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# Design and analysis of aircraft landing gear

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## ABSTRACT

***The landing gear is a vital structural unit of an aircraft that enables it to take off and land safely on the ground. A variety of landing gear arrangements are used depending on the type and size of an aircraft. Nowadays we can see that majority of failures of aircraft structure take place because of the malfunction of the landing gear system solely. This work is mainly focused on structural design and analysis of the main landing gear for an aircraft, that is economical and possesses a high strength to weight ratio but still simple in design. A typical landing load case will be assumed for which structural analysis will be carried out. During landing, there will be three different types of loads: 1. Vertical load (Compressive Load) 2. Drag load 3. Sideload Drag load and sideload values are terribly tiny in comparison to compressive load. So we will be focusing on the Vertical load. So we have taken the standard landing gear of an aircraft and it is designed by using Solid-works 2019 and analyzed for structural safety using ANSYS 19.2 software. The maximum possible load is given as design load. The landing gear assembly is analyzed for the traditional metallic materials like Aluminium Alloy-AlSI1030 Carbon Steel, Structural Steel IS2062 Fe440, and Titanium Alloy-Ti-8Al-1Mo-1V using ANSYS software and by comparing the results obtained by the mentioned material the best suitable material will be concluded that may be considered as best suitable and safer material.***

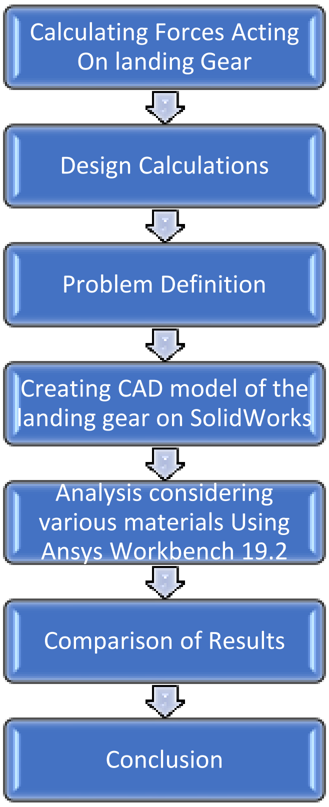
***Keywords**: Landing Gear, Total Deformation, Aircraft Landing Gear, Ansys 19.2, Stress Analysis, Deflection Analysis*

## 1. INTRODUCTION

Aircraft is machine that is able to fly from one place to another place. Many researches were made to fly the machine since from mythology, many had lost their life during their experiments, and many failed to fly their machine. But finally in 1910 Wright Brothers build machine which is able to fly for 59seconds, which is very short duration but it is first milestone for development of aviation. Further many researches were made to transport the goods and passengers. Then it is brought into business for transportation. And also used in military for air support, thus many fighter planes are developed. An aircraft is a machine that is able to fly by gaining support from the air, or, in general, the atmosphere of a planet. It counters the force of gravity by using either static lift or by using the dynamic lift of an airfoil, or in a few cases the downward thrust from jet engines. The human activity that surrounds aircraft is called aviation. Crewed aircraft are flown by an onboard pilot, but unmanned aerial vehicles may be remotely controlled or self-controlled by onboard computers. Aircraft may be classified by different criteria, such as lift type, propulsion, usage and others. The undercarriage or landing gear in aviation is the structure that supports an aircraft on the ground and allows it to taxi, takeoff and land. Typically wheels are used, but skids, skis, floats or a combination of these and other elements can be deployed, depending on the surface. The undercarriage of an aircraft supports the aircraft on the ground, provide smooth taxiing and absorb shocks of taxiing and landings. Landing gear is one of the primary structural components of the airframe. Landing gear enables the airplane to take off and land on ground. Its design considerations are significantly different. A variety of landing gear configurations and types are in use today. The landing gear withstands the ground impact load and absorbs the impact energy and diffuses the load to the surroundings attachment. Landing gear being the major load carrying subsystems of the aircraft has its substantial influence on the aircraft structural configuration itself. Hence there is a need to develop the landing gear with minimum weight, high performance and long life cycle. The major function of the landing gear is to provide support during landing and takeoff. A landing gear system comprises of many system and structural components. The structural components consist of trailing arm, Upper struts, main strut and wheel axle and side brace arms.

The material included within the current paper and project submissions included the design and analysis of the stresses in landing gear using different materials. And comparison of results obtained to decide best suitable material for the design and manufacturing of landing gear.

## 2. METHODOLOGY




## 3. DESIGN OF LANDING GEAR

**Conceptual Model**

Cad model of the landing gear is shown in fig.01.

**Fig. 01**

**Design Calculations**

Let's considering the standard passenger planes of 850-900 seating capacity the approximate specification of plane is obtained. The notations used in calculation are mentioned below

W=Maximum weight=607190 kg = 5956533.9kN

B=Wheel base =17.6m

L=Fuselage length=35m
μ = Coefficient of friction= 0.5
T=Trust of engine (2units) =82:3kN
$^{H}{}_{cg}$= Distance between aircraft c.g and ground = 6m
S = Total lifting planform area = 92m$^2$
$S_{wf}$ = Wing fuselage palnform area=72m$^2$
$S_H$ = Horizontal tail planform area= 20m$^2$
$V_L$ =Landing Velocity= 132 knots = 67.90m/s
$V_c$ = Cruise velocity = 438 knots = 225m/s
A.R = Aspect Ratio = 8.7
e = eccentricity = 0.92
$a_L$ = Acceleration level
B = Wheel base
Now let, Assume that nose wheel will carry 0.5 times of total aircraft static weight,

$$0.5W = \frac{B_M}{B} \times W$$

$$0.5 = \frac{B_M}{17.6}$$

$$B_M = 17.6 \times 0.5 = 8.8m$$

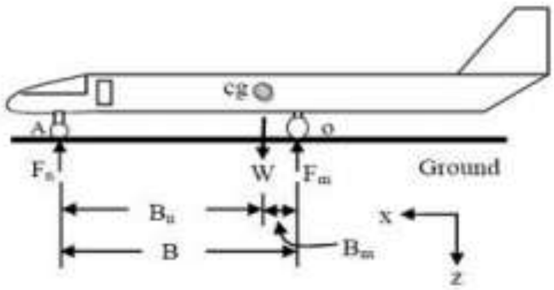



**Fig. 02**

Vertical force acting on nose landing gear is given by,

$$F_{VN} = F_{static} + F_{dynamic}$$

Since $F_{dy}$ (Dynamic force) much less than static force, Neglecting $F_{dynamic}$

$$F_{VN} = \frac{B_M \times W}{B}\ _{static}$$

$$F_{VN} = \frac{8.8 \times 607190}{17.6}$$

$$F_{VN} = 303592.34Kg = 2978240.87N$$

Considering factor of safety as 1.5times, i.e.

$$FOS = 1.5$$

Therefore, vertical force on landing gear is

$$P = F_{VN} \times 1.5$$

$$P = 455388.51\ Kg$$

$$P = 4467361.305\ N = 4467.361KN$$

Considering material ALSI 1030 Carbon Steel,

$$E = 205\ GPa$$

$$\sigma_{yt} = 395\ MPa$$

$$\sigma_{shear} = 197.5\ MPa$$

Design of Rod

$$\sigma = \frac{P}{A}$$

$$395 = \frac{4467361.305}{\frac{\pi}{4} \times d^2}$$

$$d^2 = 14400.0533$$

$$d = 120.0022 \approx 120 \text{ mm}$$

Design of Upper Strut
Internal diameter will be same as the dia of rod i.e. d =120mm

$$\sigma = \frac{P}{A}$$

$$395 = \frac{4467361.305}{\frac{\pi}{4}\times(D^2-d^2)} = \frac{4467361.305}{\frac{\pi}{4}\times(D^2-120^2)}$$

$$D^2 = 28800.05335$$

$$D = 169.70 \text{ mm}$$

$$D \approx 200 \text{ mm}$$

For Lower Strut
Dimension will be same as upper strut
D = 200 mm
d = 120 mm

**Analysis Using Ansys Workbench 19.2**

Static analysis is used to determine the displacements stresses, strains and forces in components due to loads that do not induce significant inertia and damping effects. Steady loading in response conditions are assumed and the kinds of loading that can be applied in static analysis include the externally applied forces and pressures, steady state inertial forces such as gravity or rotational velocity, imposed (non-zero) displacements, temperatures (for thermal strain). Structural and are made for analysing the stability of the structure for finding out the Stresses, Strain and Deflections.

**Material Properties**

**Table 1: Properties of materials used for analysis**

| Material | Density Kg/m$^3$ | Young's Modulus GPa | Poisson's Ratio | Tensile Yeild Strength MPa |
|---|---|---|---|---|
| Aluminium Alloy AlSI 1030 Carbon Steel | 2770 | 206 | 0.29 | 395 |
| Structural Steel IS 2062 (Fe 440) | 7850 | 210 | 0.3 | 250 |
| Titanium alloy Ti-8Al-1Mo-1V | 4620 | 127 | 0.32 | 930 |

**Modelling and Meshing**

The analysis of the landing gear is performed using Ansys workbench. The Solidworks model is imported to ansys work bench and the model is meshed. Meshing is the process that divides the model into finite number of elements for the analysis .In general, a large number of elements provide a better approximation of the solution. After meshing the model the boundary condition are specified as shown in fig. given below. After meshing the boundary condition are specified. The top of the landing gear is fixed and the other point at the center of the strut is fixed. After fixing, the compressive load is applied from the bottom of the landing gear. In our analysis we applied load only from the bottom end of the strut.For our analysis the tyre part is assumed as solid surface.The boundary and loading condition of the landing gear is shown in fig. given below.

**Lower Strut**

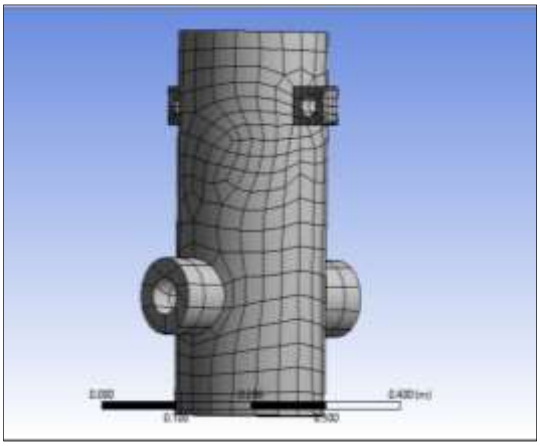


**Fig.03: Meshing**

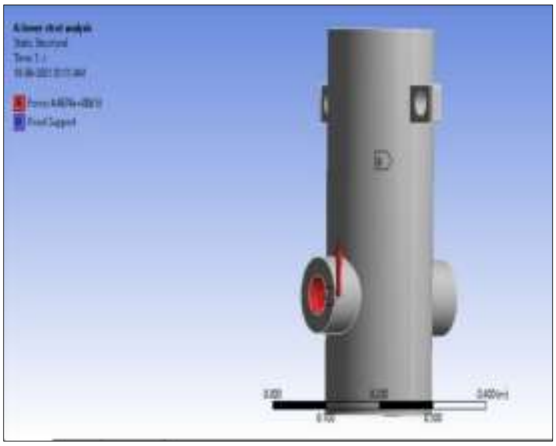


**Fig.04: Load and Fixed support**

**Upper Strut**

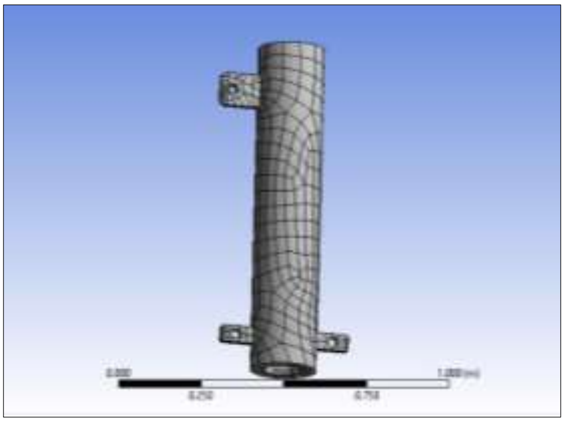


**Fig. 05: Meshing**

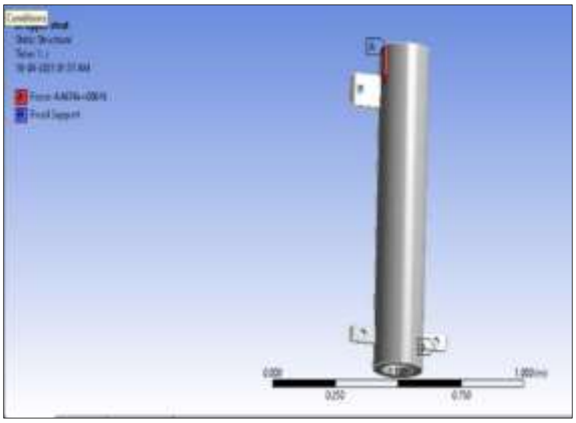
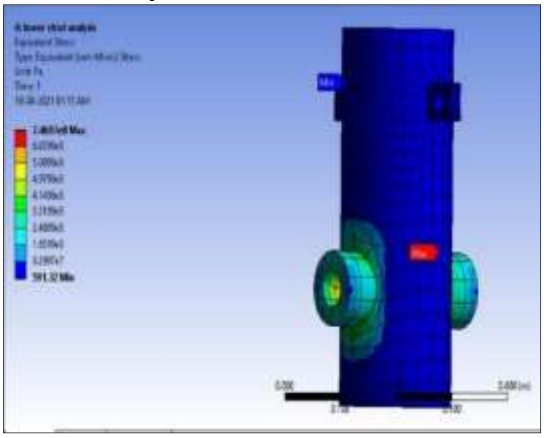


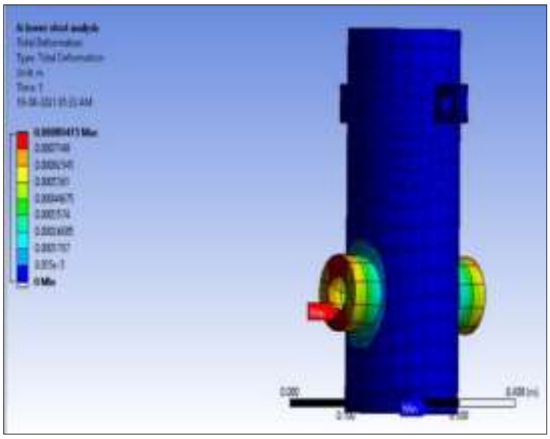
**Fig. 06: Load and Fixed Support**

**Stress, Strain and Total Deformation**

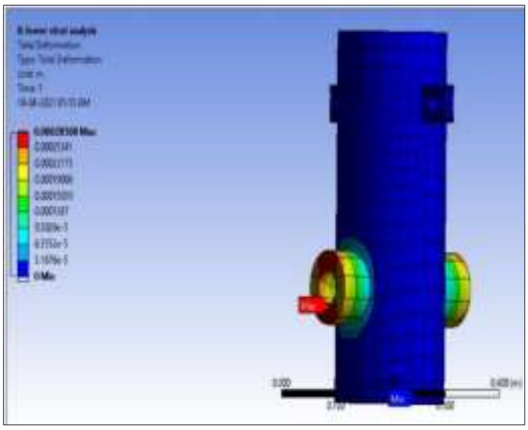
Solution for Lower Strut:

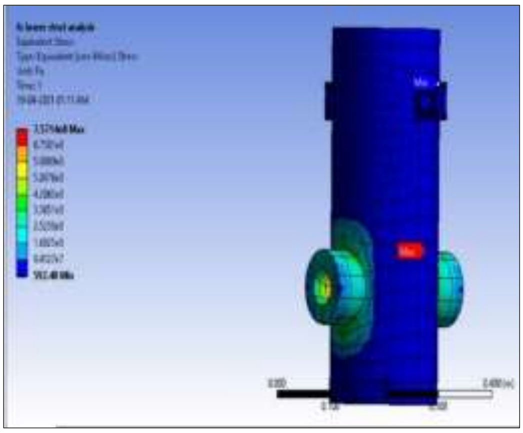
**Material: Aluminium Alloy AlSI1030 Carbon Steel**



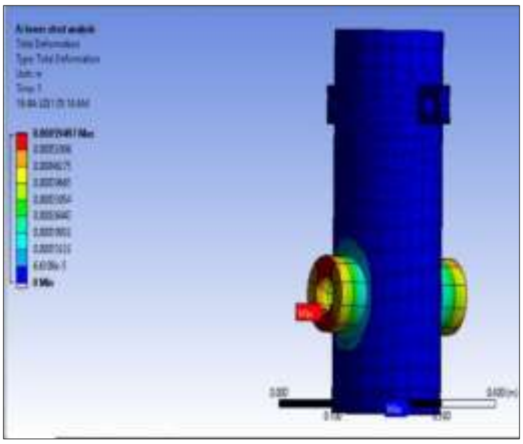


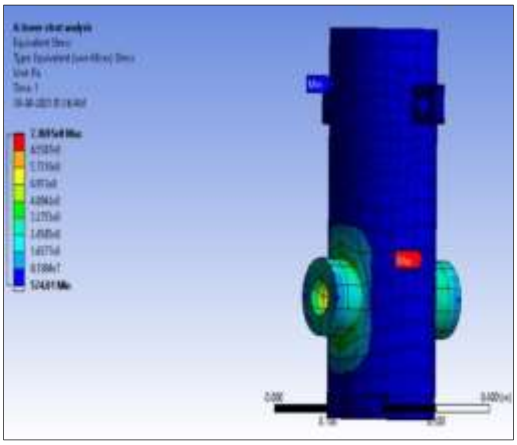
**Material : Structural Steel IS2062 Fe440**





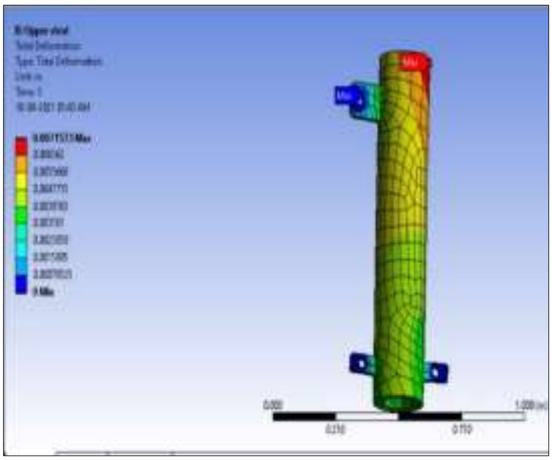
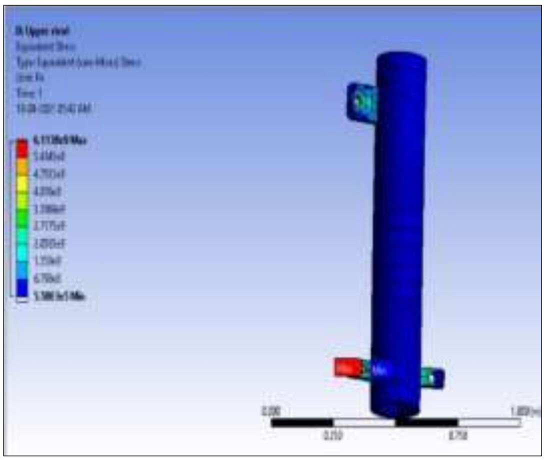
Material : Titanium Alloy Ti-8Al-1Mo-1V



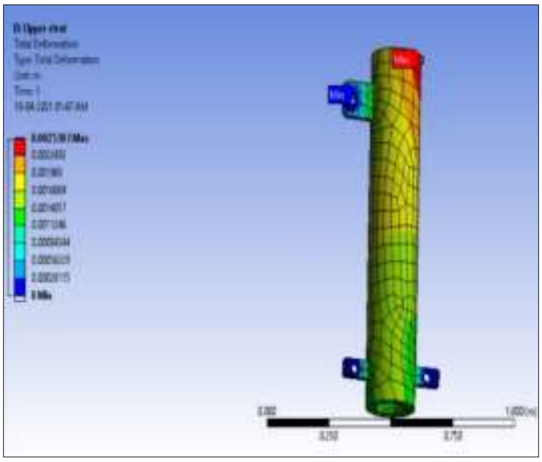
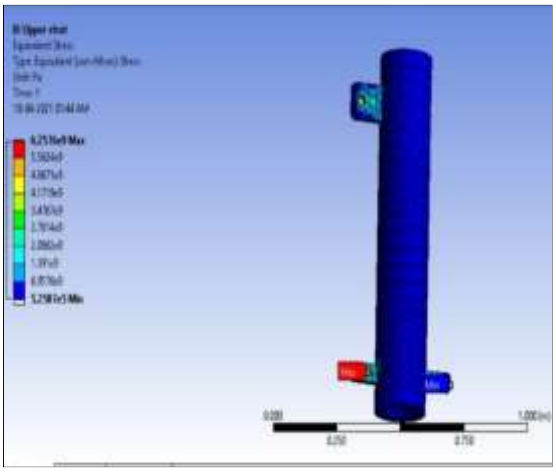


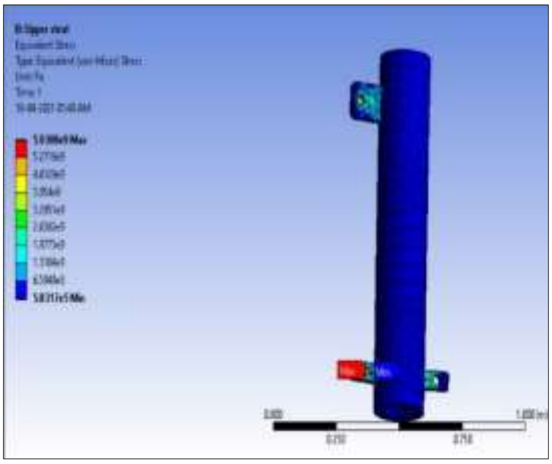
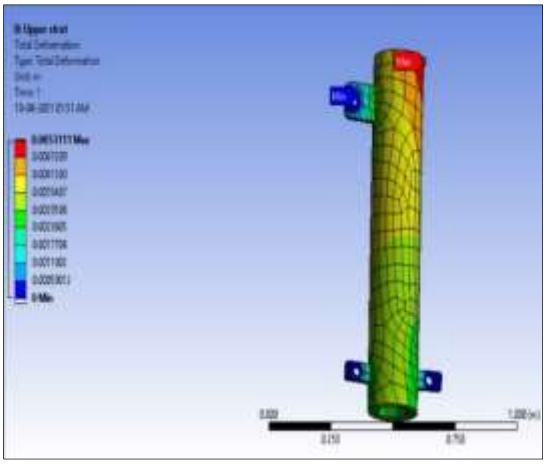
Solution for Upper Strut:
Material: Aluminium Alloy AlSI1030 Carbon Steel

Material : Structural Steel  IS2062 Fe440

Material : Titanium Alloy Ti-8Al-1Mo-1V

## 4. RESULTS

The solution phase deals with the solution of the problem according to the problem definitions. All the tedious work of formulating and assembling of matrices are done by the computer and finally deformations and stress values are given as output.

Calculated/ Theoretical Result:

**Table 2. Result Table**

| Material | Maximum Stress (MPa) | |
|---|---|---|
| | Lower Strut | Upper Strut |
| Aluminium Alloy AlSI 1030 Carbon Steel | 222.18 | 222.18 |

| | | |
|---|---|---|
| Structural Steel IS 2062 (Fe 440) | 222.18 | 222.18 |
| Titanium Alloy Ti-8Al-1Mo-1V | 222.18 | 222.18 |

Ansys Results :

**Table 3. Ansys Results**

| Material | Maximum Stress (MPa) | | Max Deformation(mm) | |
|---|---|---|---|---|
| | Lower Strut | Upper Strut | Lower Strut | Upper Strut |
| Aluminium Alloy AlSI 1030 Carbon Steel | 746.97 | 6113.8 | 0.80415 | 7.1573 |
| Structural Steel IS 2062 (Fe 440) | 757.14 | 6257.6 | 0.28508 | 2.5303 |
| Titanium Alloy Ti-8Al-1Mo-1V | 736.95 | 5930.8 | 0.59497 | 5.3111 |

As calculated value of Stress and Total Deformation is less than the Ansys Values, Design is safe for all materials.

## 5. CONCLUSION

Stress analysis plays important role to find structural safety and integrity of assemblies. The previous estimation of stress helps to find appropriate material and geometrical dimensions. The table 3 shows that the titanium alloy has less stress when compared to aluminium and structural steel. The titanium alloy has more safety factor, this indicates that the titanium landing gear can withstand more load also. This analysis shows that titanium alloy is best suitable for landing gear construction.

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