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Comparative Study and Stress Analysis on Brake Pedal using Ductile Cast Iron 350/140 and Al359-T0 Material

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***Abstract*: In a automotive vehicle, brake pedal acts a powerful component to decelerate and stop. When a person will apply a load on the pedal, stresses will be developed at the hinged point. In order to improve the strength of the brake pedal, analysis will be carried out by design optimizing and comparing strength with two different materials, such as ductile cast iron 350/140 and aluminium A 359-T0. The main objective of replacement is to reduce the weight and increase its corrosion resistance. The brake pedal will be designed by using solid edge v20 and analysis will be done by using ANSYS software.**
***Keyword*: Brake pedal, Stress, Cast iron, Al359-T0, ANSYS.**

I. INTRODUCTION

Brake pedal is the important component of automotive vehicle, which decelerate and stop the vehicle. In this, competitive world every moment there is change in design and high speed vehicles are developed. The design optimization and analysis of the component is carried out to make it comfortable, increasing strength, corrosion resistance and reducing weight of the component etc. all of this properties shows that safety of the components. The replacement of steel material with light weight polymer composite, plastic aluminium alloy materials of brake pedal, to improve corrosion resistance and strength, reduction of weight and cost of the component, analysis has been conducted by using different sections like square, I, T, U and circular section element finally discussed I-section is shows higher strength compared to other sections[1]-[7]. Fatigue analysis of the SUVs car, brake pedal has been carried out to find the life of the component for the comfort of the driver [2]. Automotive brake pedal topology optimized and static stress analysis has been carried to get better performance of the car, he has mainly focus on reduction of weight without changing material substituent [3]-[4]-[8]. Concurrent engineering technique in the total design activity of mounting and pedal, analysis has been done by using morphological chart to control motion of the different pedals which hinged to mounting bracket [5]. Brake pedal not only responsible to decelerate the vehicle that is disc brake wheel and set of callipers also helps to stop the vehicle, the design optimization analysis has been carried out reduce friction and wear of the component [6]. SAE Baja Brakes and Throttle System analysis has been carried out for off road race care brake controlling system [9]. Ductile cast iron and aluminium matrix with varying silicon reinforcement comparative study has been carried and patent registered in the year 1998 [10].

II. PROBLEM DEFINITION AND SCOPE OF PRESENT WORK

A. Objective

1) Scope of the present work, brake pedal is subjected to static loads will be predict displacement and stress developed.
2) Topology optimization of brake pedal and redesign.
3) To predict the safety of the brake pedal, using ductile cast iron 350/140 and aluminium A359-T0.

B. Methodology

1) Problem defined by using literature.
2) Ductile cast iron 350/140 and Aluminium A359-T0 materials are selected using literature [10], as per the ASTM standards.
3) Dimension will be collected from text book page number 272 [11].
4) Modelling and design optimizing of component by using Solid Edge v20 software.
5) Meshing and Applying boundary conditions.
6) Static stress analysis of component will be carried out by using ANSYS software, have three cases as follows,
7) Case-1: Normal brake pedal [11].
8) Case-2: Topology optimization of pedal design.

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9) Case-3: Topology optimized with intermediate ribs.
10) Finally comparing the results of both the materials with all three cases.

C. Assumptions

1) Behaviour of material is elastic in nature, homogenous and isotropic.
2) Maximum load is taken from literature 500N
3) Temperature of material is constant before and after loading.

D. Materials Properties

TABLE I
MATERIAL PROPERTIES

Properties	Ductile cast iron	Aluminium A359-T0
Density (kg/mm3)	7.611974e-6	2.98943e-6
Ultimate strength (MPa.)	227.526	386.108
Elastic modulus (MPa.)	1.689212e+14	1.861581e+14

E. Geometrical model of brake pedal

Case-1: Normal Brake Pedal [11]

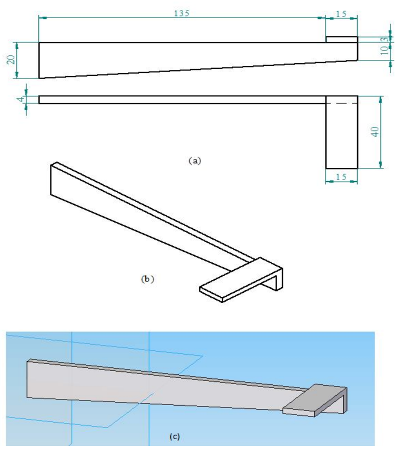


Fig.1. (a) 2D brake pedal, (b) and (c) 3D brake pedal CAD model

Case-2: Topology Optimization of Pedal Design

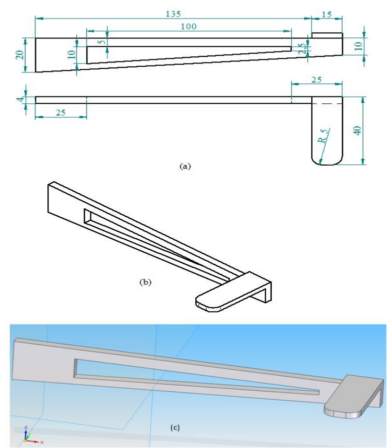


Fig. 2. (a) Optimized 2D brake pedal, (b) and (c) Optimized 3D brake pedal CAD model

Case-3: Topology Optimized with Intermediate Ribs.

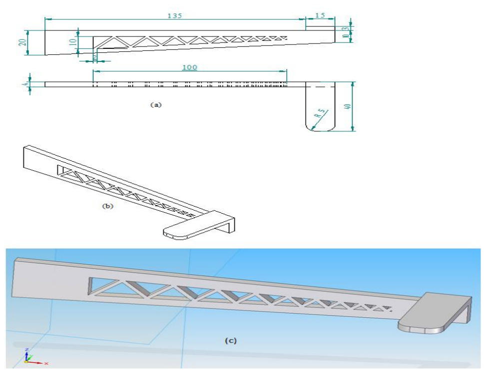


Fig.3. (a) Optimized 2D brake pedal with ribs, (b) and (c) Optimized 3D brake pedal with ribs CAD model

F. Mesh plot and boundary condition

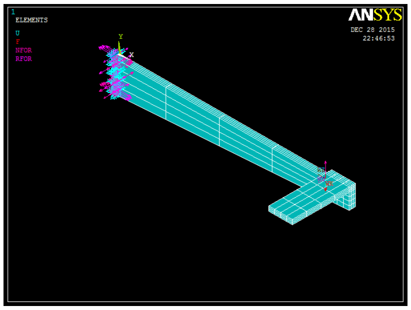


Fig.4. Mesh plot with boundary condition for normal brake pedal

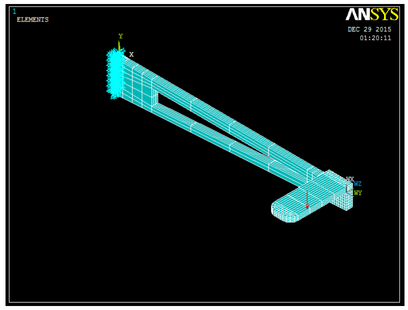


Fig.5. Mesh plot with boundary condition for optimized brake pedal

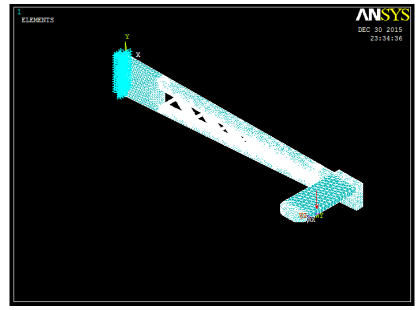


Fig.6. Mesh plot with boundary condition for optimized brake pedal with ribs

Fig.4. shows, mesh model for normal brake pedal 4 nodes hexahedral mapped meshed model each element have equally divided by 4 number of elements, one end is fixed in all direction where the displacement is zero and other end is forced at 500N.
Case-2: Topology optimization of pedal design
Fig.5. shows, mesh model for optimized brake pedal 4 nodes hexahedral mapped meshed model each element have equally divided by 4 number of elements, one end is fixed in all direction where the displacement is zero and other end is forced at 500N.
Case-3: Topology optimized with intermediate ribs.
Fig.6. shows, mesh model for optimized brake pedal with ribs, 4 nodes hex and tri mapped meshed model, one end is fixed in all direction where the displacement is zero and other end is forced at 500N.

G. Formula used

$$Factor\ of\ safety\ (\eta) = \frac{Ultimate\ strength}{Actual\ strength} \qquad (2.1)$$ [DDHB]

III. RESULTS AND DISCUSSION

A. Result

B. Case-1: Normal brake pedal [11]

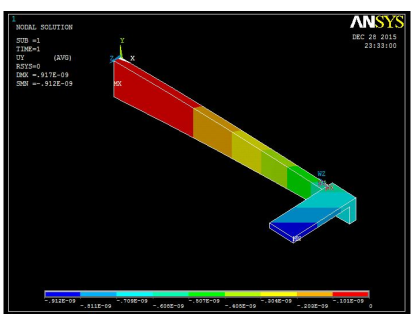


Fig.7. Maximum displacement for case-1(a)

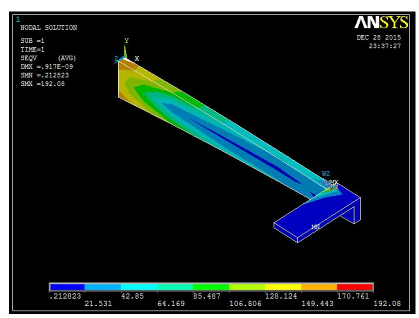


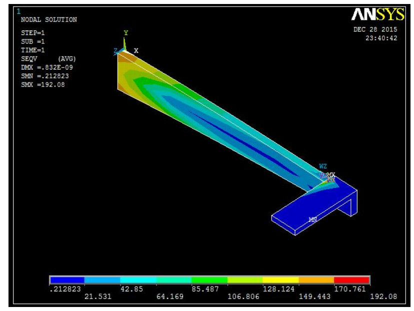
Fig.8. Maximum stress for case-1(a)

Fig.7. shows, the maximum displacement 0.917 x 10^{-9} mm for normal brake pedal of ductile cast iron 350/140. Fig.8. shows, the maximum stress 192.08 MPa, for normal brake pedal of ductile cast iron 350/140.

$$\eta_{case-1(a)} = \frac{227}{192.08} = 1.181 \qquad --- (3.1)$$

A359-T0 Aluminium with normal design of brake pedal

Fig.9. Maximum displacement for case-1



(b) Fig.10. Maximum stress for case-1(b)

Fig.9. shows, the maximum displacement 0.832 x 10^{-9} mm for normal brake pedal of aluminum A359-T0. Fig.10. shows, the maximum stress 192.08 MPa, for normal brake pedal of ductile cast iron 350/140 .

$$\eta_{case-1(b)} = \frac{386.108}{192.08} = 2.010 \quad -- \quad 3.2$$

Case-2: Topology optimization of pedal design

Case-2 (a): Ductile cast iron with optimized design of brake pedal

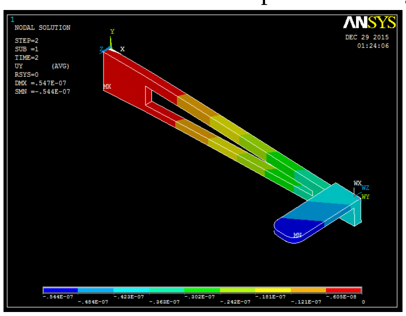


Fig.11. Maximum displacement for case-2(a)

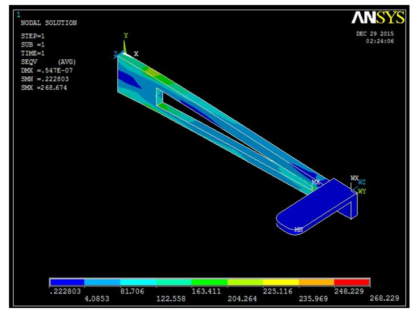


Fig.12. Maximum stress for case-2(a)

Fig.11. shows, the maximum displacement 0.547 x 10^{-7} mm for optimized brake pedal of ductile cast iron 350/140. Fig.12. shows, the maximum stress 268.229 MPa, for optimized brake pedal of ductile cast iron 350/140.

$$\eta_{case-2(a)} = \frac{227}{268.229} = 0.8446 \qquad ---3.3$$

Case-2 (b): A359-T0 Aluminium with optimized design of brake pedal

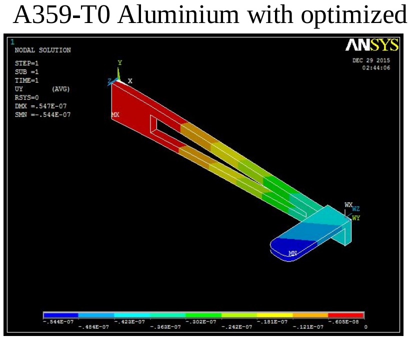


Fig.13. Maximum displacement for case-2 (b)

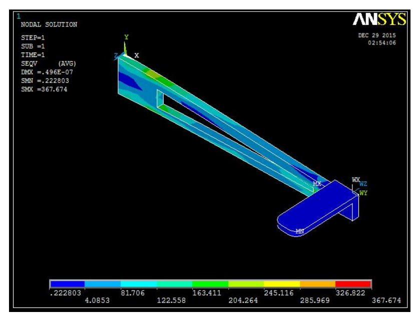


Fig.14. Maximum stress for case-2(b)

Fig.13. shows, the maximum displacement 0.547 x 10^{-7} mm for optimized brake pedal of aluminum A359-T0. Fig.14. shows, the maximum stress 367.674 MPa, for optimized brake pedal of ductile cast iron 350/140.

$$\eta_{case-2(b)} = \frac{386.108}{367.674} = 1.050 \quad --- 3.4$$

Case-3: Topology optimized with intermediate ribs

Case-3 (a): Ductile cast iron with optimized design of brake pedal with rib

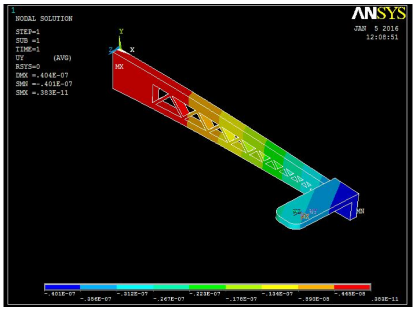


Fig.15. Maximum displacement for case-3(a)

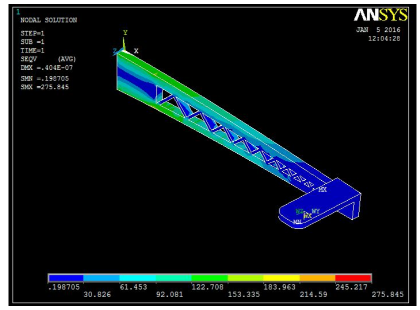


Figure (16): Maximum stress for case-3(a)

Fig.15. shows, the maximum displacement 0.404×10^{-7} mm for optimized brake pedal with ribs of ductile cast iron 350/140. Figure (16) shows, the maximum stress 275.845 MPa, for optimized brake pedal with ribs of ductile cast iron 350/140.

$$\eta_{case-3(a)} = \frac{227}{275.845} = 0.82292 \qquad ---3.5$$

Case-1 (b): A359-T0 Aluminium with with optimized design of brake pedal with rib

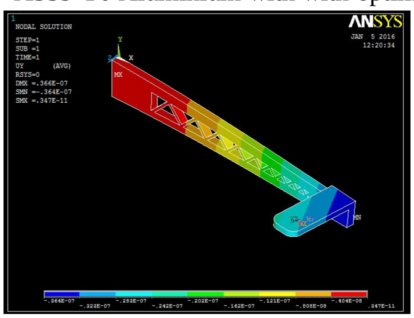


Figure (17): Maximum displacement for case-3(b)

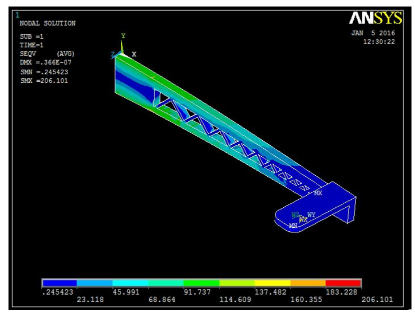


Figure (18): Maximum stress for case-3(b)

Figure (17) shows, the maximum displacement 0.366×10^{-7} mm for optimized brake pedal with ribs of aluminum A359-T0. Figure (18) shows, the maximum stress 206.101 MPa, for optimized brake pedal with ribs of ductile cast iron 350/140 .

$$\eta_{case-3(b)} = \frac{386.108}{206.101} = 1.8733 \qquad ---3.6$$

C. Discussion

TABLE II

COMPARATIVE STUDY BASED ON MATERIAL AND DESIGN OPTIMIZATION

Case	Material	Displacement (mm)	Maximum Stress (MPa)	Factor of safety (η)
1	Ductile cast iron 350/140	0.917 x 10^{-9}	192.08	1.18
	Aluminium 359-T0	0.832 x 10^{-9}	192.08	2.01
2	Ductile cast iron 350/140	0.547 x 10^{-7}	268.22	0.84
	Aluminium 359-T0	0.547 x 10^{-7}	367.67	1.05
3	Ductile cast iron 350/140	0.404x 10^{-7}	275.84	0.82
	Aluminium 359-T0	0.366 x 10^{-7}	206.101	1.8733

Brake pedal analysis is carried out Table II shows the resultant values of each case, in all three cases aluminum material shows more stiffer than ductile cast iron. These shows most effective and corrosion resistance is aluminum material, in the case-2 and case-3 aluminum shows factor of safety two times more than the iron material. Finally the comparative study will give the conclusion that aluminum 356-T0 material is preferable material for the brake pedal.

IV. CONCLUSION

Brake pedal is component of automotive vehicle, which decelerate and stop the vehicle. The design optimization and analysis of the component is carried out to make it comfortable, increasing strength. Replaced ductile cast iron with aluminium material to improve corrosion resistance and reducing weight of the component. Analysis has been carried by design optimizing and comparing strength with two different materials, such as ductile cast iron 350/140 and aluminum A 359-T0. Aluminum A 359-T0 shows higher strength, light weight, good corrosion resistance and show two times higher factor of safety than the ductile cast iron. finally conclude that, the aluminum material most suitable and preferable material for brake pedal.

V. ACKNOWLEDGMENT

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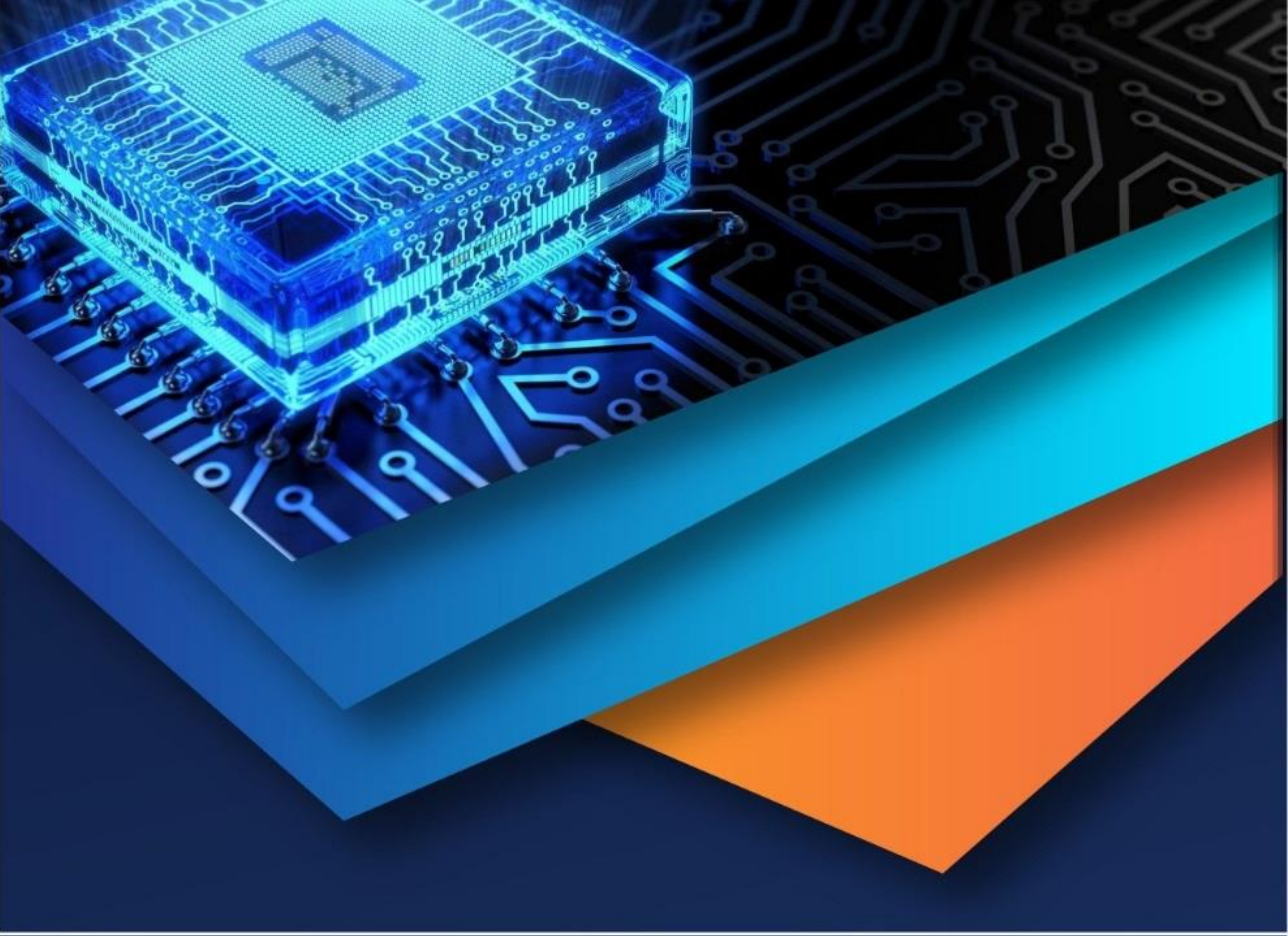

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