Analysis of a Spring Loaded interconnected Hydro-Pneumatic Suspension of a vehicle

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Abstract- *In 1950, hydro-pneumatic suspensions were used in vehicle to increase the ride comfort due to nonlinear property of oil and air. But due to the sizes of struts unreasonably large further, the pressures were also unreasonably high resulting in seal damage. Due to seal damage of hydro-pneumatic suspension they are replaced by spring loaded suspension which carry whole load of vehicle as well as they can sustain oversized struts. But spring loaded suspension could not give that much ride comfort, vehicle handling performance and economic factor. Because they do not respond on small struts. If the hydro-pneumatic suspension is connected parallel with mechanical spring, would increase performance and ride comfort and also can sustain oversized struts. In general, the results show that the proposed interconnected hydro-pneumatic suspension can provide comparatively improved performance in both bounce and roll modes. A proposed work describes the designing, modelling and analysis of hydro-pneumatic suspension interconnected with mechanical spring suspension. Also in this proposed work, the three-dimension model of Hydro pneumatic suspension system is modelled in SOLIDWORKS 2016 and imported into ANSYS 16.0 software to perform static and Dynamic analysis to analyse strength and dynamic characteristics of Hydro pneumatic and mechanical suspension system.*

Keywords- Hydro-pneumatic suspension, Mechanical spring, Strut, Non-linear, Economic factor

I. INTRODUCTION

Suspension is main component of a vehicle. As it is responsible for smoothing out the ride and keeping the car in control. Also it gives stability and good handling of vehicle. A suspension system's primary functions is to isolate the chassis from road roughness and allow the wheels to follow the road maintain required wheel orientation relative to the road, such as steer and camber angles, transmit forces and moments produced by the tires on the vehicle, resist chassis roll and maintain tire-road contact and minimize normal load variations.

In recent years the traditional light motor vehicle (LMV) cannot meet the growing requirements concerning comfort and safety of driving cars. Since the mechanical springs are used to sustain the higher struts, they do not respond on small irregularities of road. As those irregularities also affect the comfort and vehicle performance as well as vehicle handling. And mechanical springs are unable to react on those cases.

To respond in 1950 hydro-pneumatic suspension are used for small irregularities on road. The hydro-pneumatic suspension contain oil has a hydraulic medium and nitrogen gas as a pneumatic medium in diaphragm, they react easily for small action of vehicle movement on the road. This type of suspension gives ride comfort and vehicle performance. But it is limited for only small strut. So it easily breaks if size of strut is larger. The main reason of bursting of diaphragm is excessive pressure acting On it, as diaphragm can sustain limited pressure. So due to seal damage of hydro-pneumatic suspension, it is replaced by mechanical spring.

Previous studies have shown that various suspension system like hydro-pneumatic suspension and mechanical springs are used for vehicle ride comfort and better vehicle comfort. It is proposed to study the feasibility of designing interconnected hydro-pneumatic suspensions system with mechanical springs, and their feasibility for size and carrying bulk load. Interconnected hydro-pneumatic suspension can overcome drawbacks of hydro-pneumatic suspension and mechanical spring. Mechanical springs can absorb higher shock loads, so 95% of load will be kept on mechanical springs and 5% of load on hydro-pneumatic suspension. The interconnected arrangement is purpose for the pitch, roll and combined roll and pitch. The arrangement of system is also analysed for above conditions.

II.PROBLEM DEFINATION

The existing mechanical spring suspension system for vehicle is facing issues like it is not responding to small struts and also individually used hydro-pneumatic suspension is facing issues like seal damage and less load carrying capacity.

Hence there is a need to design new suspension system which will carry more load and will respond to small struts.

III. METHODOLOGY

1. Perform design calculation of hydro-pneumatic suspension.
2. Perform Static analysis to find max. Stress and max. Deflections on Hydro pneumatic suspension system.

IV. DESIGN CALCULATIONS

Mathematics of the spring rate-

Spring rate is a ratio used to measure compression and expansion during the spring's deflection. The magnitude of the spring force is

$$F = K * \delta$$

F is the force the spring exerts,
K is the spring rate of the spring,
δ is the deflection of the spring from its equilibrium position.

The spring rate of a coil spring may be calculated by a algebraic equation or it may be measured in a spring testing machine. The spring constant *k* can be calculated as follows:

$$K = \frac{d^4 G}{8ND^3}$$

Where,

d is the wire diameter
G is the spring shear modulus,
N is the number of wraps,
D is the diameter of the coil.

Module produces hysteresis loop due to linear spring and damper characteristics and the characteristics are not progressive, as with a hydro-pneumatic spring. So polytrophic process is used to model the main spring. The volume and pressure of the accumulators are known, but one unknown parameter (for the main spring) is the polytrophic constant. So, linear characteristics were assumed for the series elements. Equation shows the formula used to calculate the spring force (F) as a function of displacement (x).

$$F = \frac{kA}{(xA)^n}$$

With

F - Spring force [N],
k - Constant (function of static volume and pressure),
A - Accumulator floating piston area,
x - Floating piston displacement,
n - Polytrophic exponent.

V .DESIGN OF HYDRO-PNEUMATIC SUSPENSION SYSTEM

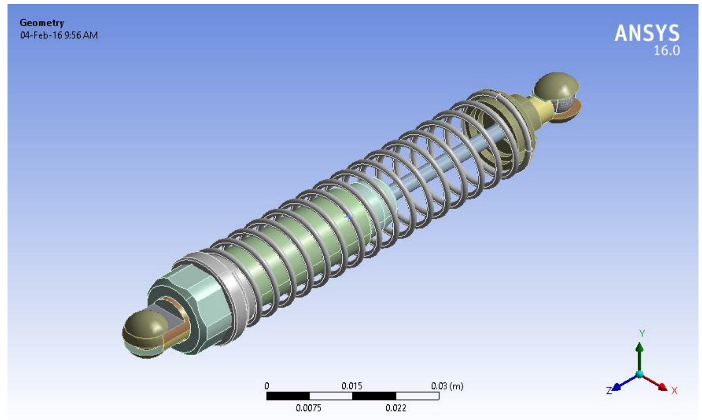

Fig. 1 Design of Hydro-pneumatic system

VI. MATERIAL PROPERTIES AND CALCULATION

Sr. No.	Property	Value
1.	Density	7850 Kg/m^3
2.	Young's Modulus	2E11Pa
3.	Poisson's ratio	0.30
4.	Yield strength	2.5E8 Pa
5.	Ultimate strength	4.6E8 Pa

VII. STATIC ANALYS OF HYDRO-PNEUMATIC SUSPENSION

A. CAD Modelling

The hydro-pneumatic suspension is modelled using a CAD software, Solidworks. Various features like revolve features, sweep features, extrude boss base and extrude cut, fillet and surface features are used. The CAD model is shown in Fig. 1.

B. Meshing

The ANSYS workbench uses a finite element method to discretize the model into finite elements. Finer the size accurate will be the answer. But at the same time the software needs more memory and time for processing. Thus optimum meshing is used.

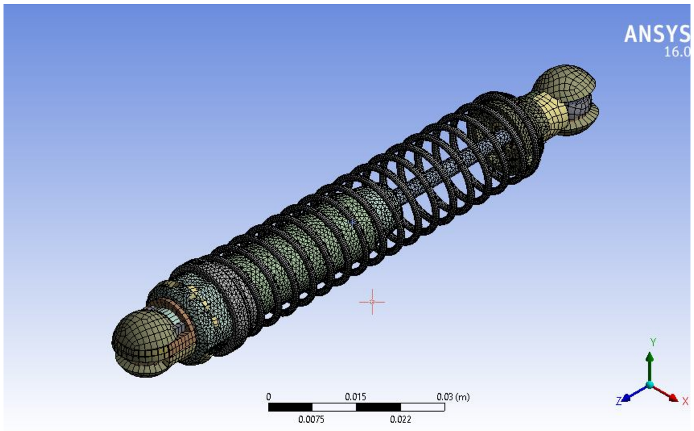

Fig. 2 Meshing

C. Analysis setup

A force 10E3 N is applied on model at one end as per the load on vehicle and other end is fixed.

D. Deformation

The maximum deformation is 0.5060 mm.
The minimum deformation is 0.005623 mm.

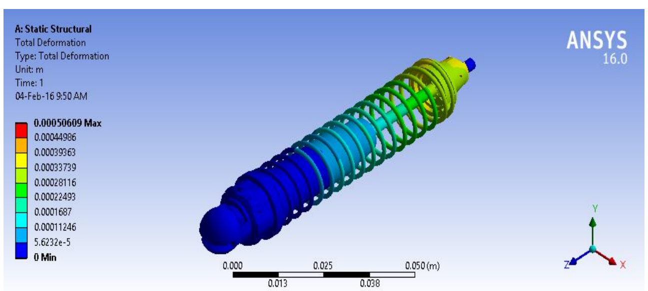

Fig. 3 Deformations occurred

E. Principle stresses

The maximum stress is 3.2455E9 Pa.
The minimum stress is 3.6061E8 Pa.

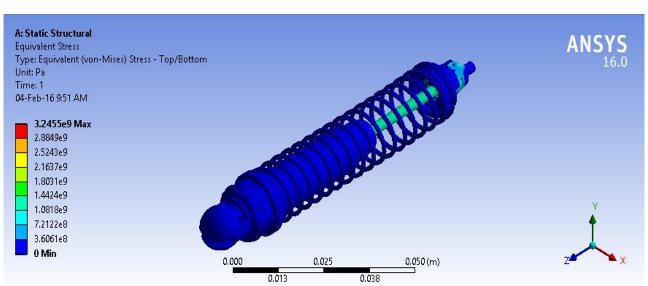

Fig.4 Principle Stresses

F. S-N Curve

Following figure shows the S-N curve.

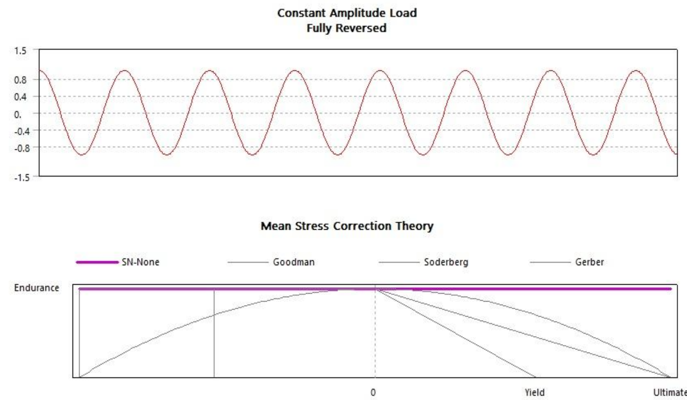

Fig. 5 S-N Curve

VIII. CONCLUSION

The hydro-pneumatic suspension as studied under two conditions

- Static analysis
- Modal analysis

From the above analysis it is concluded that the stresses and deflections occurred are under design limits. Hence the hydro-pneumatic suspension is safe under given operating conditions.

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