Development and Manufacturing of Variable Stiffness Suspension System for Automotive Application

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Abstract
Active and Semi active suspension are able to attenuate the road induced vibrations over wide range of frequencies. However cost associated with these is very high. Conventional fluid damping suspension is used over past many years, and it is well proven and dependable. With optimization performed this kind of suspension gives better results in the desired frequency range. In case of shock absorbers performance largely depends on spring stiffness, since it decides natural frequency of the system. Natural frequency of the system depends on mass and spring stiffness of the system. This paper presents development and manufacturing of variable stiffness system, that changes stiffness and damping properties of a passive shock absorber in response to mass supported by the vehicle.

Keywords
Variable Stiffness Suspension System

I. Introduction

Primary suspension is the term used to designate those suspension components connecting the axle and wheel assemblies of a vehicle to the frame of the vehicle. This is in contrast to the suspension components connecting the frame and body of the vehicle, or those components located directly at the vehicle's seat commonly called the secondary suspension. There are two basic types of elements in conventional suspension systems. These elements are springs and dampers. The role of the spring in a vehicle's suspension system is to support the static weight of the vehicle. The role of the damper is to dissipate vibration energy and control the input from the road that is transmitted to the vehicle. The basic function and form of a suspension is the same regardless of the type of vehicle or suspension [5].

In case of shock absorbers performance very much depends on spring stiffness, since it decides natural frequency of the system. Natural frequency of the system depends on mass and spring stiffness of the system. In case of vehicles, mass supported varies as the number of occupants and other load varies. As the vehicle mass changes, its natural frequency also changes. The vehicle suspension designed for standard load (4 occupants + 10% luggage mass). The Passive Shock Absorber will perform better only for this standard load within the specified frequency range. But in running condition the actual load will not be always this standard load, due to which the shock absorber performance will not be always better. For getting uniformly better performance from the vehicle Shock Absorber for varying mass, it is necessary to change stiffness and damping properties in relation to the total mass supported by the vehicle.

II. Modeling of Variable Stiffness Suspension System

Varying spring stiffness of the Shock Absorber

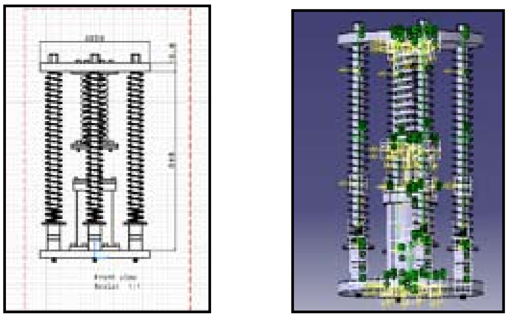
Active and Semi active suspension as discussed above are able to attenuate the road induced vibrations over wide range of frequencies. However cost associated with these is very high. Conventional fluid damping suspension is used over past many years, and it is well proven and dependable. With optimization performed this kind of suspension gives better results in the desired frequency range [6]. In case of Shock Absorbers performance very much depends on spring stiffness, since it decides natural frequency of the system. Natural frequency of the system depends on mass and spring stiffness of the system.

Variable damping can be achieved by MR fluid damper, but this method is very costly [8, 9]. The other effective method of obtaining variable fluid damping is by changing the flow area between the compression and rebound chamber [1, 4, 3, 20]. For using variable flow area between the chambers it is necessary to construct accurate mathematical model of the same. The mathematical model needs to be validated by experimentation [3, 7].

A. Assembly

The assembly consists of 47 different components and main components are 12 in numbers. For drawing the assembly select mechanical design in that select assembly design. Then the base plate is fixed and other components are assembled with its reference. Then call another component bush. By using coincidence command coincide one of the hole of the base plate with the axis of bush cylinder. By using contact command attach the bottom surface of bush with base plate. By using same procedure another three bushes are attached to the base plate.

Then call the main cylinder by using existing component command. Attach the cylinder to the base plate to the centre of the base plate. Call the piston and insert it in main cylinder. Keep a distance of 53mm in between piston and cylinder by using Offset constraint command. Call the piston piece and coincide & attach it to the piston. Then call main spring and attach it to the piston pin for that purpose we have use special command called pattern command. After that call guide bar and attach it to the one of the bush of assembly In the same way call remaining guide bars and attach it to the remaining bushes of the assembly. Call the guide spring and insert it over the guide bar and also called the remaining springs and inserted over the remaining guide bars. Then call the upper plate and attach it with the main spring and coincide its four different holes with the four different guide bars. Call a nut and attach it to the threaded portion of the guide bar in the same way call the remaining nuts and attach it to the remaining guide bars. In this way we have completed the assembly.

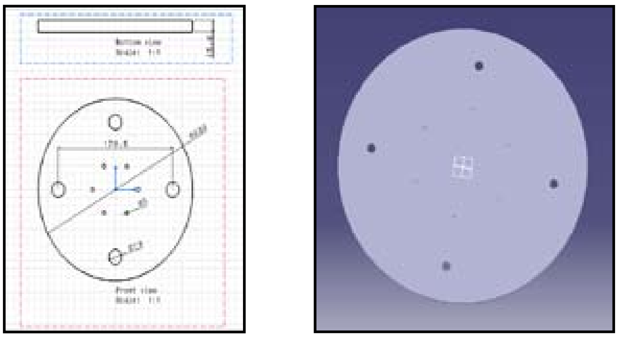


(a) (b)

Fig. 1: Assembly of Variable Suspension System (a). Drafting, (b) CATIA Modeling

2. Upper Plate

The upper plate is 14.7 mm thick of diameter and having 4 holes of diameter mm at a distance mm from the center of the circle. The plate is also having 6 small threaded holes of 4 mm in diameter at a distance mm from the center of the circle.
First of all start menu select mechanical design in part design. In that select Yz plane and in sketch work bench create geometry. Use circle command and create a circle of 230 mm diameter and using exit command exit the workbench. By using pad command make the thickness of the plate 14.7 mm. Select any face of the plate and go to sketcher workbench. Draw a circle of radius 19 mm at a distance 99 mm from the center of earlier circle. Exit the sketcher work bench and by using pocket command make a hole of 19 mm circle. Select the hole drawn earlier and using circular pattern command make three more holes of same diameter. Select any face of the plate and using thread command draw a threaded hole of 6 mm diameter. Then exit sketcher workbench. Select the threaded hole drawn earlier and using circular pattern command make five more threaded holes of same diameter. In this way the upper plate is created.

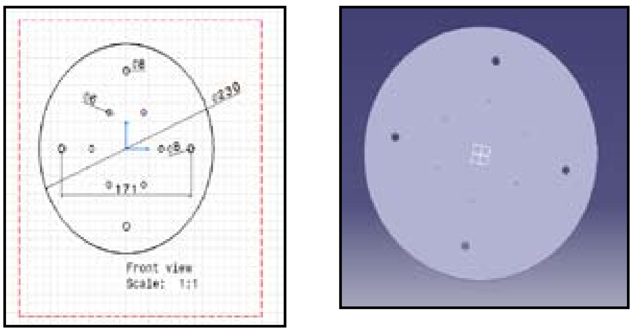


(a) (b)

Fig. 2: Upper Plate (a). Drafting, (b) CATIA Modeling

C. Lower Plate

The Lower plate is as same as the Upper plate but here instead of 19 mm diameter hole 8 mm diameter hole is present. So the same procedure of upper plate modeling can be followed to model the lower plate.

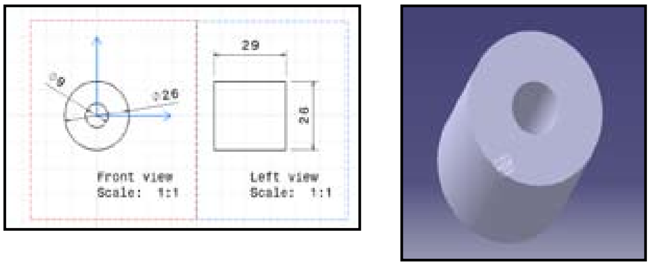


(a) (b)

Fig. 3: Lower Plate (a). Drafting, (b) CATIA Modeling

D. Bush

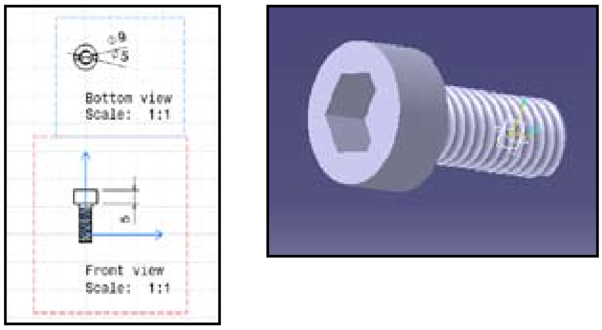
The bush is of thick cylinder type which has an inner diameter 9 mm& outer diameter 26mm. The overall height of bush is 29mm.



(a) (b)

Fig. 4: Bush (a). Drafting, (b) CATIA Modeling

E. Nut

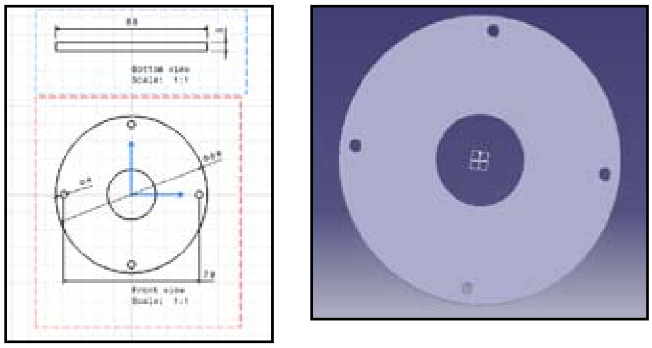


(a) (b)

Fig 5. Nut (a). Drafting, (b) CATIA Modeling

F. Cylinder Cover Plate

This plate is used to cover the cylinder.

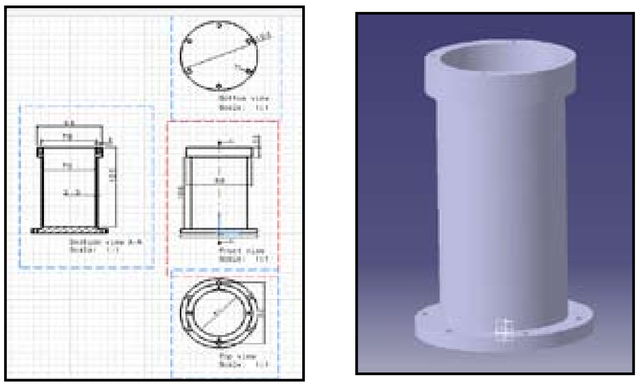


(a) (b)

Fig. 6: Cylinder Plate (a). Drafting, (b) CATIA Modeling

G. Cylinder

Cylinder having 104 diameter of circle and main height of circle is 130mm using the pad command to creating geometry.

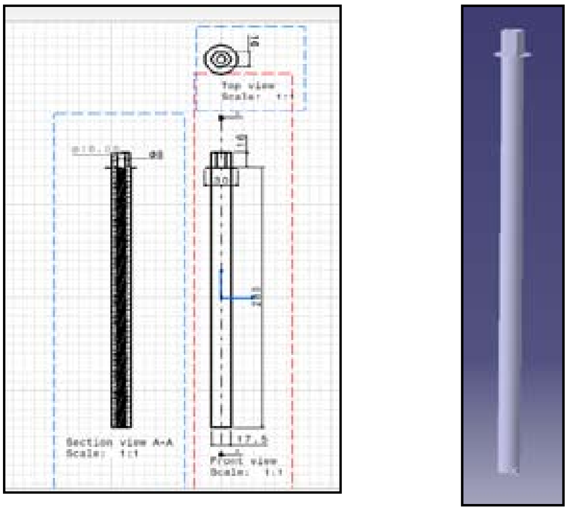


(a) (b)

Fig. 7: Cylinder (a). Drafting, (b) CATIA Modeling

H. Guide Bar

The guide bar having overall length of 280 mm. There is a threaded portion at its end of a length 50 mm. The upper portion of the bar has a diameter of 18 mm and the threaded portion has a diameter of 8 mm. The bar is having a cap type head at its top having a cap thickness of 2 mm and diameter of 30 mm. The head is of nut type having diameter 18 mm and a length of 16 mm.

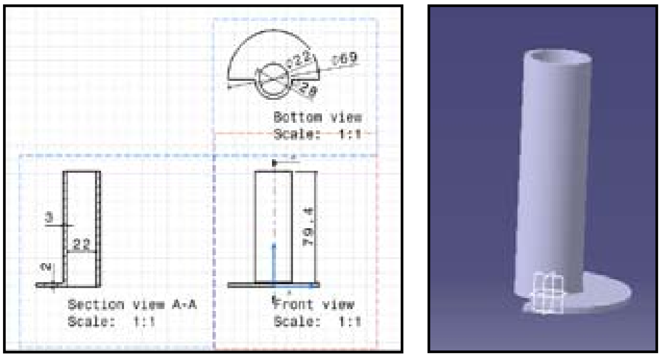


(a) (b)

Fig. 8: Guide Bar (a). Drafting, (b) CATIA Modeling

I. Piston Hole Open and Close Mechanism

The mechanism having 81.4 mm height, overall diameter of 69 of bottom side. Using groove command for removing the material.

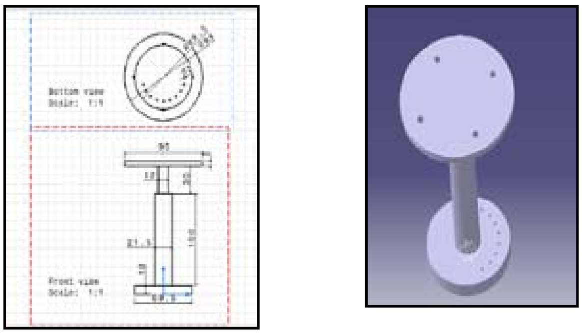


(a) (b)

Fig. 9: Piston Hole Open and Close Mechanism (a). Drafting, (b) CATIA Modeling

J. Piston

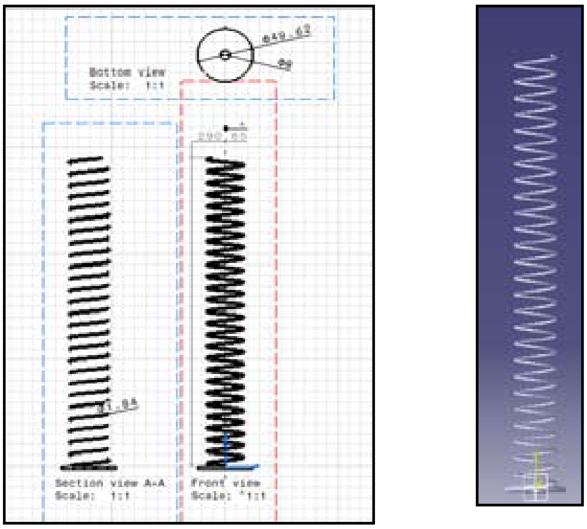
In piston design, piston having 69 mm diameter thickness 10mm. over all height having 120 mm.



(a) (b)

Fig. 10: Piston (a). Drafting, (b) CATIA Modeling

K. Peripheral Spring



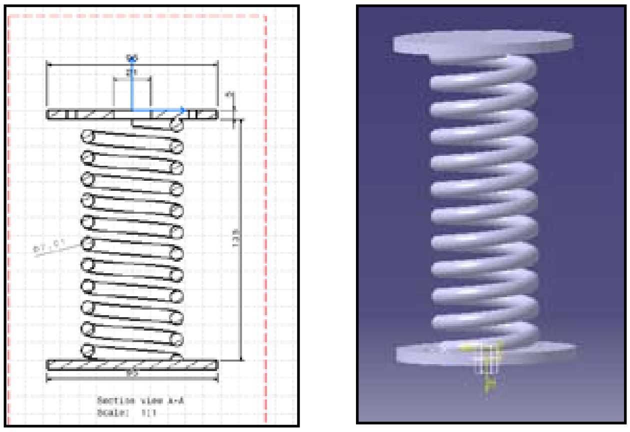
(a) (b)

Fig. 11: Peripheral Spring (a). Drafting, (b) CATIA Modeling

Peripheral spring is a spring of length 410 mm having coil diameter 22 mm. The pitch of the spring is 12 mm having wire diameter 2 mm and no of turns are 26.

L. Central Spring

Stiffness of this spring is kept higher so as to achieve wide range of stiffness adjustment in the assembly. With central spring stiffness at 45700 N/m and outer springs stiffness at 5190 N/m, variation in the stiffness up to 9 times can be achieved. Main spring is a spring of length 137 mm having coil diameter 50 mm. The pitch of the spring is 12 mm having wire diameter 7 mm and no of turns are 11. The spring is provided with two small supporting plates at its both ends. The thickness of plate is 5 mm and having six threaded holes of 6mm diameter at a distance of 41 mm from the center of plate.



(a) (b)

Fig. 12: Central Spring (a). Drafting, (b) CATIA Modeling

III. Analysis of Some Critical Components for Variable Stiffness Suspension System

In the ANSYS, analysis of structural, calculating the deformation and von mises stress some parts in ANSYS.

We have given a force on upper side of spring 400 N and select bottom side plate to given fixed constrain.

A. Deformation of Central Spring

Maximum deflection for the central spring 0.022 m at the top portion.

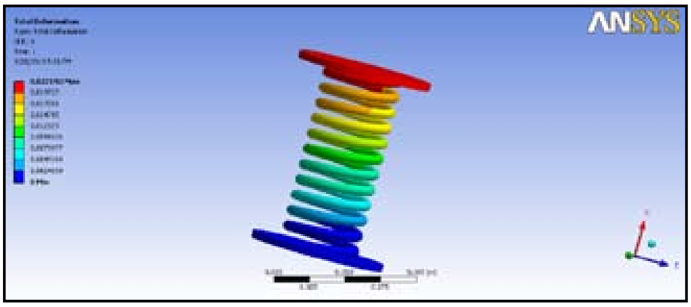


Fig. 13: Deformation of Central Spring

B. Von Mises Stress of Central Spring

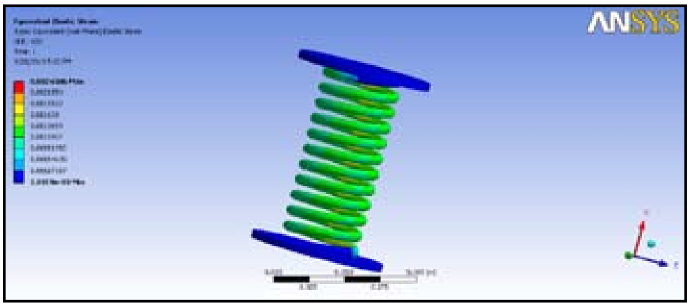


Fig 14 Van mises strain of Central spring

Spring in their CATIA modelling converting into the .stp file then after we are work on ANSYS workbench. In the workbench save the file in folder. select new geometry after word using in file command in there select import command then generate geometry few minutes after complete the geometry.
After that new mesh command using then using sub command, select fine mesh and finishing is high. Create the meshing after few minutes generate meshing on solid modelling.
Then select the simulation command in ANSYS after words in simulation in select the new analysis, in the new analysis select the structural analysis in the analysis we are the given a force on upper side of spring 200N and select bottom side plate to given fixed constrain command. Then taken to solution in solution deformation and von mass stress calculating after word result will display.

D. Deformation of Peripheral Spring

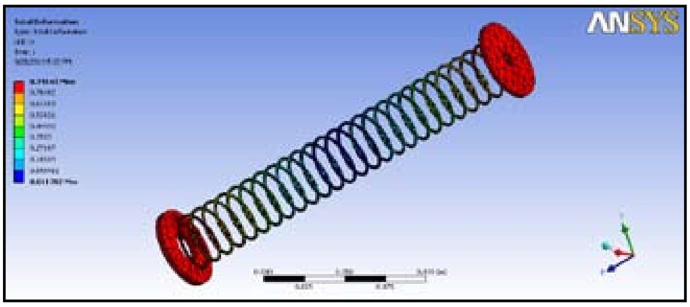


Fig. 15: Deformation of Peripheral Spring

E. Von mises stress of Peripheral spring

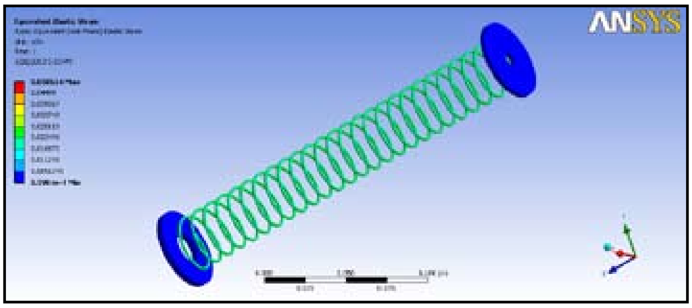


Fig. 16: Von Mises Stress of Peripheral Spring

In this CATIA modelling converting into the .stp file then after we are work on ANSYS workbench. In the workbench save the file in folder. select new geometry after word using in file command in there select import command then generate geometry few minutes after complete the geometry.
After that new mesh command using then using sub command, select fine mesh and finishing is high. Create the meshing after few minutes generate meshing on solid modeling.
Then select the simulation command in ANSYS after words in simulation in select the new analysis, in the new analysis select the structural analysis in the analysis we are the given a force on upper side of plate 1200N. And select hole of inner side plate to given fixed constrain command. Then taken to solution, in solution deformation and von mass stress calculating after word result will display.

E. Deformation of Upper and Lower Plate

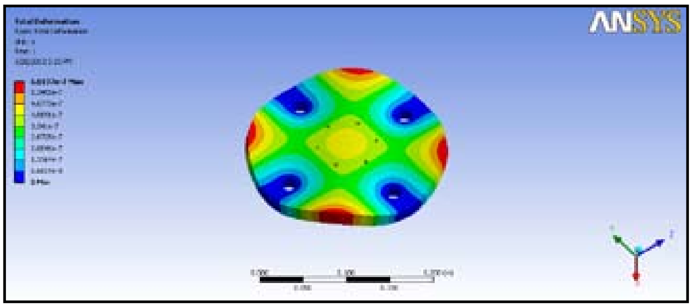


Fig. 17: Deformation of Upper and Lower Plate

F. Von Mises Stress of Upper and Lower Plate

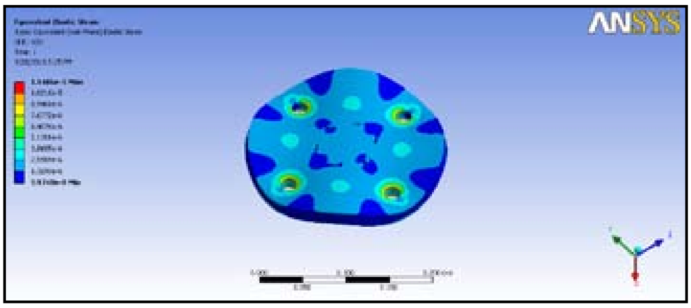


Fig. 18: Von Mises Stress of Upper and Lower Plate

In this CATIA modelling converting into the .stp file then after we are work on ANSYS workbench. In the workbench save the file in folder. Select new geometry after word using in file command in there select import command then generate geometry few minutes after complete the geometry. After that new mesh command using then using sub command, select fine mesh and finishing is high. Create the meshing after few minutes generate meshing on solid modelling.

Then select the simulation command in ANSYS after words in simulation in select the new analysis, in the new analysis select the structural analysis in the analysis we are the given a force on upper side of plate 1200N. And select hole of inner side plate to given fixed constrain command. Then taken to solution, in solution deformation and von mass stress calculating after word result will display.

Matlab Simulink model of the system is constructed to compute stiffness of the system, and is shown in table 1. Load supported by the system is 34 kg. It is seen that stiffness is varying with respect to the frequency. Also stiffness of the system is not static, but it becomes a dynamic parameter.

Table 1: Results of Matlab Simulin simulations

Sr.No.	Frequency	Peak relative displacement (mm)	Equivalent stiffness N/mm
1	2	28	12.14
2	4	20	17.00
3	6	15	22.66
4	8	10	34.00
5	10	8	42.5

IV. Final Manufacturing of the System

V. Conclusion

Design of a novel system with variable stiffness is presented in the paper. With use of two springs in parallel stiffness variation up to 9 times has been achieved. The conceived system is modeled in Catia and the same has been analyzed for stresses in Ansys workbench. The stress values indicate that the design is safe, and the system is viable for practical application. Simulations on Matlab simulink indicate significant variation in the stiffness. Additional weight of the adjustable damper is 2.4 kg, however the same can be reduced with the use of superior material and thin walled damper. Efforts are underway to fabricate the system and for analyzing performance of the same by using quarter car model.

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