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Design and Analysis of Tow Bar for LCH Helicopter

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ABSTRACT

The HAL Light Combat Helicopter (LCH) is a multirole combat helicopter being developed in India by Hindustan Aeronautics Limited (HAL) for use by the Indian Air Force and the Indian Army. This project work aims to design and analysis of tow bar for light combat helicopter with the help of static analysis and buckling analysis. A tow hitch (or tow bar) is used for towing the helicopter from flight hanger to runway for ground testing and water testing. A device attached to the chassis of a vehicle for towing, or a tow bar to an aircraft nose gear. The main objective of this project is to design the tow-bar for LCH with better geometrical features to withstand the load and operating stresses built up during the operation, and to analyze the same for stress distribution during loaded condition .Design and analysis for geometrical features of hitch type tow bar for wheeled version of light combat helicopter. Current version of the tow bar often encounters the problem of bending and breakage at various sections during towing, which has to be repaired or reworked frequently making it uneconomical to use. Hence the objective is to design the new tow-bar with better geometrical features to withstand the load during towing and to analyze the same for load bearing capacity and stress distribution in the equipment at various critical sections. Specifically the earlier version of tow-bar was designed using standards and manual calculations for stress analysis, the new version is designed and analyzed using sophisticated software like UGNX8 and ANSYS 14.0 thereby increasing the quality of the equipment increasing worker safety and economical to use.

Keywords – *Tow Bar, Helicopter, Ansys, Design, Towing*.

1. INTRODUCTION

Helicopters are classified as rotary wing aircraft and their rotary wing is commonly referred to as the main rotor or simply the rotor. Unlike the more common fixed wing aircraft such as a sport biplane or an airliner, the helicopter is capable of direct vertical take-off and landing and it can also hover in a fixed position. These features make it ideal for use where space is limited or where there is a necessity to hover over a precise area.

A helicopter's power comes from either a piston engine or a gas turbine (recently, the latter has predominated), which moves the rotor shaft, causing the rotor to turn. While a standard plane generates thrust by pushing air behind its wing as it moves forward, the helicopter's rotor achieves lift by pushing the air beneath it downward as it spins. Lift is proportional to the change in the air's momentum, the greater the momentum, the greater the lift.

Helicopter rotor systems consist of between two and six blades attached to a central hub. Usually long and narrow, the blades turn relatively slowly, because this minimizes the amount of power necessary to achieve and maintain lift, and also because it makes controlling the vehicle easier. While light-weight, general-purpose helicopters often have a two-bladed main rotor, heavier craft may use a four-blade design or two separate main rotors to accommodate heavy loads
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1.1 Towing

Movement of large aircraft on an airport and about the flight line and hangar is usually accomplished by towing with a tow tractor (sometimes called a "tug"). In the case of small aircraft, some moving is accomplished by hand or by pushing. Aircraft may also be taxied about the flight line, but usually only by certain qualified persons. The following paragraphs outline the general procedure for towing aircraft; however, specific instructions for each model of aircraft are detailed in the manufacturer's maintenance instructions and should be followed in all instances. Before the aircraft to be towed is moved, a qualified person must be in the cockpit to operate the brakes if in case the tow bar fails or becomes unhooked. The aircraft can then be stopped, preventing possible damage. Some types of tow bars available for general use can be used for many types of towing operations. These bars are designed with sufficient tensile strength but are not intended to be subjected to torsion or twisting loads. Many have small wheels that permit them to be drawn behind the towing vehicle going to or from an aircraft.

Some tow bars are designed for towing various types of aircraft; however, other special types can be used on a particular aircraft only. Such bars are usually designed and built by the aircraft manufacturer. The attachment of the tow bar varies on different types of aircraft. Aircraft equipped with nose-wheels are generally towed forward by attaching the tow bar to the main landing gear.

1) Some basic rules for towing are:

- The proper tug and tow-bar should be used for the size aircraft being moved.
- The tow-bar must be approximately level between the aircraft and the tug.
- The hitch on the tow-bar must move freely on the hitch mounted on the tug.
- Prior to moving, make sure that full swivel release pins are released (if applicable).
- Check that all the tie downs and chocks are removed and aircraft brakes are released.
- Aircraft should be towed at low very speed.
- Nose wheel towing limits: Do not exceed towing limits. If not marked or not known, do not exceed 30° from centre.

1.2 Tow-bar

Conventional tugs use a tow bar to connect the tug to the nose landing gear of the helicopter. The tow bar is fixed laterally at the nose landing gear, but allowed to move slightly vertically for height adjustment. At the end that attaches to the tug, the tow bar may pivot freely laterally and vertically. In this manner the tow bar acts as a large lever to rotate the nose landing gear. Each helicopter type has a unique tow fitting, so the tow-bar also acts as an adapter between the standard-sized tow pin on the tug and the type-specific fitting on the helicopter's landing gear. The tow bar must be long enough to place the tug far away enough to avoid hitting the helicopter, as well as to provide sufficient leverage to facilitate turns. The tow bar can be connected at the front or the rear of the tractor, depending on whether the helicopter will be pushed or pulled. The tow-bar has a shear pin. The shear pin prevents the helicopter from being mishandled by the tug—when overstressed the shear pin will snap, disconnecting the bar from the nose gear to prevent damage to the helicopter and tug.
Tow-bars comes in three different configurations-

2. LITERATURE SURVEY

Federal Aviation Administration, in its Aviation Maintenance Technician Handbook discusses about the general procedure of ground movement of an aircraft and guidelines for towing the aircraft which describes the application and working conditions a tow-bar will be subjected to. Tow-bars may be designed for various types of aircraft, but in some special cases it requires a particularly designed tow-bar for such aircrafts which will be manufactured by the aircraft manufacturer itself.

Aviation Maintenance, Technician Handbook – Airframe, explaining about the landing gear design, states that nose or main landing gear of an aircraft will be equipped with jacking points and towing lugs. Jacks should always be placed under the prescribed points. When towing lugs are provided, the tow-bar should be attached only to these lugs.

Pankaj Khannade et al., have done design and analysis of a tow bar for a portable compressor unit. The design is limited to medium sized portable compressors

Abhishek Adnoor et al., have used the concept of universal type of tow bar. Here they have conducted a non-linear analysis of a tow bar and found out the equivalent stress and deformation. Static analysis and modal analysis were carried out to find the natural frequency; finally buckling analysis was also carried out.

Christopher Cavallaro et al., have developed a new lightweight composite tow bar for MIAl and MIA2 Main Battle Tanks. This effort resulted in a new tow bar design which was lighter, stronger, and offered interchangeability of identical legs at a reasonable cost.

Fadzli Ibrahim et al., in this investigation, the structural integrity of a towing bar using finite element analysis (FEA) was studied. The simulation analysis was done for four different cases, where force was applied at four different angles; 0, 30, 45 and 60˚. The results of the FEA simulations showed that the maximum force that can be applied to the towing bar reduced drastically when the load was applied at increasing angles

3. OBJECTIVE AND METHODOLOGY

3.1 Objective

The main objective of this project is-

- To improvise the current tow-bar by designing its geometrical characteristics so as to enhance the mechanical properties of the equipment, like better load bearing capacity, to withstand shock loads and stresses built up during operation.
- To verify the same by analysing the design for stress distribution and total deformation caused in loaded condition.

3.2 Methodology

A methodology is a systematic way of conducting systems analysis and design. Application of the tow-bar is analysed for its real time loading conditions, working environment, etc. Further present design of tow-bar is studied for materials used for the component, critical dimensions, design standards used and its limitation.

A conceptual design is created using various design considerations to meet the working requirements and also to overcome the limitation of the earlier design. This new design is analysed for stress concentration and the deformation that could be produced in the component during loaded condition, using sophisticated software. Results are interpreted to verify if the design meets the requirement or if there is a need of any modification before finalising the design. Drafting phase includes preparation of detail drawing with proper tolerances for fabrication and Bill of Material (B.O.M) is generated by measuring the size of the part and quantity, material used and their special characteristics. Finally the design will be forwarded for manufacturing section for fabricating the equipment.

4. MECHANISM OF TOW BAR

A tow bar is used to move disabled vehicles to the garage. Front end of the tow bar i.e. hook part is attached to the truck .the truck acts as driven it drives the disabled vehicles. The rare part of the tow bar is attached to the disabled vehicles.

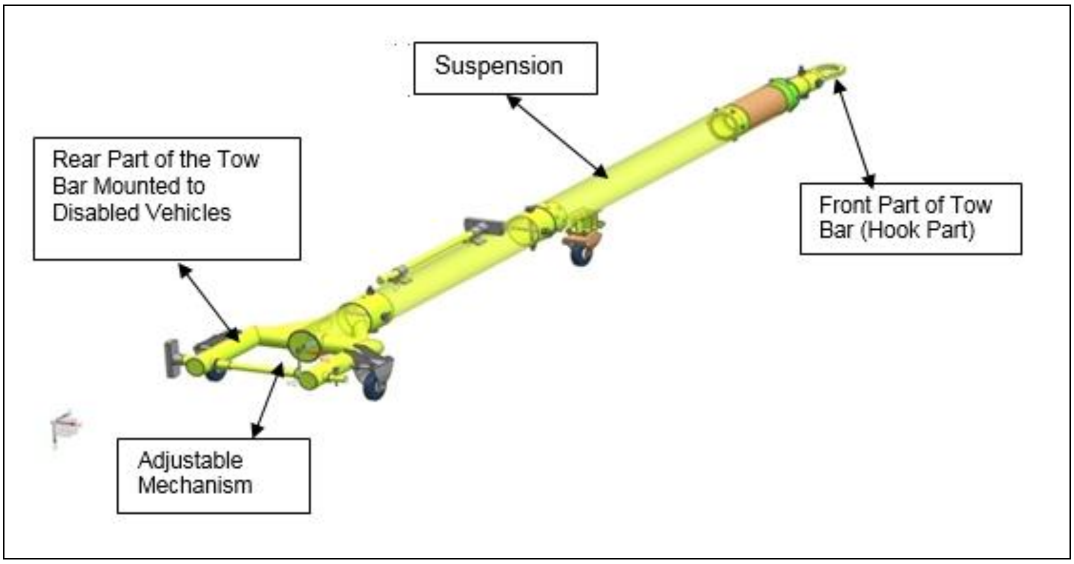

Fig 1: Description of Tow Mechanism.

5. CALCULATION AND INPUT DATA

Reference: Design data hand book by Dr K. Lingaiah, volume1, Edition 1998, TATA McGraw Hill Inc.

Mass of the helicopter,	$m = 5000\ Kg$
Coefficient of friction	$\mu = 0.3$
Impact load factor	= 2
Factor of safety	= 0.5 to 2.5
Force require to pull the helicopter Weight of the helicopter	$W = m \times g$ $W = 5000 \times 9.81$ $W = 49050\ N$
Force required for overcoming this rolling friction	$P = \mu \times W \times 2 \times 1.5$ $P = 0.3 \times 49050 \times 2 \times 1.5$ $P = 44145\ N$ $\sim P = 45KN$
Outer diameter of the spring	$D = 88\ mm$
Diameter of the component	$d = 82\ mm$
Area	$A = \pi(D-d)^2 / 4$ $A = \pi(88-82)^2 / 4$ $A = 801 mm^2$
From equation (1) tensile load condition $\sigma = P / A$	$\sigma = 44145/801$ $\sigma = 56N / mm^2$
(b) Buckling analysis $p = \pi^2 EI / l^2$ $p = \pi^2 \times 2.1e^5 \times 724032.9 / (1070)^2$ $p = 1943.07N \times 4$ $P = 7772.03N$	Where, $E = 2.1e^5$ E=young's modulus $I = \pi(D^4 - d^4) / 64$ $= \pi (88^4 - 82^4) / 64$ $I = 724032.9$

Table 1: Calculation.

6. RESULTS AND DISCUSSIONS

6.1 Meshing of Tow Bar

Meshing is a model body by dividing into an equivalent system of many smaller bodies or units (finite elements) interconnected at points common to two or more elements (nodes or nodal points) and boundary lines or surfaces. Meshing is done in Ansys using solid 186 and solid 187 and contact is defined by CONTA174 & TARGE170.The material used for tow bar in both cases is steel. Having material property as follows, Density of the material is 7850 kg/m3.Young's modules of the materials are 2E+11 Pa. and Poisons ratio is 0.3.

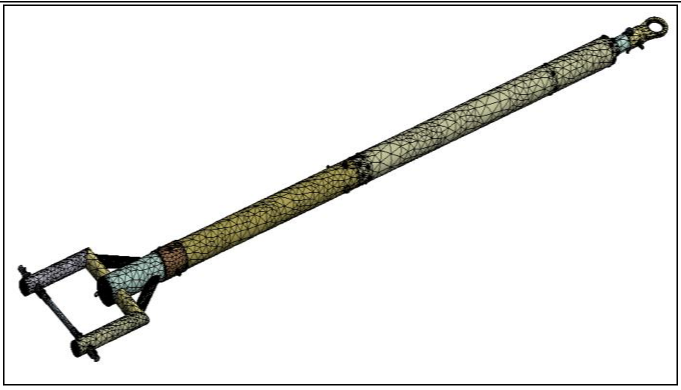

Fig 2: Meshing of tow bar

Fig 2, shows the meshing of a tow bar .Mesh optimization was effectively implemented to check the convergence of results by iteratively increasing the mesh density. Mesh was also checked for any duplicate nodes and elements.

6.2 Static Analysis:

In present analysis conventional bar and bracket were modelled in HYPERMESH with tetra elements. The element has six degrees of freedom at each node: translations in the nodal x, y, and z directions and rotations about the nodal x, y, and z-axes. For static analysis, the tow bar components are fixed at one end and the force is applied at the free end. The Stress and displacements distributions are shown in fig 3 & 4.

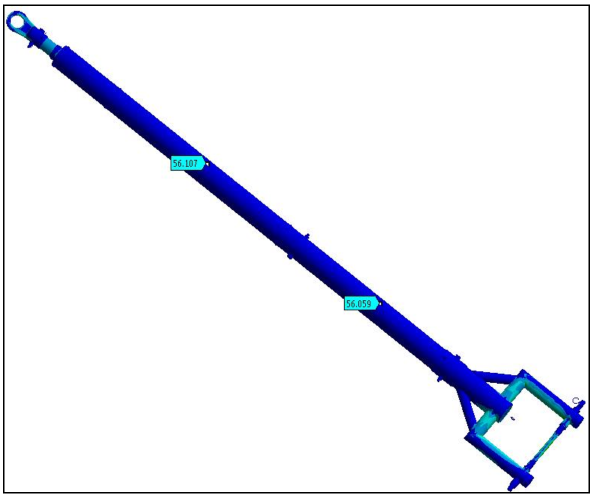

Fig 3: von-Mises Stress Plot

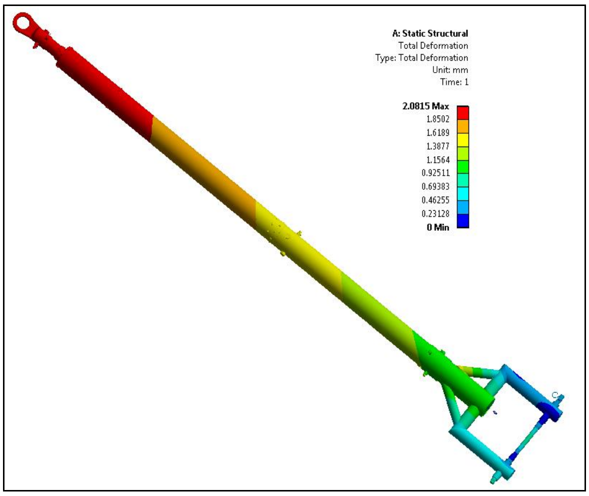

Fig 4: Deformation Plot

Description	Theoretical Calculation, (MPa)	FE Analysis, (MPa)	% Error
Stress in the column	56	56	0.0

From the fig 3 it is evident that the component experience tensile load in the main Limb at any given cross section along the column.

6.3 Buckling Analysis

There are two major categories leading to the sudden failure of a mechanical component: material failure and structural instability, which is often called buckling. The buckling load factor (BLF) is an indicator of the factor of safety against buckling or the ratio of the buckling loads to the currently applied loads.

For the ductile material used here the material factor of safety (FOS) is defined as the material yield stress divided by the von Mises ‘effective stress.

In science, buckling is a mathematical instability, leading to a failure mode. Theoretically, buckling is caused by a bifurcation in the solution to the equations of static equilibrium. At a certain stage under an increasing load, further load is able to be sustained in one of two states of equilibrium: an unreformed state or a laterally-deformed state.

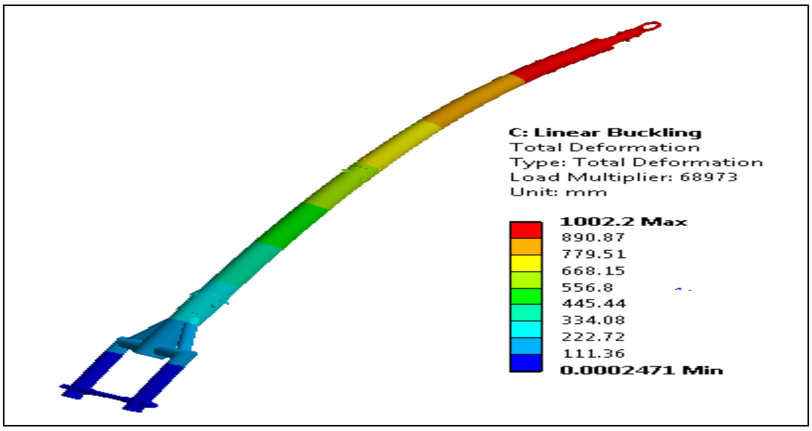

Fig 5: Buckling Mode

Buckling Load	= Applied Load x load multiplier = 1*68973 =68973 N Applied load = Unit Load

Sl No.	Buckling Mode
1	68973
2	78046
3	3.7814e+005
4	4.9894e+005

Table 2: Buckling Mode Calculation.

Where,

Buckling Load (Load Multiplier is obtained through FE analysis) from fig 5, it is evident that the buckling load is 68973N for 45000N. Buckling take place at the hook region. Maximum deformation is also found at that point.

6.4 Cost

Sl. No.	DESCRIPTION	Cost in Rs.
1	Total Material cost(A)	29921
2	Total man hour cost (B)	66068
3	Transportation cost (4%of A+B)	3840
4	Profit(10%of A+B)	9599
TOTAL ESTIMATED COST		**109427**

Table 3: Cost Distribution

7. CONCLUSION

The main objective was to design a tow-bar for 5.5 tons class light combat helicopter and to analyze it for stress concentration and deflection and buckling analysis during loading. Earlier version of tow-bar was studied for its application and other properties. The defects and incapability of the earlier tow-bar were found out by the snag report and measures were taken to overcome those defects while designing the new tow-bar. In this project static analysis, modal analysis & buckling analysis have been carried out for a tow bar. The maximum stress occurred at near to tow bar hook in static analysis due to the change in cross section. The maximum stress is below the yielding stress for the applied load. In this particular project of “Design and analysis of tow-bar for Light combat Helicopter” a completely new tow-bar was designed using HYPERMESH and analyzed in ANSYS for stress concentration and deformation upon loading. After analyzing the result obtained from ANSYS we conclude that the new design is geometrically sound, safe and economical for usage under given working conditions

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