter (D) = 70 mm

Number of coil required

$$\delta = \frac{8 x P x n x c^3}{G x d^4}$$

n = 11 mm

For flat and ground ended spring no of turns n' = 13

Free Length of spring L_f = n'd + δ + 0.15 δ
=216 mm

Pitch of the spring P = L_f / n'-1

= 17.1 mm

Table 4.3 Dimension of the spring

Sr.No.	Description	Dimension
1	Wire diameter	7 mm
2	Mean diameter	70 mm
3	Outside diameter	77 mm
4	Free length	216 mm
5	Pitch of coil	17.1 mm

5. CONCLUSION

As define in problem manual design for various components like base frame, drive mechanism of air film transporter have been carried out. Based on the obtained design data 3D modeling and assembly of various components have been done.

After the modeling, static structure analysis of the base frame has carried out with Ideas NX-12 software and results have been compared with the permissible value taken from IS 800:1984 and the result shows that stress are well under permissible stress limit.

In addition to the above calculation for the movement of air film transporter the value of torque and pulling force is obtained. The value of require pulling forces compare with the allowable literature and it has a close agreement with available literature.

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