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Optimization of Piston with the Help of FEM

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ABSTRACT

In this project, we have studied briefly about the material properties of the aluminum alloy, A360, AL GHY 1250, AL 2618, and Silumin from the different research papers done by the previous scientist. After this we have designed the Piston of Maruti Suzuki Wagon r in CATIA V5 R20 and done the analysis in the ANSYS 15.0.On the behalf of analysis, we observed that the mass of piston made of A2618 is less as compare to the previous aluminum alloy stress generated in the piston is same in the new material (A2618) as compare to the aluminium alloy. The strain generated in the piston is reduced in the new material (A2618) as compare to the previous aluminium alloy. The factor of safety of A2618 is double as the previous material (aluminium alloy) as compare to the aluminium alloy. In this way, we studied that the material A2618 is the better alternative of previous aluminium alloy for the piston.

Keywords: Finite Element Method, Reverse Engineering

I INTRODUCTION

A piston is a component of reciprocating engines, reciprocating pumps, gas compressors and pneumatic cylinders, among other similar mechanisms. It is the moving component that is contained by a cylinder and is made gas-tight by piston rings. In an engine, its purpose is to transfer force from expanding gas in the cylinder to the crankshaft via piston rod and or connecting rod. In a pump, the function is reversed and force is transferred from the crankshaft to the piston for the purpose of compressing or ejecting the fluid in the cylinder. In some engines, the piston also acts as a valve by covering and uncovering ports in the cylinder wall. The piston is a component of the vehicle in the combustion chamber that is able to pump or generate pressure so as to move the other components and become an engine work. In the combustion chamber, there is a high temperature due to the explosion of the fuel mixture.

Piston is an important component in the engine in which the design of the piston willbringa direct effect on engine performance. At high temperatures and pressures caused by the fuel, a little stress and cracks on the piston head. The piston is the heart of the automotive engine. It works at high temperatures. In a study, it was mentioned that piston temperatures could reach 2500 K, and in the upper part of piston it could reach 600-700K. An investigation showed that the highest pressure occurred on the top section.

The materials of piston must be qualified. It has become essential as the materials might act as the base for making piston.The materials that have been used is the namely aluminum alloy. Lightweight materials have high specific strength, high hardness and wear resistance, low friction coefficient and thermal expansion, high thermal conductivity, high heat-absorbing ability and good ability in abatement.

II OBJECTIVE

i. Study briefly about the functions and applications of piston.
ii. To choose the new piston material maybe it will be A2618, ALGHY1250, A360 or Silumin.
iii. To design the piston with the help of CATIA V5 and further to analysis of the predesigned piston with the help of ANSYS.
iv. To obtain light weight, high strength, high corrosion resistance, high factor of safety.

III METHODOLOGY

Methodology involves four steps which are given below.

Step 1. In this step, we have studied briefly about the material properties of the A360, ALGHY1250, A2618 and silumin.We have chosen the material which properties will near about our objectives.

Step 2. In this step, we have done the reverse engineering of the piston of **Maruti Suzuki Wagon r** and collect all dimensions which are required to design piston.

Step 3. In this step, we have designed the piston with the help of CATIA V5.

Step 4. In this step, we have done analysis on A360, A2618, ALGHY1250 and silumin (aluminium and silicon alloy). Ansys will be used for the analysis of the piston.

IV DESIGN AND CALCULATION

4.1 Design of the Piston Head

The thickness of the piston head (T_H), according to Grashoff‟s formula is given by

$T_H = 3pD^2/ 16. \sigma t$ (in mm) ....(1)

where, p = Maximum gas pressure or explosion pressure in N/mm2

D = cylinder bore or outside diameter of the piston in mm,

σt = Permissible bending (Tensile) stress for the material ofthe piston in MPa or N/mm^2.

Treating the piston head as a flat circular plate, its thickness is given by

$T_H = H /12.56k (Tc - Te)$ (In mm) ....(2)

where,H = Heat flowing through the piston head in KJ/s or watts.

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k = Heat conductivity factor in W/m/^{0}C. Its value is 46.6W/m/^{0}C for grey cast iron, 51.25W/m/^{0}C for steel and 174.75 W/m/^{0}C for aluminum alloys.

Tc = Temperature at the center of the piston in ^{0}C, and

Te = Temperature at the edges of the piston head in ^{0}C.

The temperature difference (Tc-Te) may be taken as 220℃ for cast iron and 75℃ for aluminum.

The heat flowing through the position head (H) may be determined by following expression, i.e.

H = C x HCV x m x B.P. (in kW) …… (3)

Where,C = constant representing that portion of the heat supplied to the engine which is absorbed by the piston its value is usually taken as 0.005

HCV = Higher calorific value of the fuel in KJ/kg. It may be taken as 45x103 KJ/kg for diesel and 45x103 KJ/kg for petrol.

m = Mass of the fuel used in kg per brake power per second,

B.P.= Brake Power of the engine per cylinder.

4.2 Diameter of Piston Rod

It is given by the formula which is described below

d= D$\sqrt{p/\sigma d}$…………………..…….…. (4)

where, P= unbalance pressure or difference between steam inlet and exhaust pressure

σd = allowable stress in the piston rod

4.3 Inertia Force of Reciprocating Parts on The Piston

It is given by the formula which is described below

F = 0.00040rn^{2}W$_r$ (cosθ ± cos2θ)………. (5)

Where,

r = crank radius

w = weight of reciprocating parts

l = length of connecting rod

n = l/r

Q = crank angle from dead center

(+) sign = inner dead center

(-) sign = outer dead center

4.4 Thickness of Piston Head

It is given by the formula

$T_1 = 0.43D\sqrt{p/\sigma d}$………….. (6)

Where,

P= fluid pressure

D= Diameter of piston

σd = Allowable stress (tensile)

3838MN/m^2 for Aluminum Alloy, ultimate tensile strengthis(137MN/m^2)

55MN/m^2 for special Aluminum alloy or semi steel (σ_{ut}=206MN/m^2)

4.5 Thickness of Piston Head

It is given by the formula

T_1 = 0.032D+1.5mm………. (7)

4.6 Thickness of Crown from the Consideration of Heat Flow

It is given by the formula

T_1= D^2q/1600K(T_c-T_e) …………………… (8)

Where,

q = heat flow from the gases

32000 to 128000 for cast iron piston

64000 to 256000 for aluminium piston

k = Heat Conductivity,

460 for cast iron

1600 for aluminum

T_c = Temperature at the Centre, (^{o}c)

444^{o}c for cast iron

275^{o}c for aluminum

T_e = Temperature at the edge

(T_c-T_e) = 222^{o}c for cast iron

(T_c-T_e) = 111^{o}c for Aluminum

4.7 Maximum Thickness of Thickness Barrel

It is given by the formula which is described below

T_3 = 0.03D + b + 4.5mm ……………… (9)

Where,D= diameter

b = t_r+ 0.4mm

t_r = Radial width

b= depth of ring grooves

4.8 Length of Piston

It is given by the formula which is described below

L= D to 1.5D …………………………. (10)

Length of Stroke

It is given by the formula which is described below

L_S = 1.3D to 1.4D ……………………..…. (11)

4.9 Calculation of Pressure for Ansys

Mean effective pressure

(Mep) = 60000 * Power/ V_d*n*K……….. (12)

Where,V_d = Engine Displacement

n = N/2 for four stroke engines

K = No. of Cylinder

So, calculation is done by given formula and results are found.

mep = $60000*50/249.5*10^6*3100*4$

mep = $0.969688* 10^6$ N/m^2

mep = 0.97MPa

V DESIGN DIMENSIONS AND REVERSE ENGINEERING

We have done the reverse engineering of the piston of Maruti Suzuki Wagon R (Lxi 1.0) and found the result given below

.

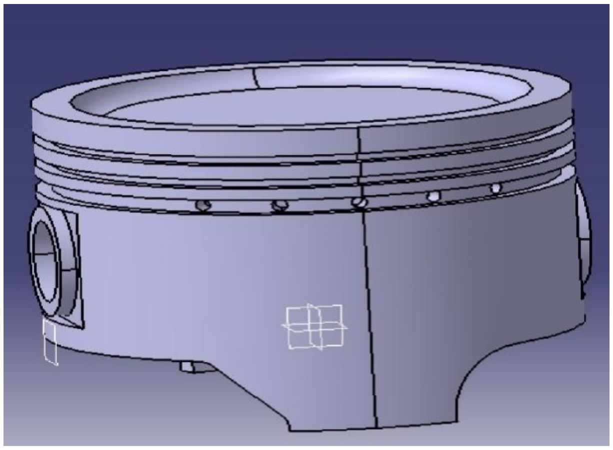

Table 1 Design Dimension

Parameter	Unit	Result
Día	mm	62.5
GL	mm	57.2
KH	mm	27.5
jPinDía	mm	16.0
Length	mm	50.0
Ring Thickness	mm	1.48
Ring Día	mm	64.3

Figure 1 Top View of Pisto

And further we have designed the piston in CATIA represent the view of piston designed by us.

VI ANALYSIS OF PISTON

6.1 Meshing of Piston

Meshing of piston is done through ANSYS software. The number of nodes generated in the piston (in the shape of tetrahedron) is 603605 and the number of elements is 385020.

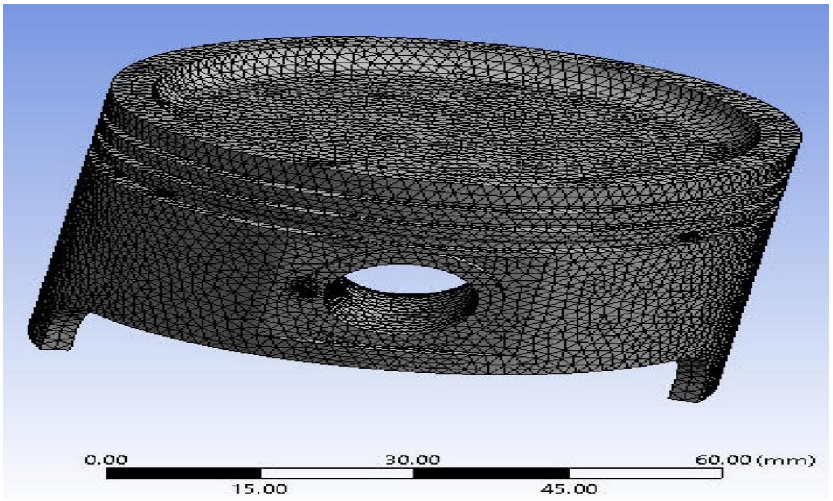

Figure 2 Meshing of Piston

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6.2 Pressure application on Piston Head

In fig. 3 we fix the hole and a uniform pressure of 0.97Mpa is applied on the head of the piston, after that we do the analysis of this piston using different materials.

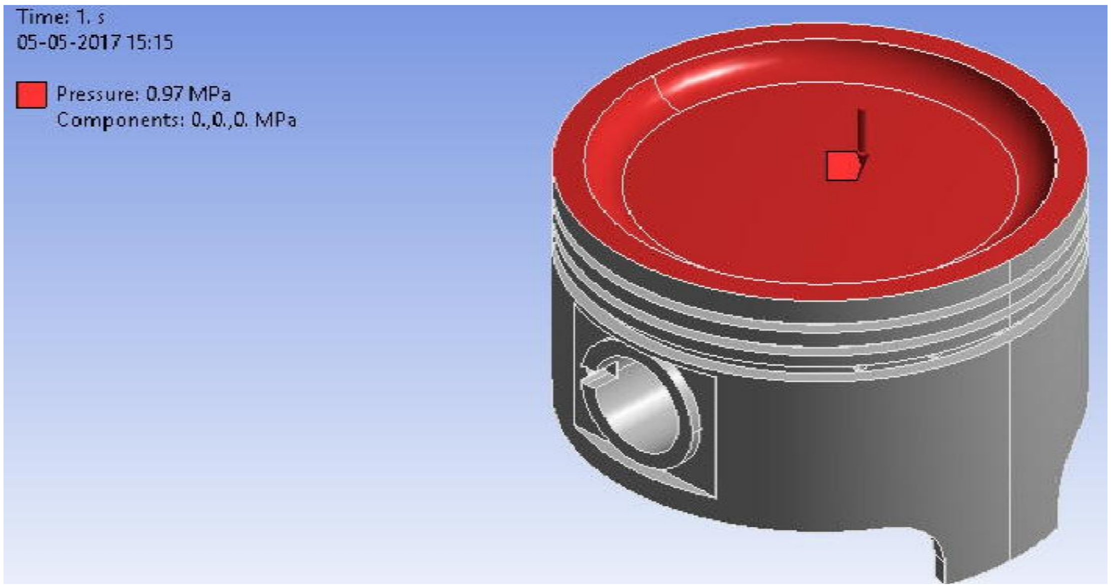


Figure 3 Pressure Application

VII. RESULT AND DISCUSSION

7.1 Ansys Report of Al Alloy

This is the view of the stress in the Al alloy in which the maximum Von Mises Stress occur at 72.302 MPa and minimum stress occur at 0.00013441 MPa.

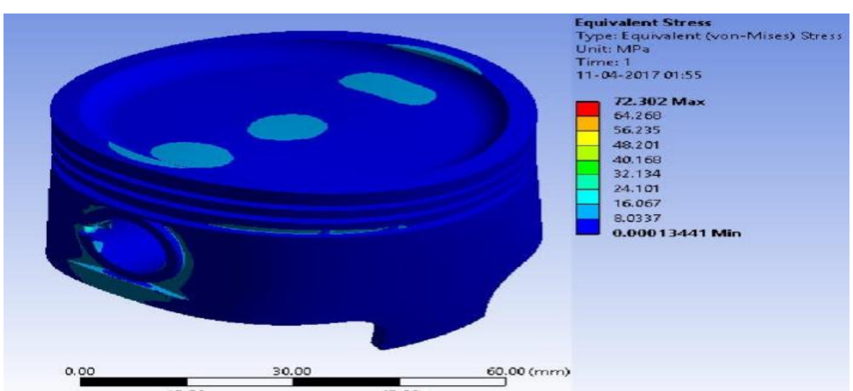


Figure 4 Stress in Piston of Al Alloy

This is the view of strain in Al alloy in which the maximum Elastic Strain occur at 0.0011879mm/mm and minimum Elastic Strain occur at 2.5774e-9mm/mm.

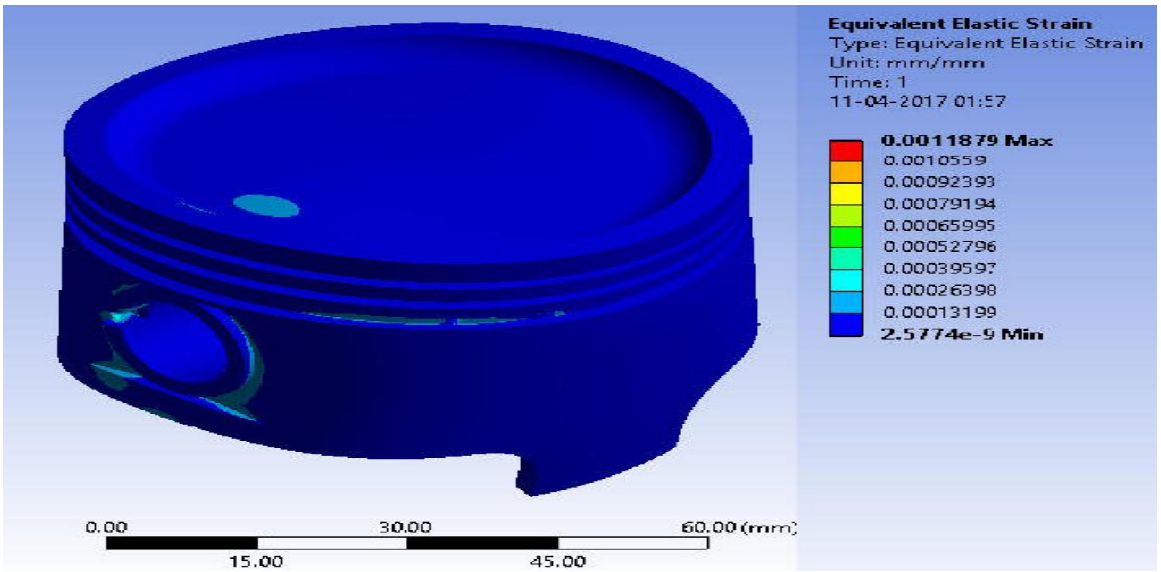
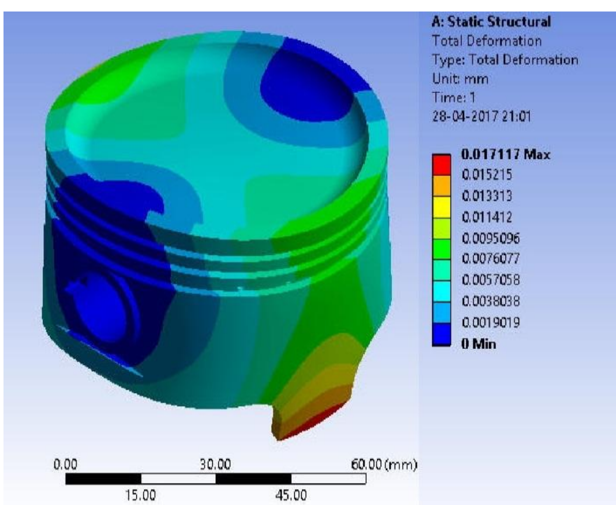


Figure 5Strain in Piston of Al Alloy

This is the view of deformation of Al alloy in which the maximum total deformation occurs at 0.017117mm and minimum deformation occur at 0.



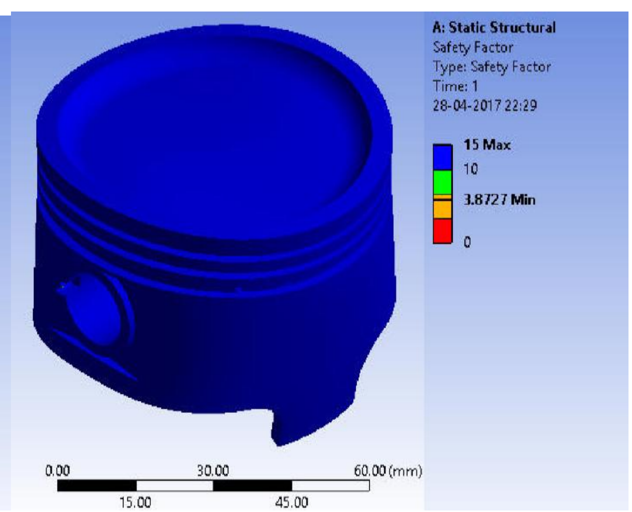


Figure 6 Deformation in Piston of Al Alloy   Figure 7 Factor of Safety in Piston of Al Alloy

This is the view of factor of safety of al alloy in which maximum value occur at 15 and minimum value occur at 3.

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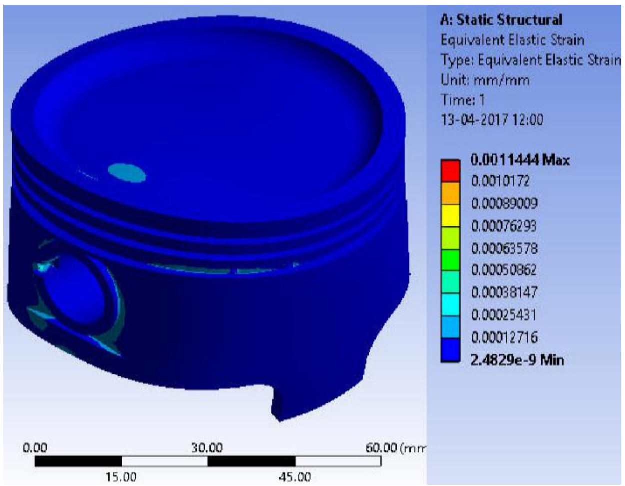
7.2 Ansys Report of A2618

This is the view of stress in in the piston made up of A2618 in which the maximum Von Mises Stress occur at 72.302 MPa and minimum stress occur at 0.00013441 MPa.



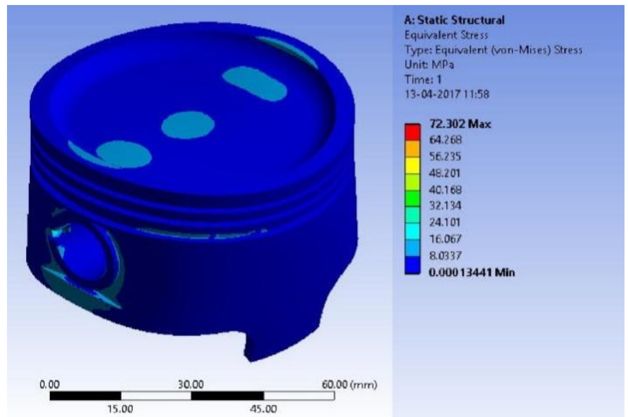
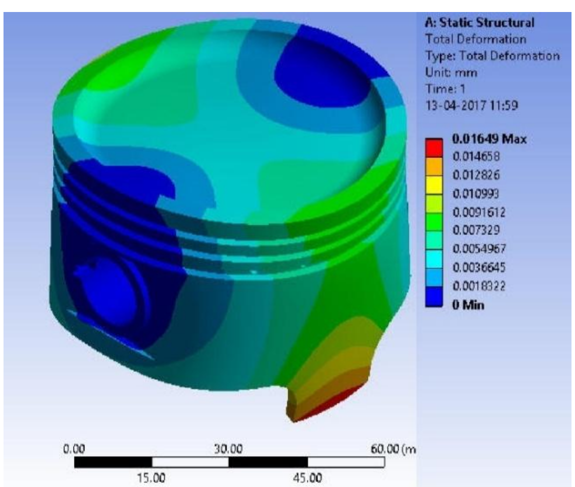


Figure 8 Stress in Piston of AL2618 **Figure 9 Strain in Piston of AL2618**

This is the view of strain in the piston of A2618 in which the maximum Elastic Strain occur at 0.0011444mm/mm and minimum Elastic Strain occur at 2.4829e-9mm/mm.

This is the view of deformation of the piston of A2618 in which the maximum total deformation occurs at 0.01649mm and minimum deformation occur at 0.



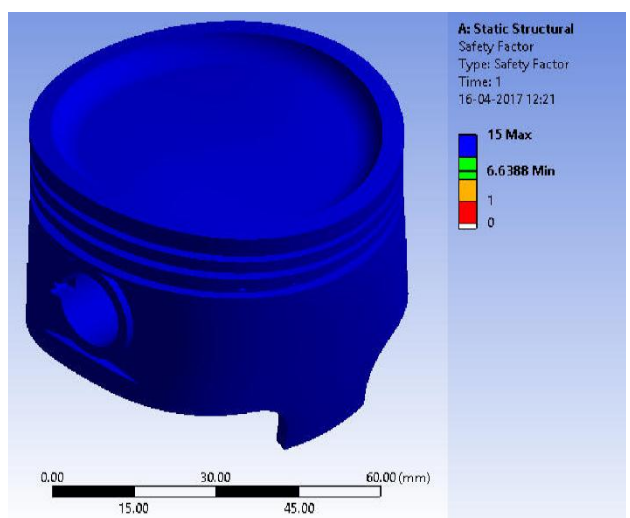


Figure 10 Deformation in Piston of AL2618 **Figure 11 Factor of Safety inPiston of AL2618**

This is the view for factor of safety of a2618's piston alloy in which maximum value occur at 15 and minimum value occur at 6.

MaterialProperties	AL ALLOY	A2618
Stress(max)MPa	72.302	72.302
Strain(max)MPa	0.0018579	0.0011444
Deformation(mm)	0.017117	0.01649
Density	2770	2668
Volum(mm^3)	56490	56490
Mass(Kg)	0.15648	0.15071
F.O. S	3	6

VII CONCLUSION

- The work presented here is a design analysis and optimization of piston from above discussion it can concluded that;
- On the behalf of analysis, we observed that the mass of piston made of A2618 is less as compare to the previous aluminium alloy.
- The stress generated in the piston is same in the new material (A2618) as compare to the aluminium alloy.
- The strain generated in the piston is reduced in the new material (A2618) as compare to the previous aluminium alloy.
- The factor of safety of A2618 is double as the previous material (aluminium alloy) as compare to the aluminium alloy.
- In this way, we studied that the material A2618 is the better alternative of previous aluminium alloy for the piston**.**

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