International Journal of Scientific & Engineering Research, Volume 8, Issue 4, April-2017
ISSN 2229-5518

Design Development Analysis of Semi-Active Suspension System for Glass Transport in Road Vehicles

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Abstract— Suspension systems are of great importance to ride comfort, handling, and safety of road vehicles. Unsurprisingly, the design of variable damping suspension systems has attracted considerable attentions during the past few decades. Compared with passive suspensions system, active damping and semi-active damping suspension systems have the capacity to improve the compromise between stability, ride, and handling by adjusting suspension damping in real time. Active and semi-active suspensions are expected to become an integral part of future vehicles, beyond the production vehicles that have already adopted them. The proliferation of such advanced systems is aided by the customer demand for improved vehicles, the broad availability of electronics and controllers in most automobiles and the emergence of electric vehicles with novel propulsions such as in-wheel independent electric drives. This concept, when applied to vehicles, will give better ride comfort and luxury, but same can be applied to the safe transport of fragile equipment like glass which prone to damage and incurs a considerable loss due to bad road condition during transport.

Index Terms— Variable Damping Suspension, Design, Transport Trolly

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1 Introduction

The main aim of the suspension system is to minimize vertical force transmitted to object and maximize a tire to road contact for better handling and stability of trolly along with their safety[1]. Adjustable variable damping suspension is an automotive technology that controls the vertical movement of wheels with an automated system rather the movement being determined entirely by the condition of the road surface. The system attempts to minimize the body roll and pitch variation in many driving situations including cornering, accelerating, and braking. This technology allows a vehicle to achieve a greater degree of ride comfort and capable of changing position up & down by keeping the wheels perpendicular to the road in corners, allowing better traction and control in order to eliminate road irregularities,vibration, and vertical acceleration[2]. The object of the paper is to illustrate the design and working of system components such as the cylinder, piston and worm gear used to change the location of the damper disk under given system of forces.

Any company looks into customers' satisfaction; they consider some important parameter like material handling and transportation cost, quality of material to be delivered with better safety, optimal cost and number of quantity to be delivered at once.So, adjustable variable damping suspension system needed to increase both material handling and safety.[5]

This objective of better material handling and safety can be achieved by introducing semi-active variable damping suspension system and active variable damping suspension system rather than by using passive suspension system in automobile and other process industries. Passive suspension system can provide damping and spring coefficient with fixed rates.

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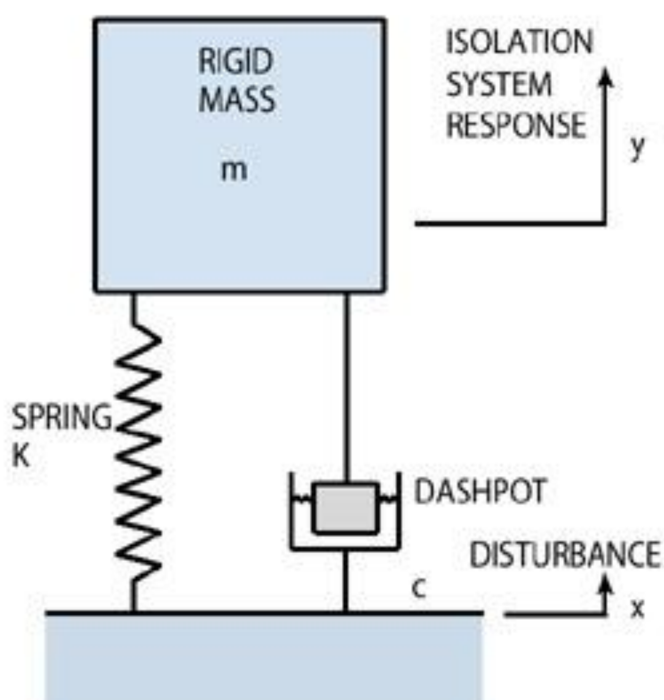

Fig. 1 Basic Concept

It can introduce vibration in very limited range of operating condition.other than this, two more suspenseon control system are introduce that is active suspension system and semi-active suspension system. it have become widely use now a days as a promising solution.these suspension system are able to modify their parameter according to control signal in order to adjust damping force.both system can provide good vibration isolation that is small acceleration of body mass and a small rattle space, which is maximal allowable relative displacement between the trolly body and various suspension component both suspension system majorly minimize effect of machine vibration.[4]

2. Method of Variable Damping Suspension

Variable damping suspension can be generally divided into two main classes according to external power input to the system and a control bandwidth.

2.1] Active Variable Damping Suspension
2.2] Semi-Active Variable Damping Suspension

2.1] Active Variable Damping Suspension

Active suspensions system has an ability to store, dissipate and to introduce energy to the system and controlled suspension externally. It may vary its parameter depending upon operating condition. Active suspension gave a better performance of suspension by using separate actuators which are a closed loop control system. The actuator is a mechanical part that added inside the system that can be controlled by PID controller. It can exert an independent force on the suspension to improve the riding characteristics and performance of the suspension system.

TYPES:

a) Hydraulic Actuated Suspension System
b) Electromagnetic Suspension System

2.2] Semi-Active Variable Damping Suspension System

Semi-active systems can only change the viscous damping coefficient of the shock absorber and do not add energy to the suspension system and thus improve either ride comfort or ride safety compared to the passive system. Though limited in their intervention (for example, the control force can never have a distinct direction than that of the current speed of the suspension). Semi-active suspensions are less expensive to design and have been investigating to meet lower energy consumption. In recent times, research in semi-active suspensions has continued to advance with respect to their capabilities and narrowing the gap between semi-active and fully active suspension systems.

TYPES

a) Solenoid valve Actuated
b) Magneto Rheological Damper

3. Design of Variable Damping System

3.1] Design Dig.

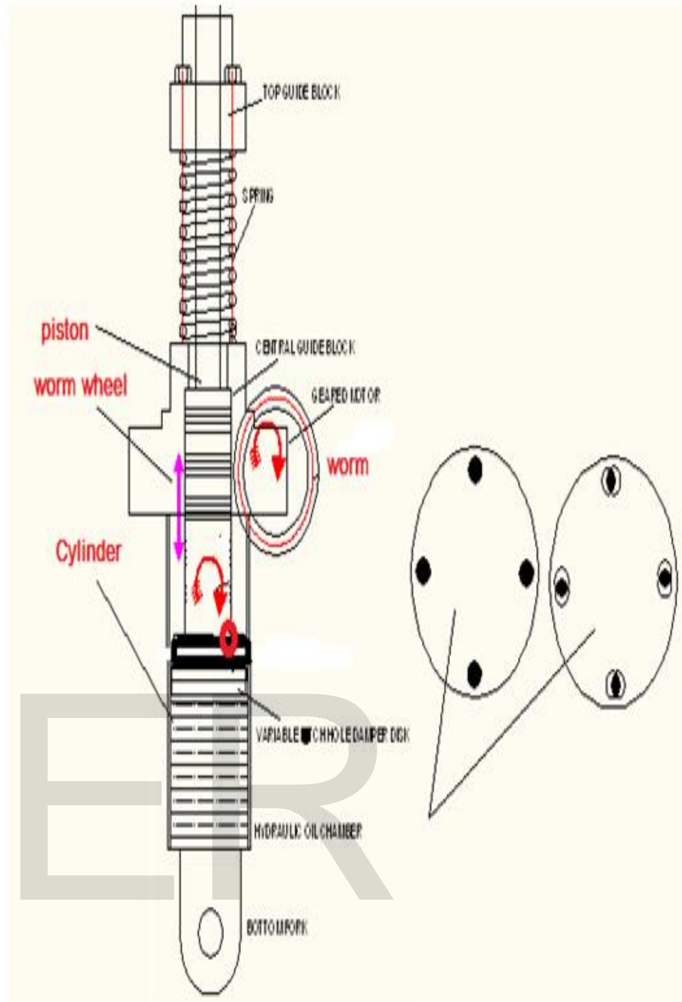

Fig. 2 Assembly of Adjustable Variable Damping System

3.2] Working and Construction of Variable Damping System

Gear motor is used to drive the worm wheel which will move the rack either up or down. Deflection of the spring to change the spring rate per condition of the road that is for large bumps spring length will be largest and for short bumps the spring length will be short. The rack moves up thereby deflecting the spring to reduce the length of spring similarly, rack moves down to deflect the spring to increase the length of spring. Here, we consider a movement of piston rod as a rack which having helical gear tooth engaged with the gear of worm wheel which can be rotated with external gear motor.

The gear motor used to drive the worm gear which will rotate the worm wheel which in turn will drive the damper disk to change damping whole dimensions. The above fig. shows two different positions of damper disk. First is fully matched and the second one is partially open. Controlling of the system is totally depending on the opening hole of

International Journal of Scientific & Engineering Research, Volume 8, Issue 4, April-2017
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one plate over other. We can use gear arrangement to control reduction ratio and better controlling over the entire working system, during continuous and uneven road disturbances. The top guide block used to restrict movement of spring and spring constant. The Hydraulic actuator is fixed at one end and having hydraulic oil is used to better control the entire system and movement of sliding piston.

3.3] Advantage of Electro-hydraulic Suspension System

1. Increases vehicle comfort.
2. Prevents damages to chassis in deep holes and pits.
3. Reduces vibrations of chassis in frequent holes and rough road conditions.
4. Simple system to implement.
5. Increases ride stability.
6. Easily reduced vibration and vertical acceleration transfer to object.
6. Cost effective than the magneto-rheological system.

3.4] Disadvantage of Electro-hydraulic Suspension System

1. Increases vehicle weight slightly.
2. Increases vehicle cost slightly.

4. Design Parameters of Critical Components Glass Trolley Variable Damper

Any vibration sequester device has joined together with the solid structure get system being isolated from vibration sources.

This interface is considered as a single point in so many cases, either for a sufficiently small area or its high stiffness. In such a cases,the model with a single degree of freedom is mostly used approached to imitate vibration isolation system.the design of variable damper is base on consideration of the single degree of freedom system.A trolly along with rigid mass is resting on spring of stiffness K and a variable damper having damping coefficient C.

The equation of motion for given system, consider as a free vibration

Mx + Cx + Kx = 0 (1)
(Inertia Force) (Damping Force) (spring Force)

Where,
x = Displacement of rigid mass
$\dot{x}$ = Velocity of mass
$\ddot{x}$ =Accleration of mass
According to equation of (1), we consider
There is no external force on the system during vibration.
If damping system subjected to a loading force, then equation of motion become

Mx + Cx + Kx = F (2)
(Inertia Force) (Damping Force) (spring Force) (Loading Force)

This equation of motion is used for distinct practical application and design exercises.In particular; we can easily get information about structural and machine vibration transmissibility, natural frequencies, an effectiveness of damper and absorber.

4.1] Worm Wheel Design to Operate Variable Damping Disk

Design of Nylon -66 Gear
Considering beam strength of tooth,
Power =5 Watt, Speed=92 rpm,
Tooth face width (b) =10,
Reduction ration (I) =55,
Gear Speed =92 rpm,
Material of gear = Nylon-66,
Tensile Strength =55N/mm²
Service Factor (Cs) =1.5
Diameter of Gear =55,
Now,
We know that stalling torque of the motor is0.52 N-m. Hence,
Net Load on Gear Tooth (Failure Load)
Pt=Torque x Diameter of Gear/2
=520x (55/2) =18.90 N
Peff = 19 x 1.5 = 28.5 N-------- (A)
A/c to Lewis Strength Equation,
Ft= σ (Ultimate tensile strength) x b (Face Width) x Y (Lewis firm factor) x m (Pitch)
Y = 0.484
Ft = (Syp) x b x m
= 23.65 x10m xm= 236.5m²-------- (B)
Compare Equation (A) and (B) we get,
M = 0.34, selecting standard module m=1 mm

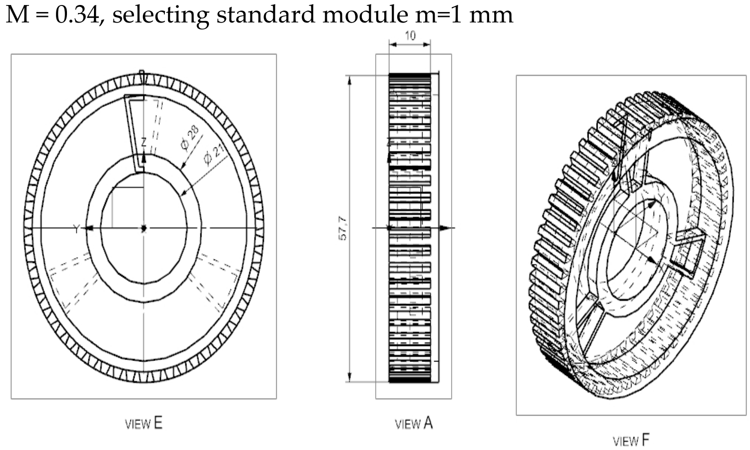


Fig. 3 Worm Wheel

4.2] Design of Hollow Piston rod

Maximum load on piston for 1:10 scale
Material use =En24, Tensile strength=800N/mm², Yield strength =680N/mm²
Load = 50 kg =490 N (on single damper)

Direct tensile or Compressive stress due to an axial load,

Fc act = W (Load)/A (Area)

$=490/\pi/4 \times (16^2-10^2)$
$=3.998\ N/mm^2$

As, fc act < fc all piston rod is safe in compression

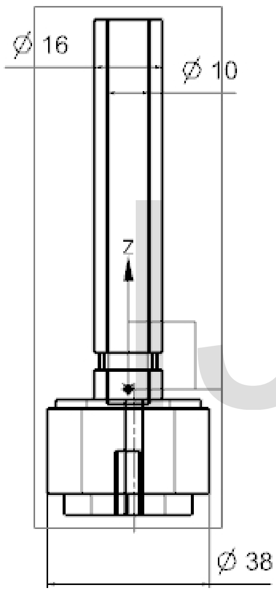
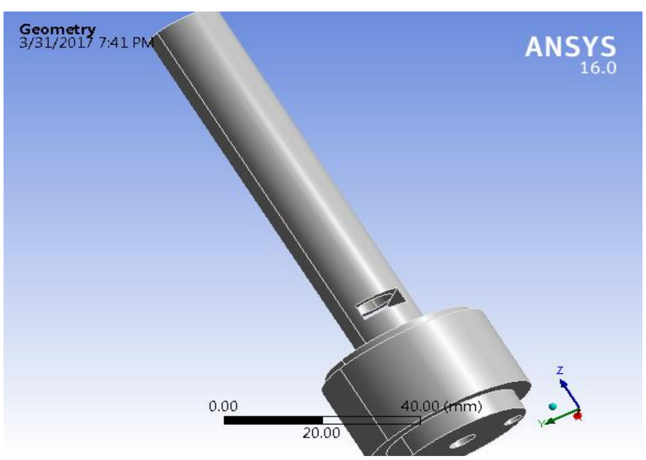
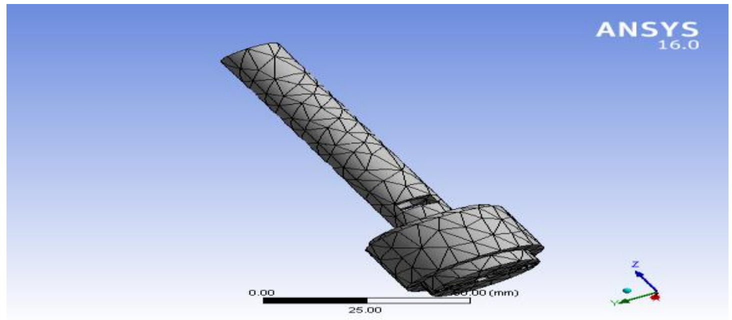
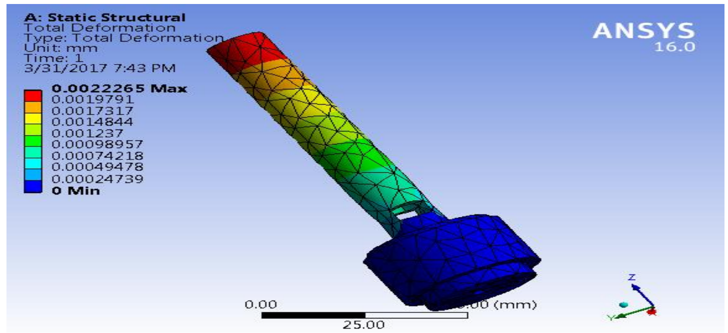
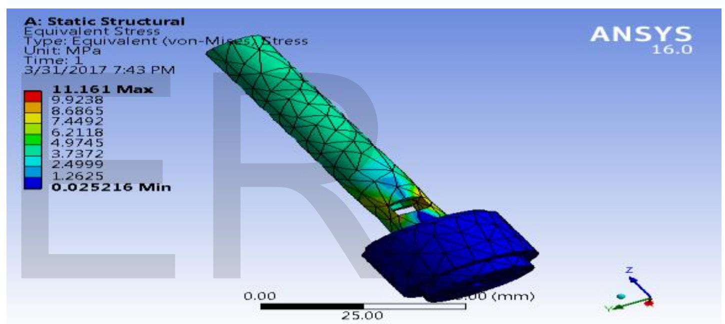


Fig .4 Hollow Piston Rod









4.3] Design of Vibrator Ring

Maximum load on vibrator for scale 1:10,
Material use =En24, Tensile strength=800N/mm²,
Yield strength =680N/mm²

Load = 50 kg =490 N which is shared in two end of ring hole.
Direct Tensile or Compressive stress due to an axial load,

Fc act = W (Load)/A (Area)

$=490/2/\pi/4*(19^2-16^2)-(1.5x3)$
$=3.14N/mm^2$

As, fc act < fc all Vibrator Ring is safe in compression

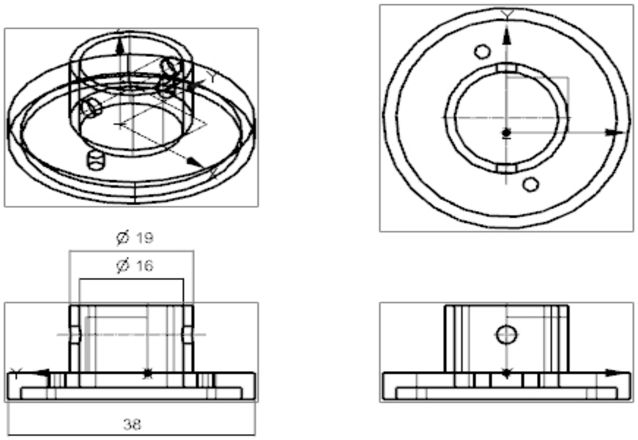
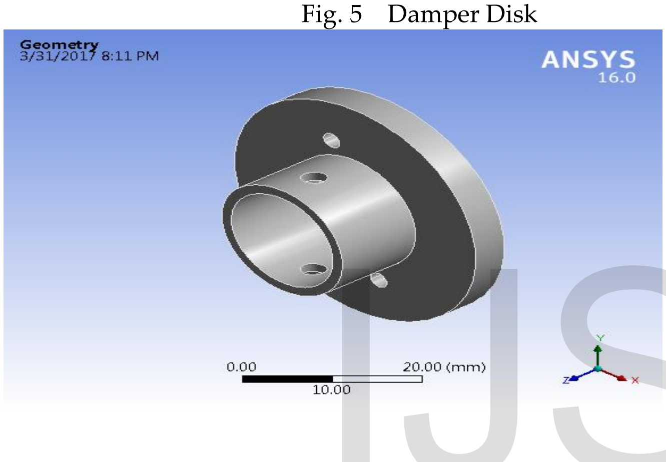
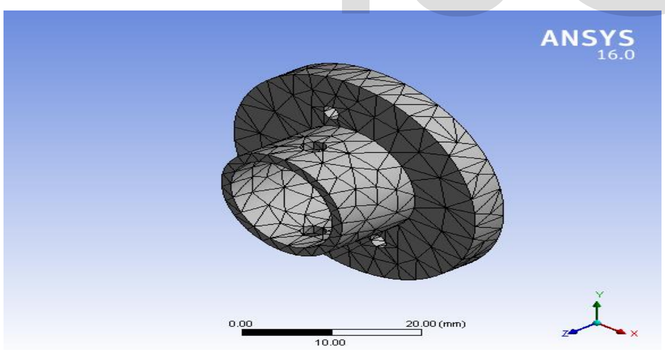
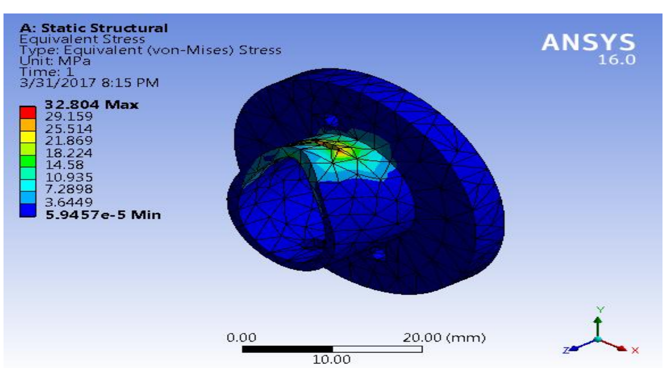
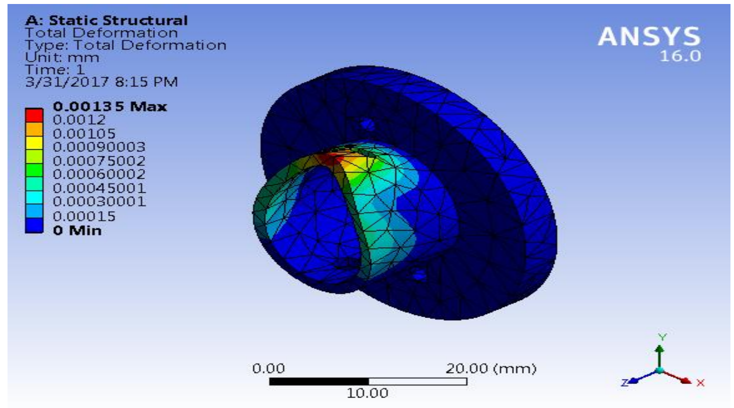


Fig. 5 Damper Disk









5. Result & Discussion

So, during design and analysis of critical components of glass transfer trolly following theoretical results is getting,

TABLE. 1

RESULTS

Part Name	Maximum Therotical Stress N/mm²	Von-misses Stress N/mm²	Maximum Deformation mm	Results
Worm Gear	28.5	2.61	4.6E-7	safe
Hollow Piston Rod	3.998	11.16	0.002	safe
Vibrator Ring	3.141	5.94e-5	0.001	safe

Here, Gear show negligible deformation under the action of a system force And worm gear is safe because von mises stress is within the allowable limit.maximum stress by a theoretical method and von-mises stress are well below the allowable limit hence the design of hollow piston are safe.there is a negligible deformation on hollow piston rod.vibrator ring is also safe due to von-misses stress in the allowable limit.

6.CONCLUSION

The arrangement of adjustable damper suspension system with vibrator damper disk is provided for better control of the vertical movement of trolly and better stability of a system.Also, this system is very cost effective with simple positional and damping control.the given system use a minimum number of components that are at very low-cost, easy to manufacture, Implement and maintenance.it is very user-friendly for all processing industries and shop floor activity.

7. Acknowledgment

I would like to thank our gratitude to all those who gave me proper direction and possibility to complete this research paper work. I deeply indebted to my guide Prof.N.K.Gawade and all other faculty of department of mechanical engineering SKNSITS Lonavala who always help me to walk on a right path related to project work and encouraged me in all time .

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