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Design and Analysis of Coil Transfer Car for Steel Industries

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Abstract: The floor type coil transfer vehicle is an industrial vehicle designed for transporting heavy coils. This will be primarily used in the steel industry for transporting coils from one location to another for fabrication. This floor-standing coil transfer vehicle can carry 20-25 tons of coil weight. In this case the coil weight (maximum load of 20 tons) mainly falls on the bottom beam structure.The critical part of the coil car is the driving shaft which is made of EN 24 steel for movement by connecting it to a hydraulic motor. The trolley is equipped with a flat surface to support the weight of the coil.

Designing and manufacturing a floor-standing coil transfer vehicle capable of carrying a 20-ton load was a challenging project that required careful consideration of various design principles and analyses. The main load-bearing components of a car include the I-beam and drive shaft. I-section beams are subjected to uniformly distributed loads (UDL) caused by the weight of the coils. Therefore, the choice of beam material and its cross-sectional area is crucial to ensure its strength and durability. The design process included analyzing the stress and strain of every component of the car, including cross members, drive shafts and other structural elements, to ensure they were strong enough to withstand the 20-ton load. Finite element analysis (FEA) is commonly used to simulate and optimize vehicle performance, allowing designers to identify potential problems and improve vehicle designs. We get a maximum principal stress on the shaft of 100 Mpa, where the UDL load of the 10-ton load is fixed on both sides and is below the yield strength of the material and the bending moment is 18.6×10^3 N-mm. The main maximum stress of 410 Mpa is obtained on the transmission shaft of the simply supported beam on both sides.

This is under allowable pressure, so our design can be considered safe.

Keywords: Coil transfer**,** hydraulic motor, Drive shafts, stress.

Introduction

Coil transfer cars, also known as coil cars, are industrial vehicles designed for transporting heavy loads of steel coils. These vehicles are commonly used in steel mills and metalworking plants, where the transport of steel coils is a crucial part of the manufacturing process. Coil transfer cars are typically designed with a flat platform or bed, which allows steel coils to be loaded and secured for transport. Cars can be powered by a variety of means, including electric motors, hydraulic systems, or diesel engines. They are often equipped with specialized features such as lifting arms, adjustable supports, and braking systems that enable the safe and efficient transport of steel coils.

The use of coil transfer cars offers numerous advantages for manufacturing plants, including increased productivity, improved safety, and reduced labor costs. By automating the transport of heavy loads, coil cars can significantly reduce the risk of worker injury and increase operational efficiency. They are also versatile and adaptable, with a range of customizable features that can be tailored to meet specific manufacturing needs. Overall, coil transfer cars play a critical role in the steel industry and other metalworking applications. They offer an efficient and safe means of transporting heavy loads, which can help to improve productivity and reduce costs for manufacturing plants.

Coil transfer cars come in different types, including motorized and non-motorized cars. Motorized coil transfer cars have a drive system that allows them to move independently, while non-motorized cars rely on external power sources. Coil transfer cars also come with different load capacities and deck sizes to accommodate various types and sizes of steel coils.

The use of coil transfer cars offers several benefits, including improved safety, increased efficiency, and reduced labor costs. Coil transfer cars are designed to transport heavy and bulky steel coils safely, reducing the risk of injuries and damage to the coils. They also allow for faster and more efficient transportation of coils, reducing loading and unloading times and increasing overall productivity. With coil transfer cars, fewer workers are needed to handle the coils, reducing labor costs, and improving safety.

Coil transfer cars are used in various industries that require the transportation of steel coils. In the automotive industry, coil transfer cars are used to move steel coils from the manufacturing plant to the assembly line to produce vehicles. In the construction industry, coil transfer cars are used to move steel coils to construction sites to produce steel structures such as bridges and buildings. In the manufacturing industry, coil transfer cars are used to move steel coils within a facility during the production process.

Coil transfer cars are an essential part of the material handling process in various industries that require the transportation of steel coils. With their features, benefits, and applications, they offer a safe, efficient, and cost-effective means of transporting heavy and bulky steel coils. When selecting and maintaining coil transfer cars, it is essential to consider factors such as load capacity, deck size, rail gauge, power source, and safety measures. Proper maintenance is also crucial to ensure safe and efficient operation.

Fig. 1 A typical Coil car

Problem Statement

The objective is to design a secure and reliable floor type coil car that can take safely a load of 20 tons heavy steel coil and move it to other locations in the steel industry. The primary goal of the system design is to ensure safety and efficiency and complying with safety for using transporting equipment in this operation.

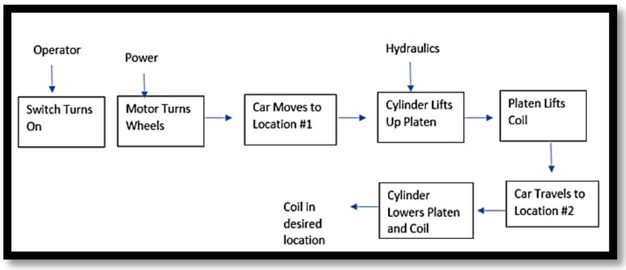


Fig. 2. Flow chart showing steps of operation

In order to accomplish this, the coil transfer system will be made of I-section beams as the support with a comprehensive design process and it also includes analysis and also load calculations of the complete unit to ensure the balance and capacity of taking load and transport it in the industry selection of the material which will have strength to sustain the load. Also calculating the cost that is required for the fabrication in industry.

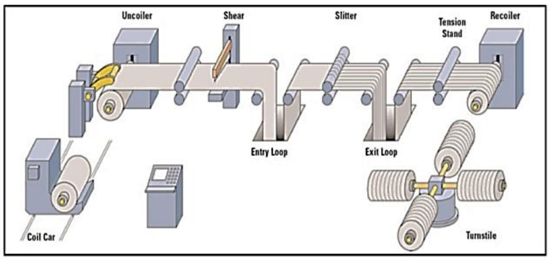


Fig. 3Cycle of coil car performance

And, to find the which type of the hydraulic motor is required to transporting the load from one place to another in the industry and also how much power is required for dragging the complete coil car with the load of 20 tons of coil.

Dimensions of the coil

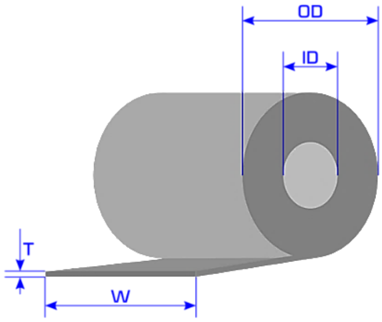


Fig. 4 Dimensions of the coil

OD = Outer Diameter
ID = Inner Diameter
W = Width
T = Thickness
Calculating the length of the coil
Thickness of coil = 0.63mm
Width = 1020mm
Inner diameter = 508 mm
Outer diameter = 1854mm
D = 7.81 x 10^3 kg/m^3
Weight = 20 Tons
Length = Weight / (Density x Width x Thickness)
Length = 20,000 / (7.81 x 10^3 x 1.02 x 0.00063)
Length = 3,203.4 m

According to this problem statement we must design the model of the floor type coil transfer car for carrying the coil of steel which is of 20 tons of the weight. Accordingly, we must do the literature survey which will help to get the information of the design and dimensions and the process and also the material used for the fabrication and which type of the material is used that will sustain the wait and have the long life for that model.

Literature Survey

Coil cars are used in mills where the transportation of coils is necessary. Author: Abigail A. Eberly Advisor: S. Graham Kelly discussed that working of the coil design in these coils, which often sit on saddles, come in a variety of sizes and weights. In addition, mills are often set up differently, requiring a variety of sizes and shapes, unique for each location. The coil cars run on rails to the location where the coil is sitting on the saddle. The motion is initiated by a motor, controlled by an operator, that is linked to a gear on the drive axle connected by a chain. The platen then raises, due to the force of a cylinder, hoisting the coil above the saddle. The coil car will then travel to a new location along the rails and lower its platen, setting the coil on a new set of saddles.

The main function of the coil car is to transport a coil from one location to another. In order to do this, power, operator, and hydraulics must be used.

Transport car for metal coil:

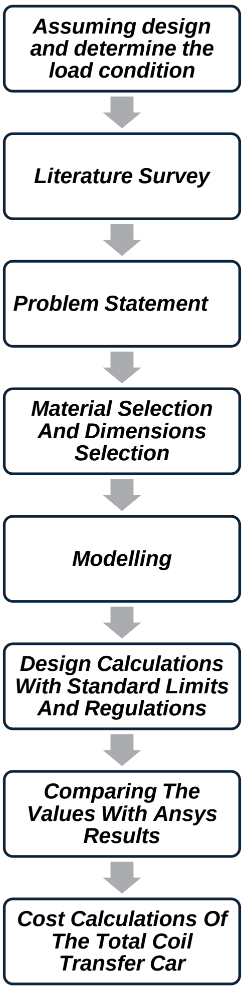
The transfer car of the design includes a chassis that may be moved along a conveyance path by an electric motor and mechanisms for moving a support saddle along a linear vertical guide on a base frame. Authors Josef Zug, Monheim, Peter de Kock discussed about the working of transfer metal coil.

The transfer car is used in a conveyance system for metal coils. transfer car in a conveyance System for metal coils with a chassis that can be moved along a conveyance path by means of a drive and with means for raising and lowering a Support Saddle along a linear vertical guide on a base frame, wherein a steel slab, for example, is used as the plate-like base frame, on which a Scissor lifting unit is mounted for the purpose of linear vertical guidance, Such that, to raise and lower the Support Saddle. An invention relates to a transport car in a Supply unit for metal coils, comprising a chassis which may be displaced along the Supply path by means of a drive, with means for raising and lowering a carrying Saddle along a linear vertical guide on a base frame. The coil transport car construction can be improved, whereby, for example, a Steel Slab is used as a plate-like base frame.

Methodology

First for getting Ideas for designing of the coil transfer car and selection of the type of coil transfer car,referred the literature survey that is done for knowledge aboutthe coil car and selection of the material that is required for the fabrication purposewhich will withstand the load and get long-life without any damage.

The design process for a coil transfer car involves several steps, including literature survey, problem statement definition, material and dimension selection, Modelling, design calculations, comparing results with Ansys, and cost calculations. These steps are essential to ensure the successful development of a reliable and cost-effective coil transfer car. Literature survey, gathers relevant information on similar designs and existing solutions. Problem statement definition outlines specific goals and objectives to be achieved. Material and dimension selection considers load capacity, environmental conditions, and manufacturing feasibility. Modelling: creates a virtual representation of the car using specialized software. Design calculations: evaluates structural integrity, stability, and load-bearing capacity. Cost calculations: assesses economic feasibility.



Flow chart for methodology

Material Selection

The choice of materials for a beam is a crucial aspect of lifting heavy loads safely and efficiently. It is placed at the base of the transmission coil designed to withstand the weight. A lifting beam is a critical component of a lifting system that helps distribute the weight of the load evenly across multiple lifting points, minimizing the risk of damage or failure. There are several factors to consider when selecting materials for a beam, including the strength, stiffness, durability, weldability, and weight of the materials.

The selection process must also consider the work environment such as temperature, humidity and corrosive substances, as well as any regulatory requirements or industry standards. The beams can be made from several materials, each with different advantages and disadvantages. Steel alloys, aluminum alloys and composites are among the most used materials for beams. Steel alloys, for example, are popular for their high strength, toughness, and durability. Aluminum alloys, on the other hand, are lightweight and have high corrosion resistance, making them ideal for marine and offshore applications.

Composites offer excellent strength-to-weight ratios, making them an attractive option for lightweight applications. For heavy lifting applications, mild steel is the preferred choice due to its reliability and cost-effectiveness. Structural steel is available in a range of shapes and sizes including I-beams, H-beams, angles, and channels that can be customized to meet the specific needs of a design.

Calculations

Shaft calculations are done taking weight of the shaft as 15 tons

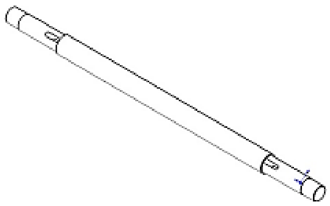


Fig. 5Drive shaft

Bending Moment:

w = 15 tons

= 149870 N

w = load per unit length

w = $\frac{load}{lengt\ h}$

w = $\frac{15\ tons}{1.537m}$ = 97.3 N/m

M = $\frac{wL}{8}$

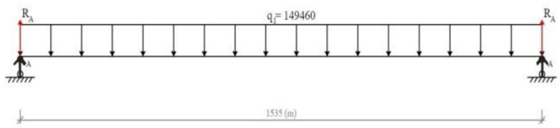


Fig. 6 Loading diagram

= $\frac{97.3 \times 1535}{8}$

= 18.66×103Nmm.

Bending moment of the drive shaft is 18.66×103Nmm.

Cross Sectional Area:

A= $\frac{\pi d^2}{4}$

= $\frac{\pi \times (110)^2}{4}$

= 9.4×103 mm2

Section Modulus:

Z = $\frac{\pi}{32}$ × d3

= $\frac{\pi}{32}$ × (110)3

= 130.6×103 mm3

Bending Stress:

σ = $\frac{m}{z}$

= $\frac{18.66 \times 10^3 mm}{130.6 \times 10^3\ mm^3}$

= 0.142 N/mm2

Torsion Equation:

$\frac{T}{j} = \frac{f_s}{r}$

T = $\frac{f_s}{r} \times$ J

= $\frac{f_s}{r} \times \frac{\pi}{32}$d4

=$f_s \times \frac{\pi}{16} \times d^3$

= 433 × $\frac{3.14}{16}$ × (110)3

= 72.1× 106 N-mm.

Torsional Shear Stress:

TSS = $\frac{TC}{J}$

= $\frac{T(r)}{\frac{\pi \times d^3}{32}}$

= $\frac{T(r)}{\pi \times d^3} \times 32$

= $\frac{Td}{\pi \times d^3} \times 16$

= $\frac{72.1 \times 10^6 \times 16}{3.14 \times (11o)^3}$

TSS = 275.8 N/mm

Axial stress :

σa= $\frac{4 \times w}{\pi d^2}$

= $\frac{149870 \times 4}{3.14 \times (110)^2}$

σa = 15.77 N/mm2.

Moment of inertia :

I = $\frac{mr^2}{2}$

= $\frac{117.80 \times (55)^2}{2}$

I = 178.1x103 mm4.

Deflection of the shaft:

$$\delta = \frac{5wl^4}{384EI}$$

=$\frac{5 \times 97.3 \times (1535)^4}{384 \times 2.1 \times 10^5 \times 178.1 \times 10^6}$

δ = 0.188mm.

$$\tau_b = \frac{F(AY)}{I_b}$$

= 5.24 N/mm^2

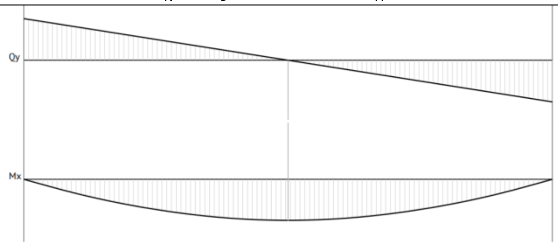


Fig. 7 SF and BM diagram

$$\tau_T = \frac{T_r}{J}$$

$= \frac{72.1\times10^6\times55}{\frac{\pi}{32}\times(110)^4} = 275.88$ N/mm2

σb = 0.142 N/mm^2=

$$\tau = \tau_b + \tau_T$$

= 413.12 N/mm^2

Principal stress :

$$\sigma_{1,2} = \frac{\sigma}{2} \pm \frac{1}{2}\sqrt{(\sigma^2) + 4\tau^2}$$

$= \frac{0.142}{2} \pm \frac{1}{2}\sqrt{0.142^2 + 4(413.5)^2}$

σ_{P_1} = 421.4

σ_{P_2} = -402.16

Von misses stress :

$$\sqrt{(\sigma_{P1})2 + (\sigma_{P2})^2 - \sigma_{P1} \times \sigma_{P2}} = \frac{Y}{1.5}$$

$$\sqrt{(421.3)2 + (-402.16)2 - (421.3) \times (-402.16)}$$

= 410 N/mm2

Finite Element Analysis

The finite element analysis has become a powerful tool for the numerical solution of a wide range of engineering problems. Applications range from deformation and stress analysis of automotive, aircraft, building and bridge structures to field analysis of heat flux, fluid flows, magnetic flux, seepage and other flow problems. With the advances in computer technology and CAD systems, complex problems can be modeled with relative ease. Several alternative configurations can be modeled with relative ease. Several alternative configurations can be tested on a computer before the first prototype is built. In this method of analysis, a complex region defining a continuum is discretized into simple geometric shapes called finite elements. The material properties and the governing relations are considered over these elements and expressed in terms of unknown values at the element corners. An assembly processes duly considering loading and constraints, result in a set of equations, solution of these equations gives us the approximate behavior of the continuum.

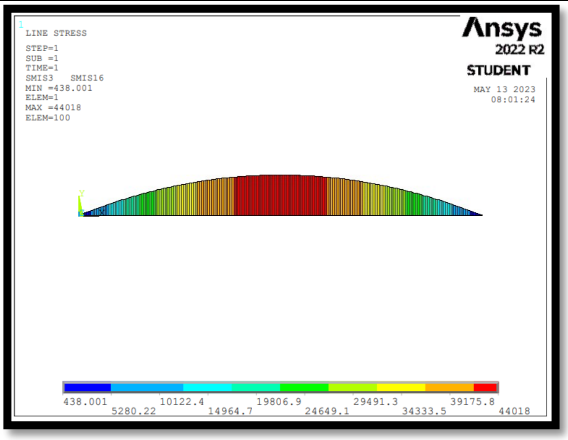


Fig. 8 Bending moment diagram

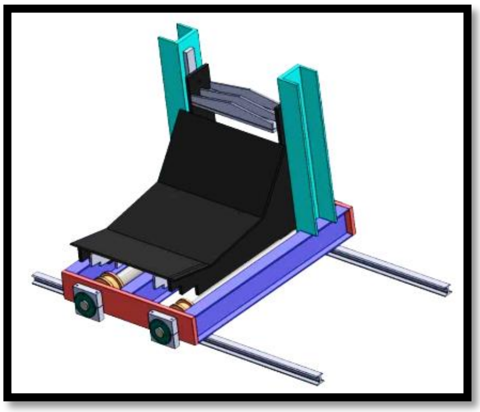


Fig. 9 Assembly of Coil Transfer Car

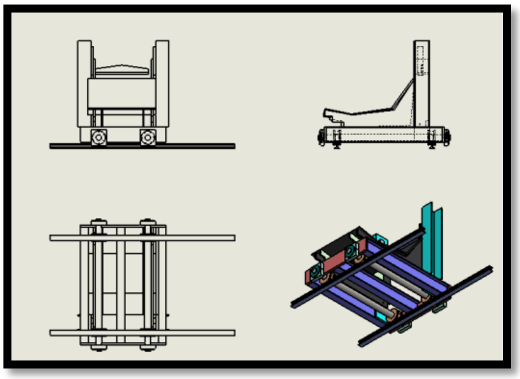


Fig. 10 Assembly Drawingof Coil Transfer Car

Results & Discussions

Shaft Results:

In this figure we can see the von mises stress that is formed by keeping the 15 Tons of the load on drive shaft which is made of EN24 Steel whose yield strength is 650 MPa. We are using the safety of 1.5 and we get 410 N/mm^2 which is safe design. It has been observed the nodal solution that is displaced sum vector.

We can observe the bending moment of the drive shaft due to the 15 Tons load that is applied. We got results by selecting SMIS6 and SMIS19 in sequencing numbers.

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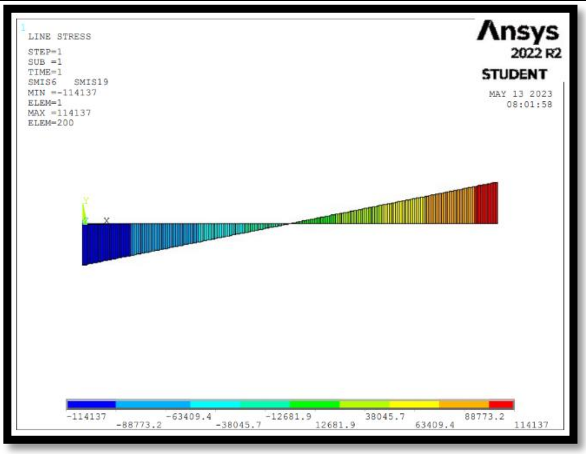

Fig 11 Shear force diagram

We can observe the shear stress diagram of the drive shaft due to the 15 Tons load that is applied. We got results by selecting SMIS3 and SMIS16 in sequencing number.

Shaft	Theoretical values	FEA values
Von mises stress	410 N/mm^2	387.5 N/mm^2
Deflection	0.188mm	0.155mm

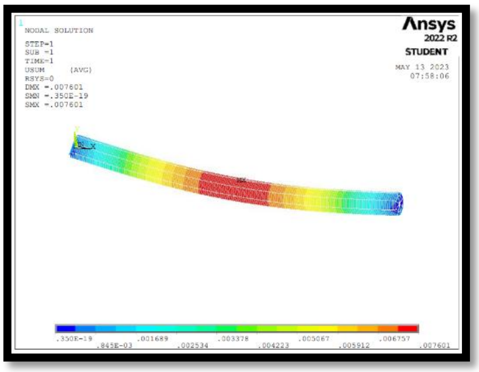

Fig 12 Displacement of shaft

The theoretical calculations of the drive shaft which is simply supported at both ends subjected to UDL load of 10 tons on each beam. And deflection of the beam is 0.188mm.

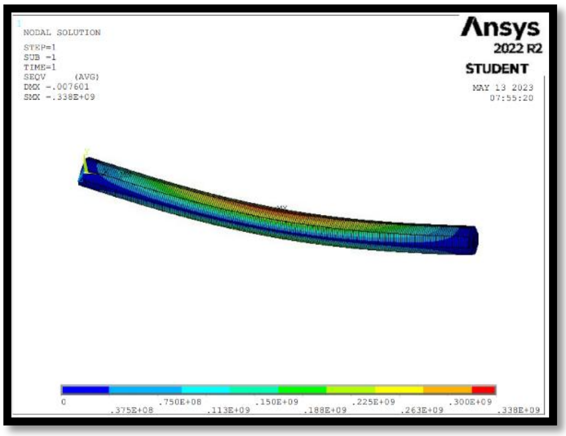

Fig. 13 Stress in shaft

We observed the von misses stress of the beam is 410 N/mm2. And we observed that von misses in finite elemental analysis in ANSYS 387.5 N/mm2.

Comparisons:

Shaft	Theoretical values	FEA values
Von mises stress	410 N/mm^2	387.5 N/mm^2
Deflection	0.188mm	0.155mm

Conclusion

- The shaft which is made of EN 24 steel have the von mises stress 410 N/mm2 which less than the allowable stress compared to the EN 19 steel so we token EN 24 as the design material.
- It has been observed that in finite element analysis von mises stresses of the shaft is 384.9 N/mm2, which is well with the limits of theoretical calculated values of 410 N/mm. Hence the design is safe.
- The stress and strain analysis showed that the design was safe and capable of carrying the load without exceeding the allowable pressure.
- This industrial vehicle is an essential tool for transporting heavy coils in the steel industry and will greatly improve efficiency and productivity. Overall, the successful design and manufacture of the floor-standing coil transfer vehicle demonstrated the importance of careful design and analysis in developing effective and safe industrial equipment.

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