IMPLEMENTATION OF HYDRO PNEUMATIC SUSPENSION SYSTEM FOR TRACTOR

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ABSTRACT: During the tractor movement, with being attached to the hitch-system working equipment over Rough road surfaces oscillation of the machine take place. These oscillations are a reason of pressure pulsations in the hydraulic hitch-system. The pressure pulse reduction in the tractor Hitch-system is important for increasing of the system components lifetime. Pressure oscillation damping in the tractor hydraulic hitch-system can reduce overall system oscillations and improve the driving control.

The design of spring in suspension system is very important. In this project a shock absorber is designed and a 3D model is created using Solid works. The model can be changed by changing the thickness of the spring.

Structural analysis and modal analysis are done on the suspension system by varying material for spring, Spring Steel and Beryllium Copper. The analysis is done by considering loads, tractor weight, single person and 2 persons. Structural analysis is for validating the strength and modal analysis is for determining the displacements for different frequencies for number of modes. Comparison is done for two materials to verify the best material for the spring in suspension system. Analysis done in ANSYS.

INTRODUCTION:

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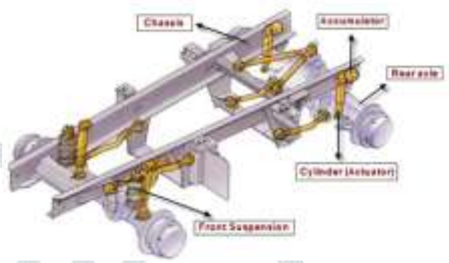
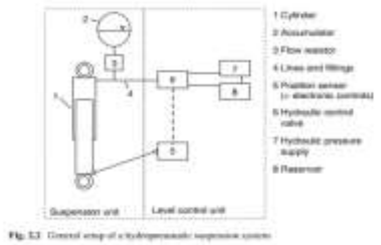
HYDRO PNEUMATIC SUSPENSION:

Hydropneumatic suspension is a type of motor vehicle suspension system, designed by Paul Magès, invented by Citroën, and fitted to Citroën cars, as well as being used under licence by other car manufacturers, notably Rolls-Royce (Silver Shadow), Maserati (Quattroporte II) and Peugeot. It was also used on Berliet trucks and has more recently been used on Mercedes-Benz cars. Similar systems are also used on some military vehicles. The suspension was referred to as oléopneumatique in early literature, pointing to oil and air as its main components.



WORKING PRINCIPLE:

The simplest hydropneumatic suspension system consists of only three components: a hydraulic cylinder, a hydropneumatic accumulator, which is directly mounted on the cylinder and, of course, the hydraulic fluid. In case cylinder and accumulator need to be separated – for example due to design space reasons – additional oil lines and fittings are necessary to provide the hydraulic connection. After adjusting the hydraulic pressure to the required level (by adding or releasing hydraulic fluid) this system now already provides the suspension function. When displacing the piston rod, the fluid volume in the accumulator is changed and therewith the pressure (p1 → p2). This causes a change of the force at the piston rod which, in combination with the change of the position, defines the spring rate c. The external spring force FF which acts upon the piston rod is always in balance with the forces resulting from the pressures onto the piston, when neglecting inertial and friction forces When the force FF is increased to FF the position of the piston changes (s) and therefore some hydraulic fluid is displaced into the accumulator.



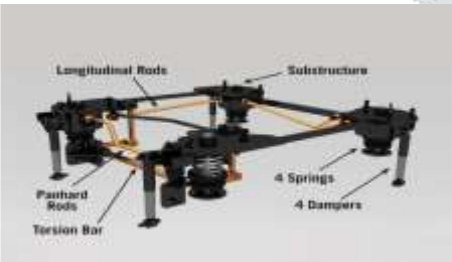
APPLICATIONS FOR HYDROPNEUMATIC SUSPENSIONS:

Hydro pneumatic suspension systems are used especially in applications where:

- a level control is needed in particular for level readjustments after major load changes,
- a level control needs to work frequently and needs to react quickly,
- a manual operator control for the suspension level is desired,
- little space is available for suspension elements,
- possibly hydraulic cylinders are already available for control of the desired suspension degree of freedom,
- robust components are required due to the harsh working environment,
- a lockout of the suspension in the design position is required,
- the spring rate needs to be adjustable,
- a hydraulic energy supply is already available.

REQUIREMENTS FOR SUSPENSION SYSTEMS:

Suspension systems have a broad range of applications in our daily lives. Usually people do not even know that they exist, yet they are doing a hard job in many cases. If they malfunction it is often the first time that one starts thinking about them. For example, anybody who has ridden a bicycle with too low tire pressure will probably remember how soft and wobbly the bike felt on smooth roads and how badly he felt the bumps when there was even the slightest unevenness. A ride behavior which is unsafe and uncomfortable. In this case the spring rate of the suspension system (i.e. the tire) was too low and the available suspension travel was too small. Therefore the suspension reached the limit of its stroke and ran heavily into the end stop – rim and road surface with the rubber of the tire in between. On the other hand, a too high tire pressure and an accordingly too high spring rate can also lead to discomfort on the bike. Without sufficient tire elasticity the roughness of the road is transferred directly into the bike frame and furthermore into the rider. This again has a negative effect on the comfort of the rider. It is clear that it is necessary to find a suitable level of tire pressure and thus spring rate which fits in particular to the weight of the rider.



SPRING CHARACTERISTICS:

The spring rate of a hydro pneumatic suspension system can be determined from the pure spring force–displacement curve measured at the suspension cylinder when the hydraulic flow resistor, is removed. An increase of force onto the cylinder leads to an increase in hydraulic pressure and therefore to a change in position of the piston rod. This is due to the following reasons:

- compression of the gas in the accumulators
- widening of the (elastic) fluid lines and fittings
- compression of the hydraulic fluid

Each of these three effects causes an individual spring rate.

ADVANTAGES:

Hydropneumatics have a number of natural advantages over steel springs that are poorly understood, leading to general public perception that hydropneumatics are merely "good for comfort". They actually also have great advantages related to car handling and control efficiency, solving a number of problems inherent with using steel springs that suspension designers have always dreamt they could eliminate.

- Hydropneumatic is naturally a progressive spring-rate suspension; i.e., the more it is compressed, the harder it becomes. This results in the suspension being extremely soft around its initial course (softer than a steel spring) but getting harder and harder as compressed (more than a steel spring). This is because of the properties of gas: halve its volume, and its pressure doubles. When the suspension operates, the ram is pushing oil into the sphere altering its gas volume (and therefore the pressure). This natural principle of hydropneumatics has not been met so far by any other type of suspension. The nearest is steel springs with a softer course and a harder course (two different spring rates, while hydropneumatics offer an infinite number of rates). Usually steel-sprung cars are either too soft ("comfortable"), or too stiff ("sporty"), or some intermediate compromise, while hydropneumatics offer "two cars in one".
- This advantage pays off in a spectacular way when *slaloming* (otherwise known as the 'moose test'): the swinging speeds and acceleration patterns of the body of a hydropneumatic car offer ideal body control, and "load" the tyres in an ideal linear-like manner, helping to get the most out of them. A steel-sprung car acts more like a violently-swinging pendulum, "crashing" on its tyres (and abusing them) when leaning from side to side.
- The same natural law governing gases also ensures that the suspension's spring-rate (hardness) is continuously adapted to the weight it has to carry, and to infinite positions. For example, when the car is standing empty, the pressure within its spheres is in balance. If one passenger enters the car, this pressure becomes higher by the value of his weight (the gas in the spheres compressed to an equal degree, i.e. has now become "harder"). The car will have lost some height, so the self-leveling system immediately reacts and brings the car up to the predetermined ride height. The result is that the spring rate is kept constant, regardless of the load of the car. I.e., a car with 4 passengers and full payload will be equally well controlled as a car with just one passenger (bar the tyres, which of course remain at the same pressure.). With a steel-spring car, either the car would be set up to be comfortable with 1-2 passengers but getting too

soft as more weight is added (becoming uncontrollable under full payload), or it would be too stiff with 1-2 passengers and okay on full payload.

- This effect is especially pronounced at the rear axle, where the designer of a steel-sprung car has to make the greatest compromise: the rear suspension has to be able to deal satisfactorily with a large range of load. Because of the above property of hydropneumatics, Citroën vehicles can have a rear that is set very soft; one can easily push the empty car down with his hand. When load is added, it stiffens as much as necessary. Steel-sprung cars need to have rear springs much stiffer than necessary for average daily driving.

DISADVANTAGES:

- Service sometimes requires a specifically trained mechanic, but can be done by any DIYer with knowledge of the system or the correct manual.
- Hydro pneumatic suspension systems can be expensive to repair or replace, **if** poorly maintained or contaminated with incompatible fluids.
- Failure of the hydraulic system will cause a drop in ride height and braking power will decrease. However, an acute failure will *not* lead to acute brake failure as the accumulator sphere holds enough reserve pressure to ensure safe braking far beyond that needed to bring a vehicle with a failed system to a standstill.

INTRODUCTION TO CAD

Computer-aided design (**CAD**) is the use of computer systems (or workstations) to aid in the creation, modification, analysis, or optimization of a design. CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing.

<u>INTRODUCTION TO SOLID WORKS</u>

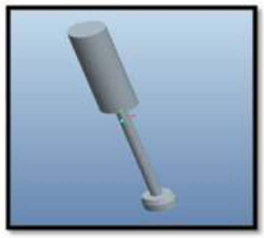
Solid Works (stylized as SOLIDWORKS) is a strong modeling computer-aided layout (CAD) and laptop-aided engineering (CAE) computer application that runs on Microsoft Windows. Solid Works is published with the aid of Dassault Systems.

MODEL OF SUSPENSION SYSTEM USING SOLIDWORKS

Top Part

Casing

Helical Spring

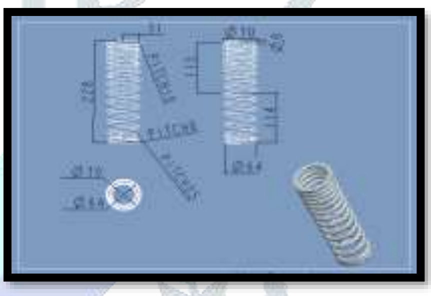


Inner Assembly

Lower

Exploded view

Total Assembly



2D Drawing of Helical Spring

INTRODUCTION TO FEA

Finite element analysis is a method of solving, usually approximately, certain problems in engineering and science. It is used mainly for problems for which no exact solution, expressible in some mathematical form, is available. As such, it is a numerical rather than an analytical method. Methods of this type are needed because analytical methods cannot cope with the real.

ANSYS Mechanical

ANSYS Mechanical is a finite element analysis tool for structural analysis, including linear, nonlinear and dynamic studies. This computer simulation product provides finite elements to model behavior, and supports material models and equation solvers for a wide range of mechanical design problems. ANSYS Mechanical also includes thermal analysis and coupled-physics capabilities involving acoustics, piezoelectric, thermal–structural and thermo-electric analysis.

MATERIAL PROPERTIES

- **Structural steel**

Density: 7850KN/m^3

Ultimate Tensile Strength: 515-827Mpa

Yield Tensile Strength: 207-552Mpa

Young's Modulus: 190-210Gpa

Poisson's Ratio: 0.30

% of elongation: 12-40

- **Beryllium copper**

Density: 8260 KN/m^3

Ultimate Tensile Strength: 483-810Mpa

Yield Tensile Strength: 221-1172Mpa

Young's Modulus: 115Gpa

Poisson's Ratio: 0.30

Shear Modulus: 50Gpa

STRUCTURAL ANALYSIS OF HYDROO PNUMATICSUSPENSION SYSTEM

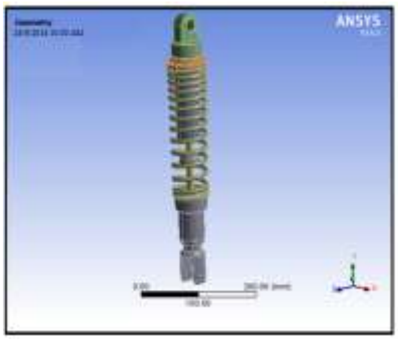
MATERIAL - STRUCTURAL STEEL

LOAD 113KN

Open ANSYS>Open work bench 14.5>select static structural >double click on it.

Select engineering data> window will be open in that enter required material properties> update project and return to the project.
Select geometry > right click on it >select import geometry> select file>ok

IMPORTED MODEL



Select model>right click on it> select edit> window will be open in that select mesh>right click on it>select generate mesh

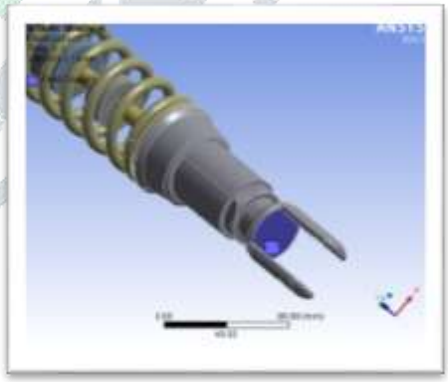
MESHED MODEL

Select static structural >right click on it >insert> pressure> select area> enter magnitude> apply.

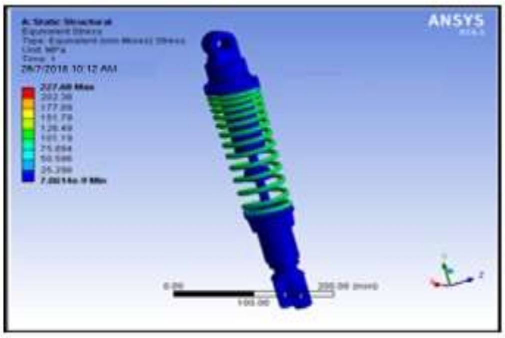
PRESSURE

Select static structural >right click on it >insert> fixed support> select area> apply.

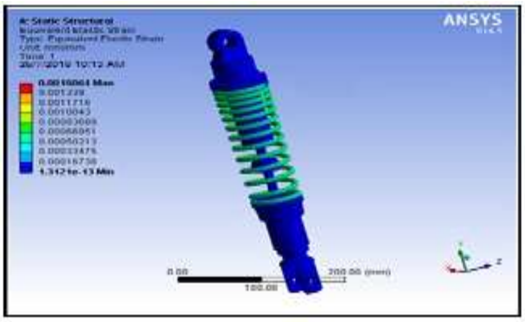
FIXED SUPPORT



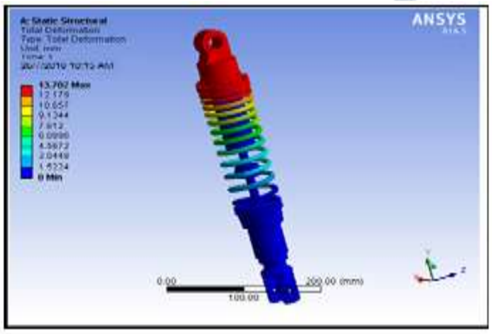
Right click on solution> insert > Deformation >Total>Right click on solution> insert> Strain> Equivalent (Von-mises)> Right click on solution> insert> Stress> Equivalent (Von-mises). Right click on solution> insert > Solve.



STRESS



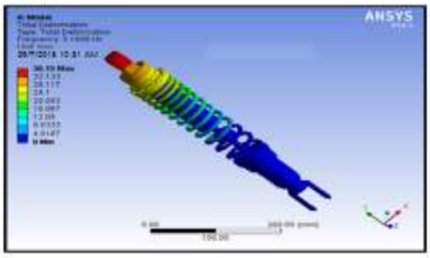
STRAIN

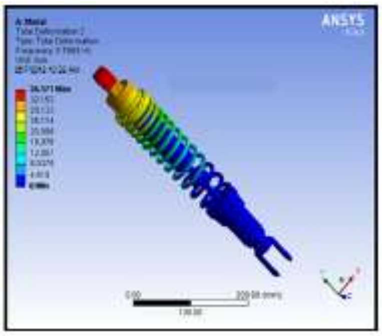


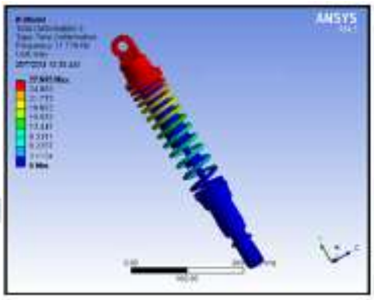
TOTAL DEFORMATION

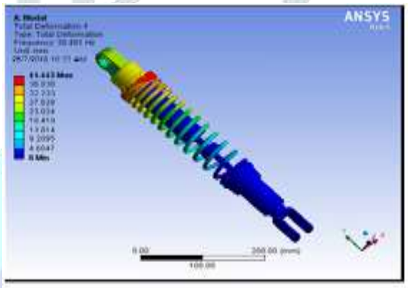
MODAL ANALYSIS OF HYDROO PNUMATIC SUSPENSION SYSTEM

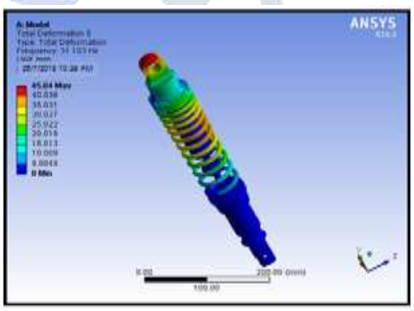
MATERIAL - STRUCTURAL STEEL

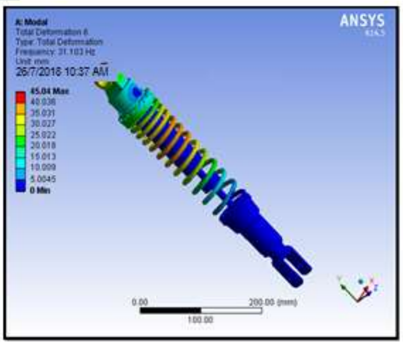












RESULTS FOR 6 MODE SHAPES

STRUCTURAL ANYLYSIS RESULTS

Material	Load(KN)	Von-mises stress [MPa]	Von-mises strain	Total deformation [mm]
Structural steel	113	227.68	0.0015	13.702
	188	377.89	0.0025	22.741
	263	529.68	0.0035	31.875
Beryllium copper	113	233.23	0.0026	23.794
	188	387.1	0.0044	39.492
	263	542.59	0.0062	55.355

RESULTS TABLE FOR MODAL ANALYSIS

Structural steel

	Deformation (mm)	Frequency (Hz)
Mode 1	36.15	5.1808
Mode 2	36.171	5.1969
Mode 3	27.993	17.776
Mode 4	41.443	30.481
Mode 5	45.04	31.103

Beryllium copper

	Deformation (mm)	Frequency (Hz)
Mode 1	35.241	3.8298
Mode 2	35.261	3.8417
Mode 3	27.29	13.14
Mode 4	40.401	22.532
Mode 5	44.397	22.847

CONCLUSION

By observing the structural analysis results, the stress value is less for Beryllium Copper than Structural steel but the deformation is more.

By observing the modal analysis results, the deformation and frequency are less for Beryllium Copper than Structural Steel. Due to less frequency, the vibrations of suspension system when Beryllium Copper is used are less.

So it can be concluded that using Beryllium Copper is better.

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