Modeling And Structural Analysis of Diaphragm Accumulator

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Abstract- *Diaphragm accumulators are hydro pneumatic accumulators with a flexible diaphragm as a separation element between the compressible gas cushion and the operating fluid. There are 30 diaphragm accumulator variants and more than 300 different fluid connections. The diaphragm accumulators are designed thereby either as weld type or as screw type and offered in various different steels, elastomers and with different gas ports. In the present work the screw type diaphragm accumulators is studied thoroughly and modeling of the diaphragm accumulator is done by the unigraphics and static and Modal analysis is performed on the structure by varying the different pressures and amplitudes and the mechanical properties are calculated along with the flexural rigidity of designs.*

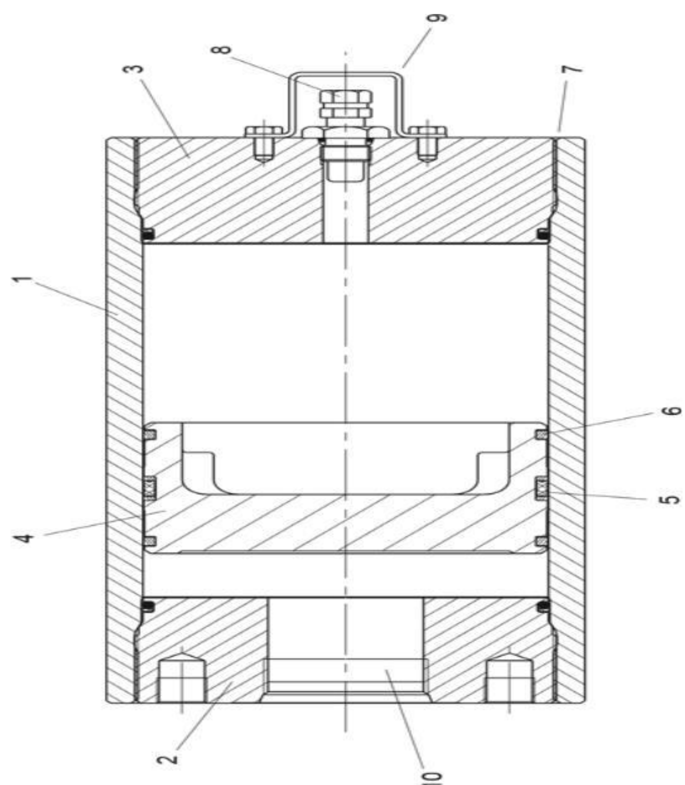
Keywords- Static analysis, Modal Analysis. NX, also known as NX Unigraphics, is an advanced CAD/CAM/CAE software package developed by Siemens PLM Software.

I. INTRODUCTION

All energetic systems, whether they are mechanical, electric, hydraulic, or some combination can be expressed in terms of effort and flow. The power transferred from one energetic element to the next is always a product of these two elements, force and velocity, voltage and current, pressure and volumetric flow rate. Since energy is the time integral of power, energy transfer can simply be measured as the integral of this product over time. The relationship between effort and flow is a reactionary one, governed by the properties of each system element. For potential energy storage elements, this relationship is an algebraic function between effort and the integral of flow, force and displacement for springs, voltage and charge for capacitors, pressure and volume change for hydraulic accumulators. Just as spring constants dictate the force displacement relationship of springs, bulk modulus—the inverse of compressibility— dictates the relationship between pressure and volume change in hydraulic accumulators. Since hydraulic fluid itself has a very high bulk modulus, miniscule changes in the volume of a closed hydraulic system result in large swings in pressure. Pump-motor noise can cause unsafe pressure fluctuations in this way if unaccounted. Commercial hydraulic accumulators remedy this by providing temporary storage for this oscillating flow in a device with a much more favourable pressure-volume change relationship. Because they contain bags of compressible gas, these accumulators have a much lower effective bulk modulus and thus respond to small changes in volume with much smaller changes in pressure.

II. HISTORY OF HYDRAULIC ACCUMULATORS

- Hydraulic accumulators have the ability to store excess energy and release it when needed. They are useful tools for improving hydraulic efficiency.
- Industrial accumulators are classified as hydro pneumatic. This type of accumulator applies a force to a fluid by the use of compressed gas



1, 2 & 3 Shell and Caps 4. Piston 5. Piston Sealing 6. PTFE Bearing Rings 7. Safety Bleed Grooves, 8. Gas Valve, 9. Gas Valve Protector, 10. Ports

III. TYPES OF HYDRAULIC ACCUMULATORS

- PISTON TYPE ACCUMULATOR
- BLADDER TYPE ACCUMULATOR
- DIAPHRAGM TYPE ACCUMULATOR
- SPRING TYPE ACCUMULATOR

Calculating Accumulator Size

Accurate calculation of accumulator size requires many factors to be considered – the working volume of fluid, ambient and maximum operating temperatures, the working pressure range etc. In addition, correction factors must be applied to allow for temperature compensation between the ambient and gas temperatures, and the consequent effect on pre-charge pressure the accumulator. Where the working cycle is sufficiently rapid that no heat transfer takes place, the process is termed adiabatic. Conversely, where the process takes place at a constant temperature, it is termed isothermal.

Accumulator Sizing Charts

The charts shown opposite are used to estimate the size of piston accumulator required to provide a given volume of fluid discharge from the accumulator.The curves are based on the following formula:

$\Delta V = 0.855\ Vo\ [(P_2/P_1)^{1/n} - 1]\ /(P2/P1)1\ /f$

Where,

ΔV = volume of fluid discharged,
Vo = Accumulator size,
f = charge coefficient,n = discharge coefficient,
P_2 = maximum system pressure,
P_1 = minimum system pressure
It is assumed that the gas pre-charge pressure = 0.9 P_1

Isothermal and Adiabatic Operation : In constructing the curves, the following factors have been assumed.For isothermal operation,

e.g.: slow charge and discharge time, f and n = 1

For adiabatic operation

,e.g.: fast charge and discharge time, f and n = 1.8

Note: The charts provide an estimate of the volume of accumulator required to store and release a given volume of fluid under specified conditions. In practice, the true charge and discharge coefficients will depend on the application, and may cause significant variations from the chart results. Where the ratio P_2/P_1 exceeds 1.9, a fatigue analysis is necessary

IV. DIAPHRAGM TYPE ACCUMULATOR

Description HYDAC diaphragm accumulators utilize the compressibility of a gas (nitrogen) in storing hydraulic energy. The gas is required because fluids are practically incompressible and thus, cannot store energy by themselves. The diaphragm is utilized to separate the gas and the fluid sides of the accumulator.

The diaphragm accumulator functions by drawing in fluid from the hydraulic circuit when the pressure increases and thus, compresses the gas. It returns this energy to the circuit as the pressure decreases by the expansion of the gas. A poppet is incorporated into the diaphragm to prevent its extrusion through the fluid port.

HYDAC manufactures two types of diaphragm accumulators:

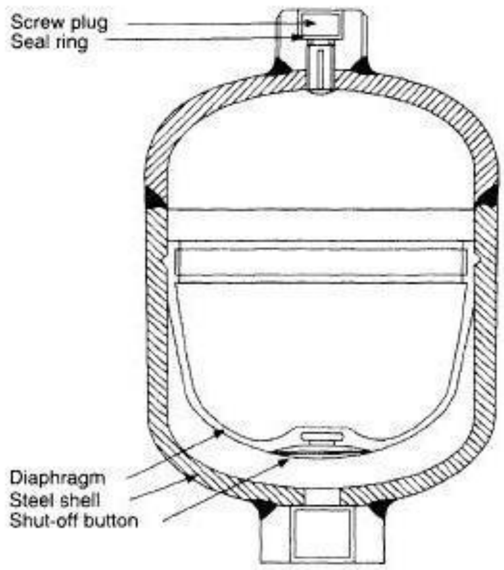
- welded (non-repairable)
- Threaded (repairable)

These have been successfully applied to both industrial and mobile applications for energy storage, maintaining pressure, leakage compensation, and vehicle hydraulic systems (e.g. Brake and suspension).

Construction Both types of diaphragm accumulators have the same basic construction. The difference is in the shell. The welded version has a shell that is electron-beam welded, and therefore cannot be repaired. The threaded type has a shell made up of two halves (top and bottom) which are held together by a threaded locking ring.

Diaphragm Materials Not all fluids are compatible with every elastomer at all temperatures. Therefore, **HYDAC** offers the following choice of elastomers:

- **NBR** (Standard Nitrile)
- **LT-NBR** (Low Temperature Nitrile)
- **ECO** (Epichlorohydrin)
- **IIR** (Butyl)
- **FPM** (Fluor elastomer)



diaphragm type accumulateor

Corrosion Protection

For use with certain aggressive or corrosive fluids, or in a corrosive environment, **HYDAC** offers protective coatings and corrosive resistant materials (i.e. stainless steel) for the accumulator parts that come in contact with the fluid, or are exposed to the hostile environment.

Mounting Position Diaphragm accumulators by design may be mounted in any position. In systems where contamination is a problem, a vertical mount with fluid port oriented downward.

HYDAC diaphragm accumulators are designed to be screwed directly onto the system. We also recommend the use of our mounting components, to minimize risk of failure due to system vibrations.

Applications: Some common applications of diaphragm accumulators are:

- Agricultural Machinery & Equipment
- Forestry Equipment.
- Energy power plants
- Plastic, die casting machinery
- Steel industry
- Machine tools
- Cranes vehicles
- Oil & gas / off shoreSuspension system for vehicles

To improve computational convergence and efficiency, the accumulator shell is assumed to be compliant. As a result, the fluid starts accumulating in the chamber even before the preload pressure is reached, so that at preload pressure the accumulator already stores a certain volume of fluid. The structural compliance can be set to a very small value, but not to zero.The accumulator is described with the following equations:

$$q = \frac{dV_F}{dt}$$

$$V_F = \begin{cases} K_s \cdot p & \text{for } p \le p_{pr} \\ V_{pr} + k\left(p - p_{pr}\right) & \text{for } p_{pr} < p < p_{\max} \\ V_{\max} + K_s\left(p - p_{\max}\right) & \text{for } p \ge p_{\max} \end{cases}$$

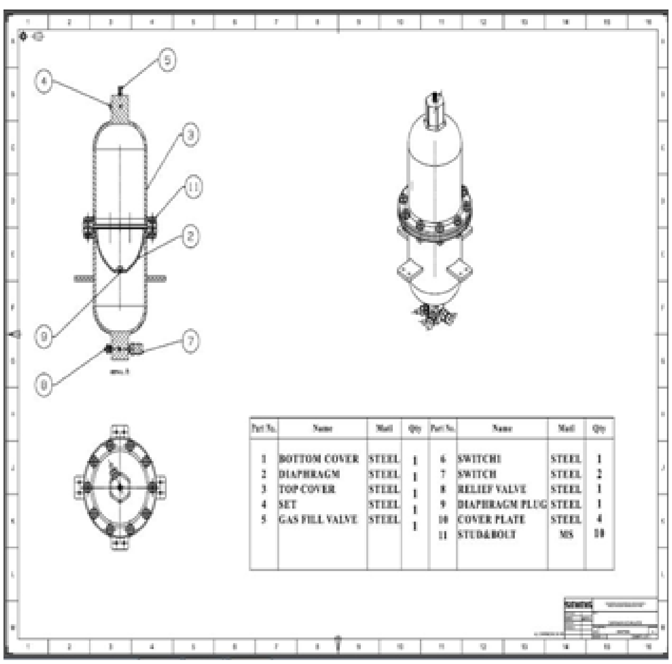
$$k = \frac{V_{\max} - V_{pr}}{p_{\max} - p_{pr}}$$

Literature Survey: Zainol (1990) have reported that the major problem of back pressure vessel was the loss of steam of about 27 to 50% to the atmosphere. This is due to its design and size which are not specific for accumulating and controlling the steam distribution to the sterilizers and factory heating. Its function is more as a temporarily steam storage vessel for maintaining the turbine performance. The practice of venting off steam from the back pressure vessel to atmosphere over a certain minimum time is inevitable when the accumulation of steam in the back pressure vessel exceeds the relief valve set point (around 45 psi). Consequently, there is a deficit in steam supply to the sterilizers, resulting in fresh fruit bunches not being fully sterilized. Mustafa (1994) have identified three major types of disturbances that led to the severe steam fluctuations in steam supply and demand. The most critical type is random steam fluctuations in boiler, steam turbine, back pressure and sterilizers resulting in steam venting or time delay. The next disturbance is variation of boiler pressure due to inconsistent fuel quality which affects all units downstream and the last type is random steam injection in palm oil stream such as digester to maintain temperature and flow.

V. WHAT IS CADD ?

Computer-aided design (CAD), also known as computer-aided design and drafting (CADD), is the use of computer technology for the process of design and design-documentation. Computer Aided Drafting describes the process of drafting with a computer. CADD software, or environments, provides the user with input-tools for the purpose of streamlining design processes; drafting, documentation, and manufacturing processes. CADD output is often in the form of electronic files for print or machining operations. The development of CADD-based software is in direct correlation with the processes its seeks to economize; industry-based software (construction, manufacturing, etc.) typically uses vector-based (linear) environments whereas graphic-based software utilizes raster-based (pixilated) environments.

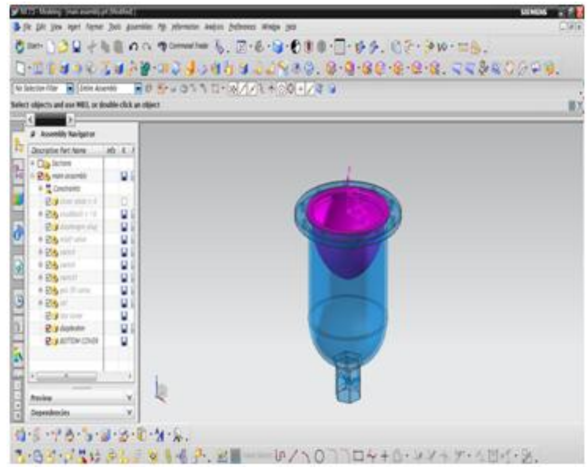
VI. INPUTS FOR THE PROJECT



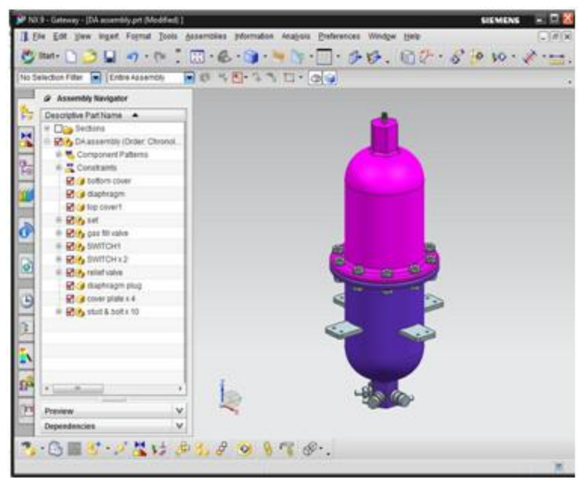
2D Drawing

Different parts of diaphragm accumulator

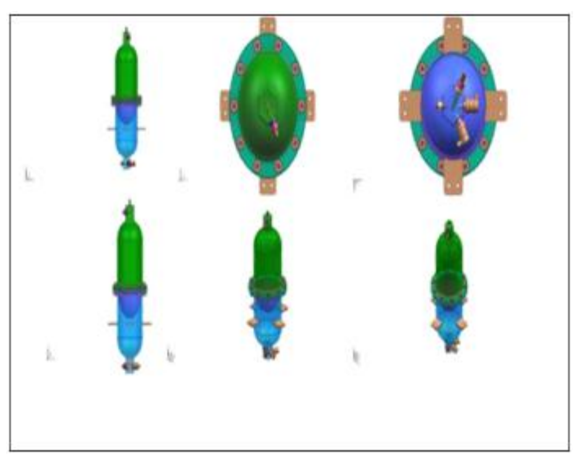
1. Bottom cover
2. Top cover
3. Diaphragm
4. Diaphragm plug
5. Gas inlet valve
6. Pressure valve (i)
7. Pressure valve (ii)
8. Hydraulic inlet valve
9. Gas outlet valve
10. Relief valve
11. Nut & bolt
12. Assembly of bottom cover & diaphragm
13. Total assembly
14. Different views of diaphragm accumulator



Assembly of bottom cover & diaphragm



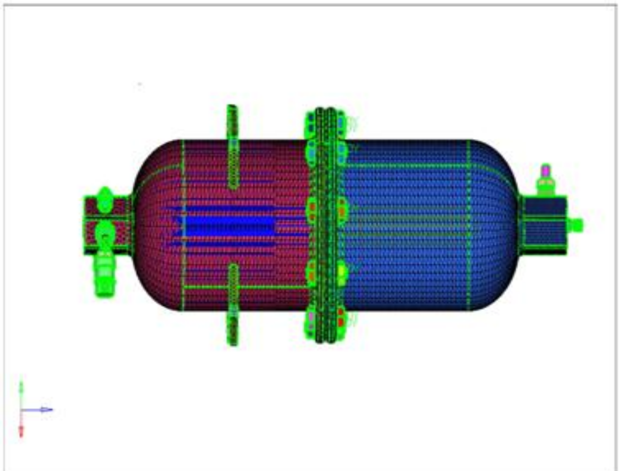
Total assembly



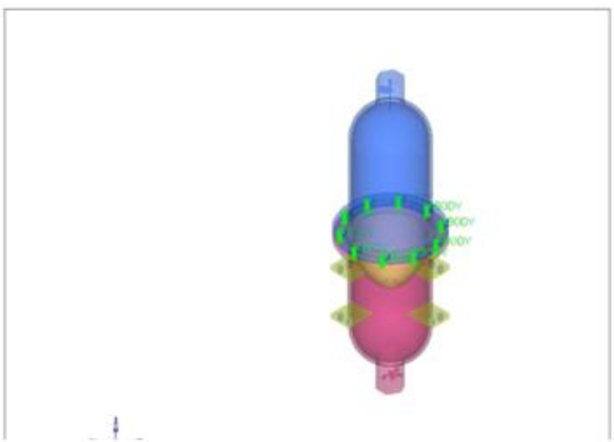
Different views of diaphragm accumulators

MESHING OF A DIAPHRAGM ACCUMULATOR

Hyper Mesh delivers customers with a advanced suite of simple to-utilize official document to assemble and modify CAE models. For 2d and 3d model creation, customers have access to a mix of mesh-generation capabilities, and also Hyper Mesh's compelling auto coinciding module.



Meshed Parts of Nuts And Bolts & Total Assembly in hypermesh



Meshed Parts of Top View & Total Assembly

STRUCTURAL ANALYSIS:

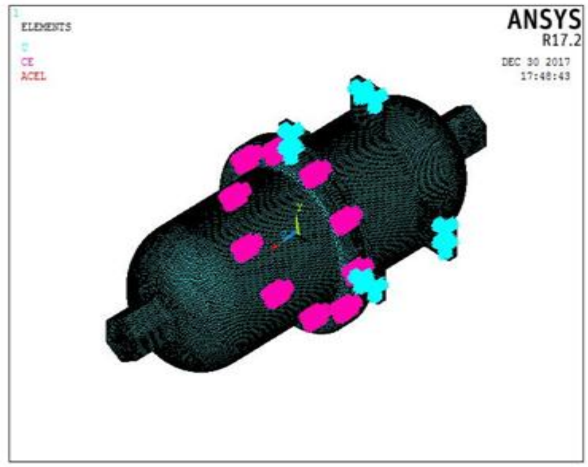
Structural analysis is probably the most common application of the finite element method. The term structural (or structure) implies not only civil engineering structures such as bridges and buildings, but also naval, aeronautical, and mechanical structures such as ship hulls, aircraft bodies, and machine housings, as well as mechanical components such as pistons, machine parts, and tools.

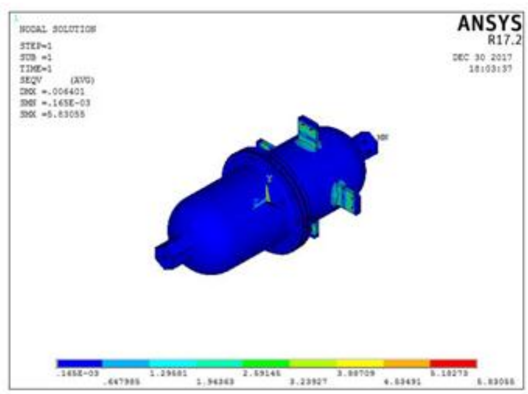
Modal Analysis:

Modal analysis is used to determine the vibration characteristics (natural frequencies and mode shapes) of a structure or a machine component while it is being designed. It can also serve as a starting point for another, more detailed, dynamic analysis, such as a transient dynamic analysis, a harmonic response analysis, or a spectrum analysis.

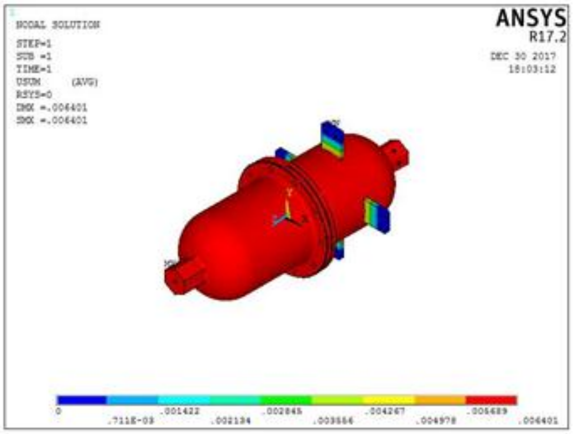
GRAVITATIONAL ANALYSIS

- **9810 mm/s2 load applied in-ve Z direction**
- **Below are the stress & displacement details**

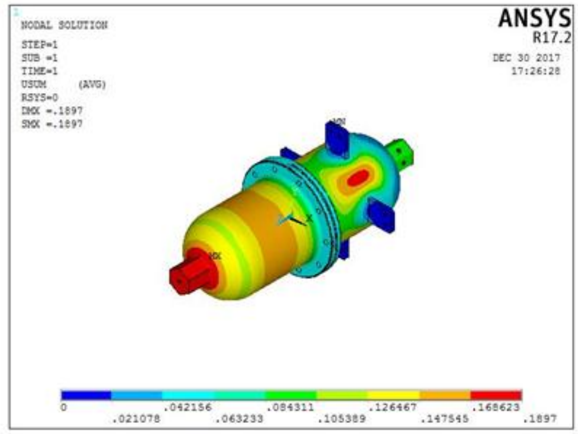




Vonmises stresses



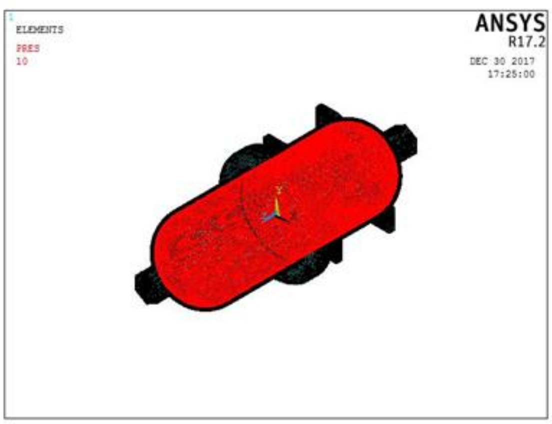
Displacement plot



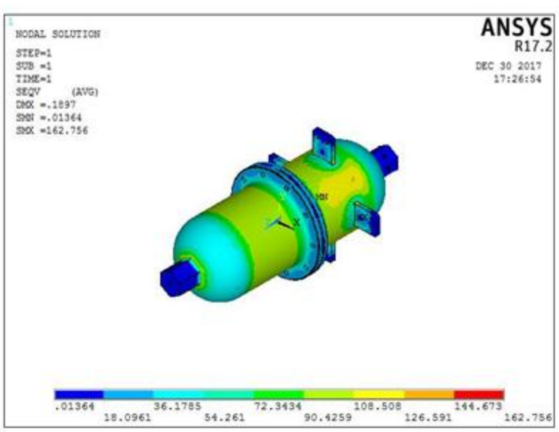
Displacement plot

Pressure analysis

- Varying Pressure load applied internally
- Below are the stress & displacement details
- Steel material has the yield strength has 250 Mpa, the stress achieved is 135 Mpa.
- The structure is safe with the working load on 10 Mpa.



Pressure analysis with 10mpa



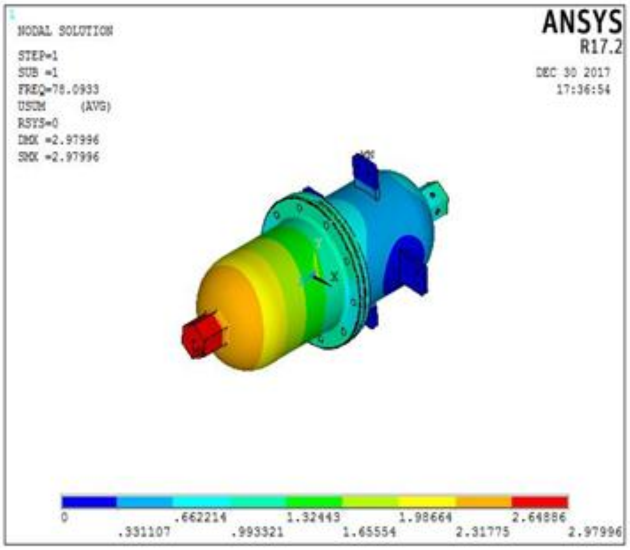
Vonmises stress

Result Summary:

Pressure load (N/mm^2)	Displacement (mm)	Stress (Mpa)
2	0.37	32.5
5	0.94	81.3
8	0.15	130.2
10	0.18	162.7
15	0.28	244.1
18	0.34	292.9

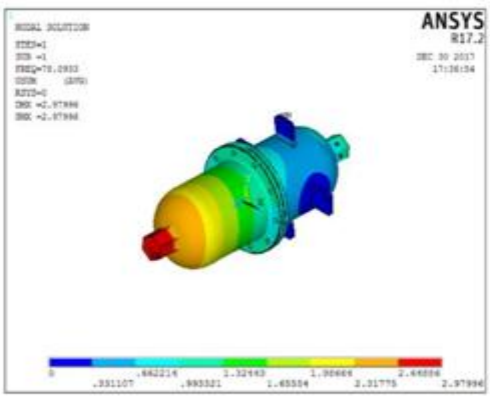
MODEL ANALYSIS

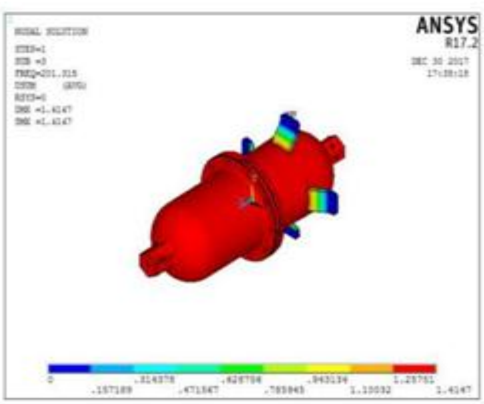
- Constrained Modal Analysis has to be performed in 20 modes
- First Natural Frequency of this structure is 78Hz.

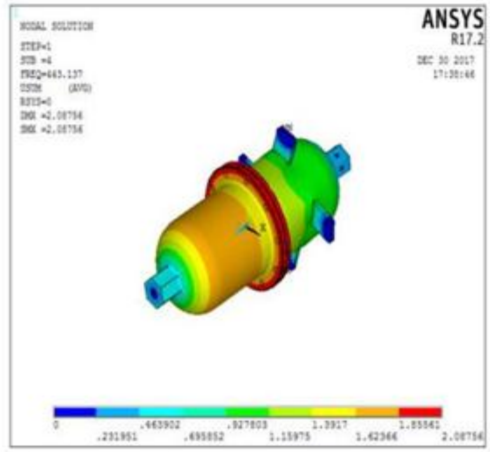


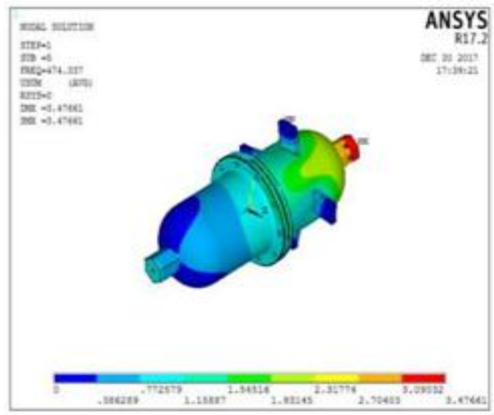
Displacement plot of diaphragm accumulator in constrain analysis

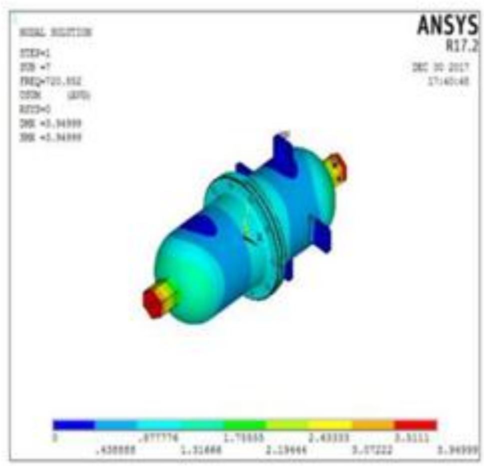
Frequencies at 20 mode shapes

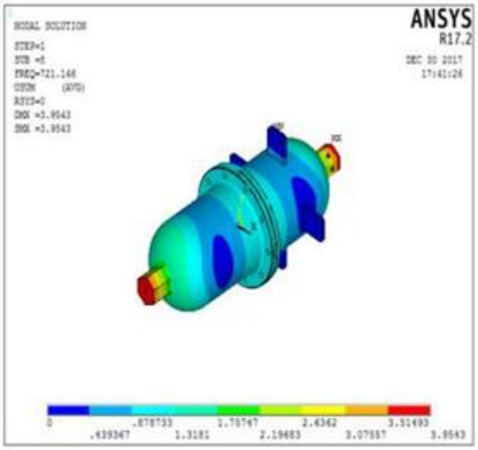












VII. CONCLUSION

- Steel material has the yield strength has 250 Mpa, the stress achieved is 135 Mpa.
- The structure is safe with the working load on 2 Mpa.
- First Natural Frequency of this Structure is 86Hz this is above the excitation criteria of 25Hz
- Lower installed system costs, accumulator assisted hydraulics can reduce the size of the pump and electric motor which results in a smaller amount of oil used, a smaller reservoir and reduced equipment costs.
- Less leakages and maintenance costs, the ability to reduce system shocks will prolong component life, reduce leakage from pipe joints and minimize hydraulic system maintenance costs.
- Improved performance, low inertia bladder accumulators can provide instantaneous response time to meet peak flow requirements. They can also help to achieve constant pressure in system using variable displacement pumps for improved productivity and quality.
- Reduced noise levels, reduced pump and motor size couple with system shock absorption overall machine sound levels and result in higher operator productivity.
- Flexible design approaches. A wide range of accumulator types and sizes. including accessory items, provides a versatile and easy to apply design approach
- Reduce energy cost and cost savings up to 33% are achievable in high performance industrial machinery using accumulators.

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