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Design and Fabrication of Industry Based Hydraulic Manifold Using Additive Manufacturing

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Abstract

The main objective of our project is to re-design the hydraulic manifold and fabricate the prototype using 3D printing to reduce weight, improve flow performance and reduce the cost. The simple existing industrial manifold block is designed using CAD software. Then analysis of the flow field characteristics and change in pressure of right-angled flow passage of supply line and return line is carried out in the typical hydraulic manifold block which is made from the conventional manufacturing process. Then to redesign the industrial manifold effectively with angled flow passage and analyze the optimization level. This modified design mainly reduces the major loss in the fluid called pressure loss and reduces the velocity of fluid during the change in direction of flow. As we are in the era of industry 4.0, the fabrication of this product is to be made with the currently emerging technology called additive manufacturing. Another reason to go with AM is because of the complex structure of this manifold. It will significantly reduce the production time and machining cost. Our project comes up with producing the 3D printed prototype of the modified manifold from the industry. For this analysis process, we have selected the materials Aluminium alloy (AL 6061-T6) and Stainless steel (SS-316), because of their high strength to weight ratio and low material cost. Hence it will reduce the overall production cost and it will greatly reduce the weight.

Keywords: Hydraulic manifold, Additive manufacturing, 3D printing, pressure analysis, flow analysis (CFD), Pressure loss.

1. Introduction

Hydraulic systemsuse the pressure of fluid inside an enclosed structure to transfer electricity. Hydraulic systems have a number of benefits over mechanical and electrical systems, including the ability to provide a large amount of power in a confined room**.**For a variety of purposes, a hydraulic device is an effective power transmitter. To begin with, its basic levers and push buttons render starting, stopping, accelerating, and decelerating a breeze. This also improves power precision. It can also handle a wide range of weights and it is a fluid mechanism with no bulky gears, pulleys, or levers. It maintains a steady force independent of speed changes. Hydraulic systems, on the whole, are easy, stable, and cost-effective since they have less moving parts than mechanical and electrical systems, making them simpler to operate. One of the main reasons for selecting a hydraulic system over other systems is its power density is high.

1.1 Hydraulic Manifold

A pressure-driven complex is a part inside a pressure-driven framework used to direct the progression of liquid which thusly controls the exchange of force between actuators, siphons, and different segments. It is considered as the core of the water-driven framework since it is the Middle from which all the stream ways of the framework are defined. It resembles a switchboard in an electrical circuit since it allows the administrator to

control how much liquid streams between what segments of water-driven hardware. A complex is made out of grouped pressure-driven valves associated with one another. It is the different mixes of conditions of these valves that permit complex control conduct utilizing a complex. These waters powered valve manifolds easily direct liquid stream and pressing factor between siphons, actuators, and different parts in a pressure-driven framework. Various line associations at one focal area permit the utilization of fundamental extras, for example, pressure switches and measures. The complex is associated with the switches in the administrator's lodge which the administrator uses to accomplish the ideal complex conduct. It is the different mixes of conditions of these valves that permit complex control conduct utilizing a complex.[1-5].

1.2 Additive Manufacturing:
Metal Additive Manufacturing processes

The design of a three-dimensional structure from a CAD model or a digital 3D model is known as additive manufacturing. To fabricate this manifold block, we have chosen two materials AL-6061 T6 and SS-136.Metal Additive Manufacturing processes currently use a variety of technologies. For the fabrication of manifolds, the Selective Laser Sintering (SLS) method was chosen.

1.2.1 Selective Laser Sintering (SLS):

A powdered metal type material is transferred from compartments containing fresh powder material into the formation stage in the process chamber with a recoating system in the Specific Laser Sintering (SLS) measure. A powerful laser checks the slender layer of powder at that stage, sintering powder particles that resemble the cross-segment of the primary layer of the 3D component. The recoater then transfers all of the newer powder from the jar to the outside of the main sheet, and the shape stage slips one layer depth. The resulting cross-section of the 3D model is filtered and sintered in the same way as the principal layer.The current layer is created and appended to the last layer by the laser filtering measure, resulting in a strong component.[6-10].
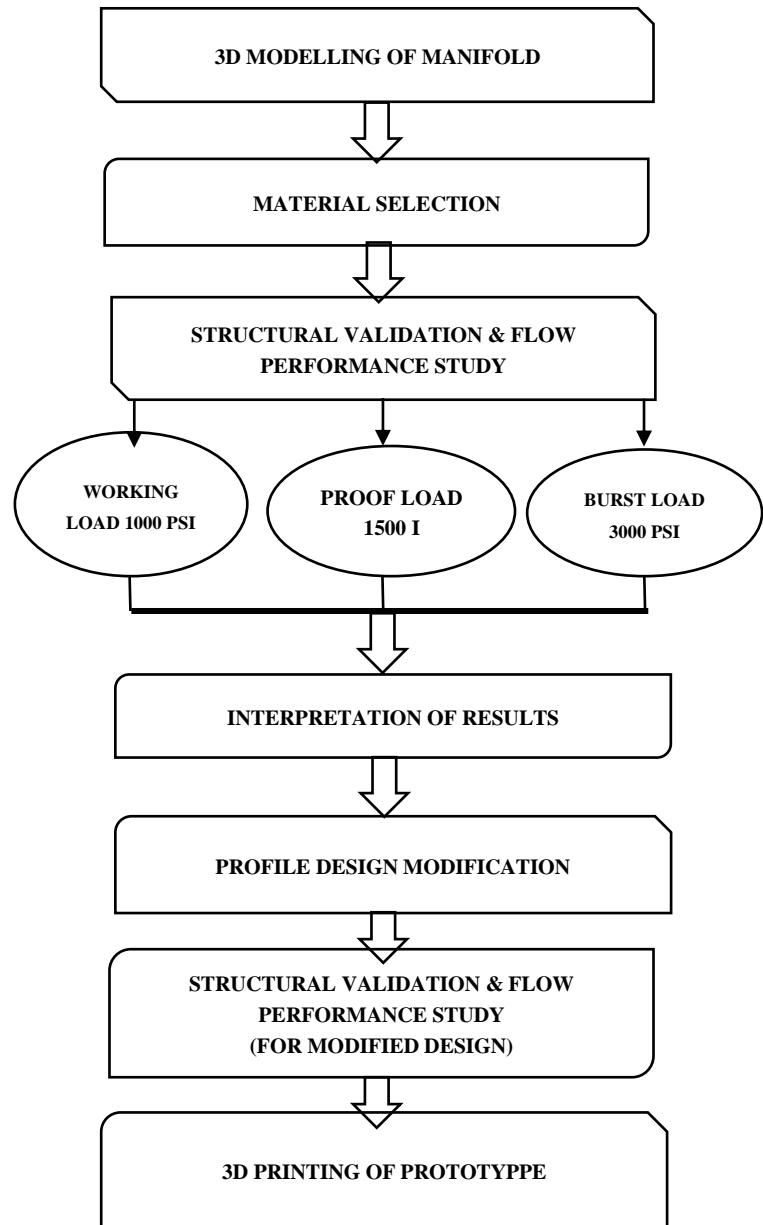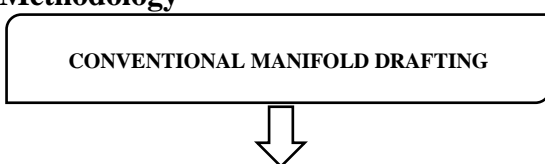
2. Methodology and Procedure
2.1 Methodology

Fig.1.Methodology

2.2 Material Description:
AL 6061-T6 (AMS 4117)

Precipitation-hardened 6061 aluminium alloy (UNS designation A96061) contains magnesium and silicon as main alloying components. Originally known as "Alloy 61S." It is one of the most widely used aluminium alloys for general-purpose applications.

2.3 Mechanical Properties:

The temper, or heat treatment, of 6061 has a significant impact on its mechanical properties. Regardless of temper, Young's Modulus is 69 Gpa (10,000 ksi). It also has a Poisson's ratio of 0.33.

The T6 temper 6061 has been treated to have the highest precipitation hardening (and therefore yield strength) for a 6061-aluminum alloy. It has a yield strength of at least 240 Mpa and an overall tensile strength of at least 290 Mpa (42 ksi) (35 ksi). 310 Mpa (45 ksi) and 270 Mpa (39 ksi) are the more common values. In addition, the yield power of some varieties of stainless steel can be exceeded.It has elongation of 8% or more in thicknesses of 6.35 mm (0.250 in) or less; in thicker pieces, it has elongation of 10%. Mechanically, T651 temper is similar to T651. At 25 °C (77 °F), the thermal conductivity of 6061-T6 is usually about 152 W/mk

Table.1 Chemical Composition of 6061 alloy

CHEMICAL ELEMENT	MASS %
Aluminium (Al)	95.85 – 98.56
Magnesium (Mg)	0.8 – 1.2
Silicon (Si)	0.40 – 0.8
Iron (Fe)	0.0 – 0.7
Copper (Cu)	0.15- 0.40
Chromium (Cr)	0.04 – 0.35
Zinc (Zn)	0.0 – 0.25
Titanium (Ti)	0.0 – 0.25
Manganese (Mn)	0.0 – 0.15
Remainder	0.05 each, 0.15 total

2.3 Drafting of Conventional Manifold

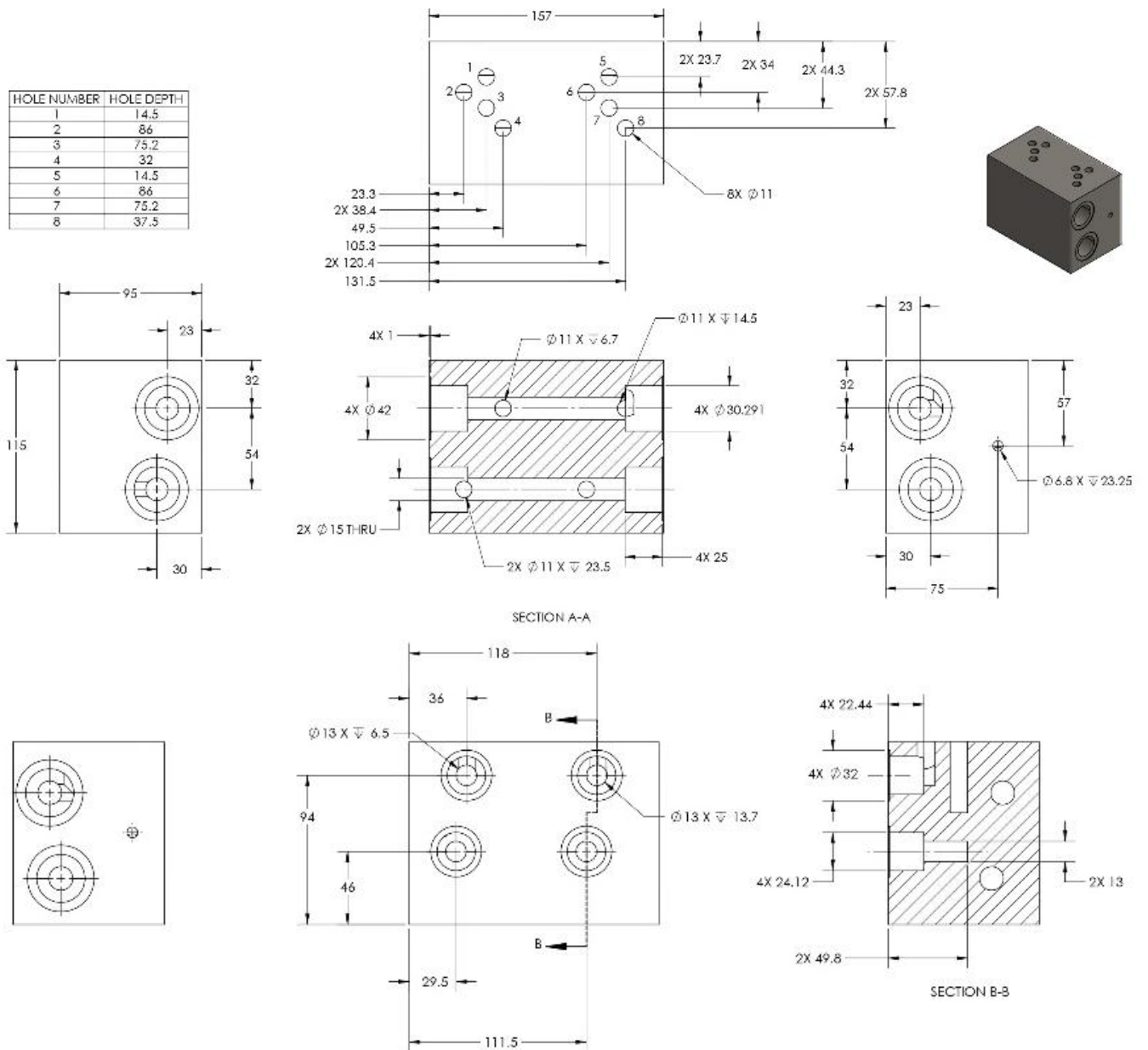| HOLE NUMBER	HOLE DEPTH
1	14.5
2	86
3	75.2
4	32
5	14.5
6	86
7	75.2
8	37.5

Fig.2. 2D Drawing of the Hydraulic Manifold

2.4 Designing of Manifold:

The 3D model of a manifold is generated from the draft sketch, with the CAD software SOLIDWORKS
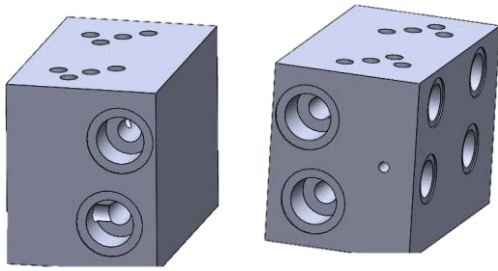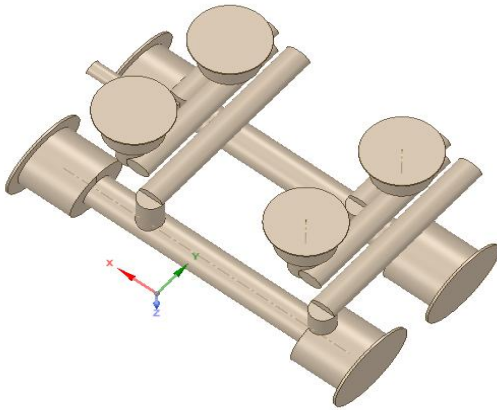
Fig.3. Solid model of hydraulic manifold

Fig4.3D model of manifold- flow path

2.5 Structural Analysis and Flow Simulation

Structural Analysis:

The objective of this analysis is to find the stress concentration factors at various points of the manifold profile. First, the static structural analysis option is chosen from the workbench and the geometry of the manifold which we have created earlier is imported. Then in Geometry Modeler, the Meshing of the manifold is done. Then the edges are refined finely for getting more accurate values.Since it is a higher-order 3-D, 10-node element, theSOLID187element form is used. SOLID187 has quadratic displacement behaviour, making it ideal for modelling irregular meshes (such as those produced by CAD/CAM systems). The element is made up of ten nodes, each of which has three degrees of freedom: translations in the nodal x, y, and z directions.

- Fixed support is applied on two edges of the manifold on the edges of the side adjacent to the supply line and return line.
- Then the flow passage is selected (supply line/return line) and the working pressure of 1000psi is applied
- As this hydraulic system works on a closed path, we applied the compensating force on the inlet and outlet regions directing outside the manifold with the formula:

$$Force = Pressure \times Area$$

- After applying all constraints, the force reaction is verified. In general, for pressure analysis, the force reaction should be zero always.
- Then by solving the analysis, the total deformation and equivalent stress are obtained for the applied load conditions. Then the maximum and minimum values are noted and the region of stress concentration is simulated.
- Then with the help of probe, marked the regions where the change in direction and sudden change in diameter of flow passage to get the values of equivalent stress.
- From the stress values, the Factor of Safety is calculated for all the three load conditions separately with the help of the formula and the results are obtained successfully.

2.6 Flow Analysis:

The incompressible fluid flow analysis is carried out for the various load conditions, for supply line and return line with the following steps.

- The flow simulation analysis begins with picking 'Fluid Flow (CFX)' from the toolbox.
- The inverted geometry of the hydraulic manifold block which is solid at the flow path is imported.
- Next, the mesh is generated by refining the element size to 2.5mm
- Then the named selection of names INLET, OUTET, and WALL is created in the meshing window to make the software understand the flow path.
- After this, the steady-state flow analysis is setup and the boundaries are fixed for the inlet, outlet, and wall of the flow path. Here the fluid is assumed to be water and the setup ends with guiding the tool to solve with the continuity equation.
- Next, the pressure contour and velocity streamline are obtained as a result. It shows that the pressure applied at the inlet reduces due to a sudden change in direction of flow, which leads to an increase in velocity at that region of turning.

3. Results and Discussion
3.1 Structural Analysis:
From the structural analysis, we found that the Factor of safety is more than 1 for all the stress-concentrated areas in every load condition. So, the hydraulic manifold is structurally safe.
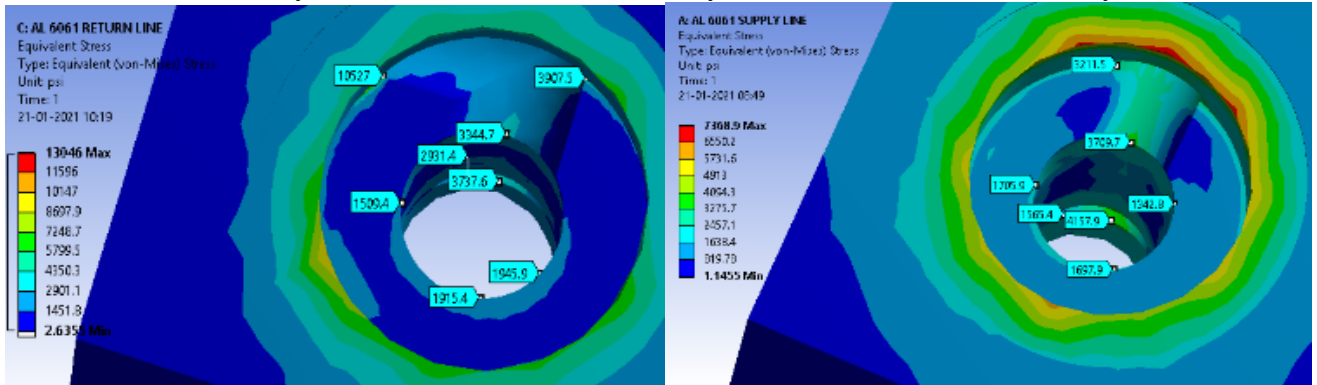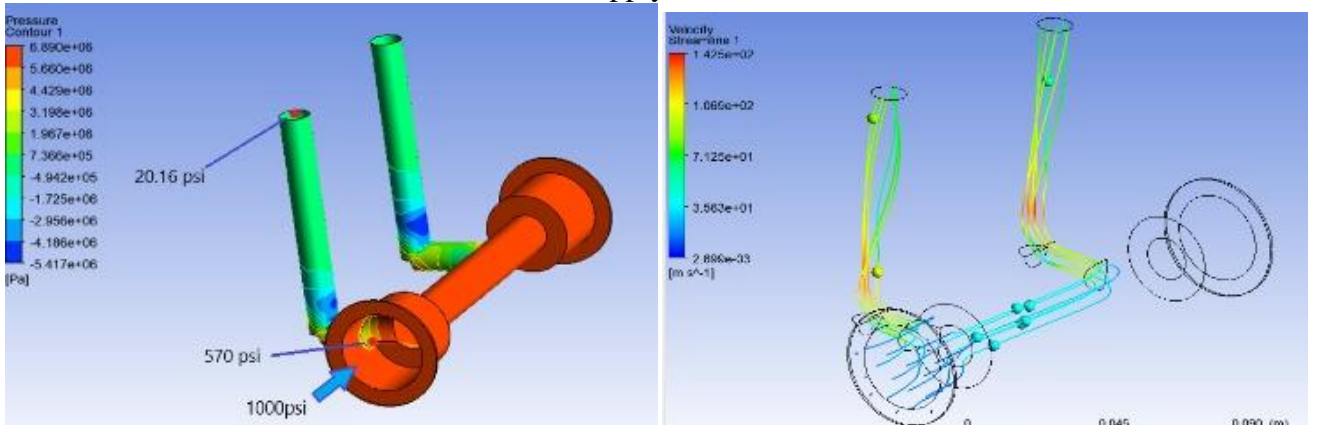

Fig.5: Supply line & Return line

3.2 Flow Analysis:
The incompressible fluid flow analysis is carried out for the three load conditions in the supply line and return line individually and the results are posted here:
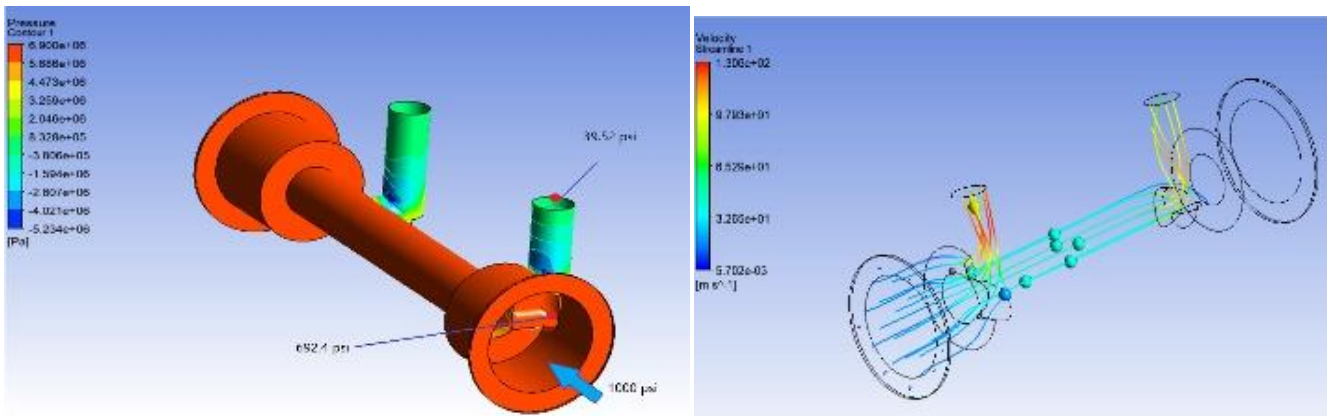
3.2.1Working load or Endurance load (1000 psi)
Supply Line

Pressure contour   **velocity streamline**
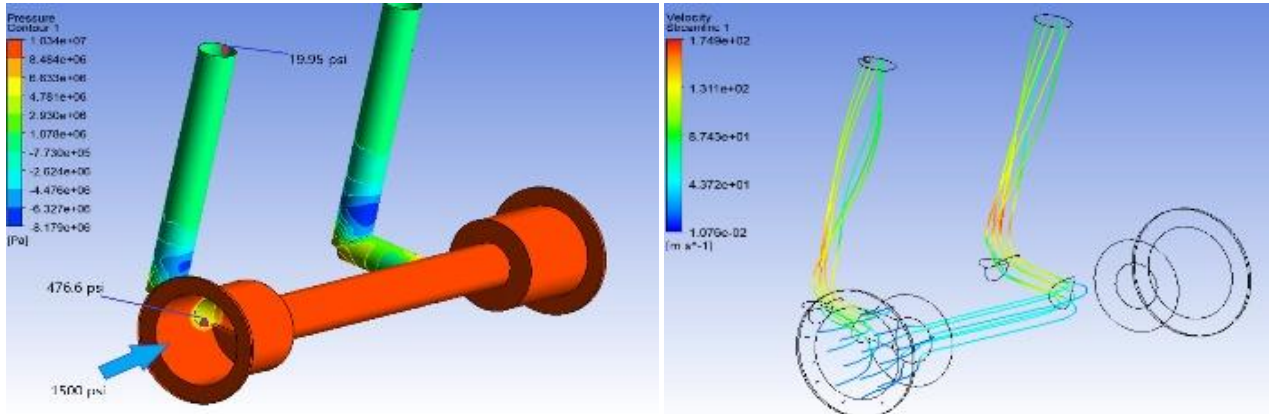**Fig.6: working load (Supply line)**

Return Line

Pressure contour   **velocity streamline**
Fig.7: working load (Return line)
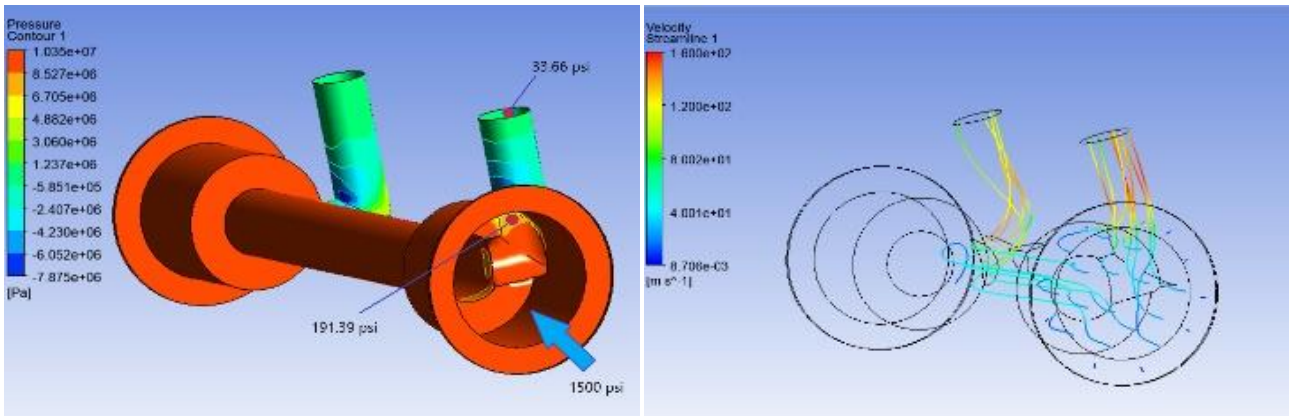
3.2.2Proof load (1500 psi)

Supply Line

Pressure contour   velocity streamline
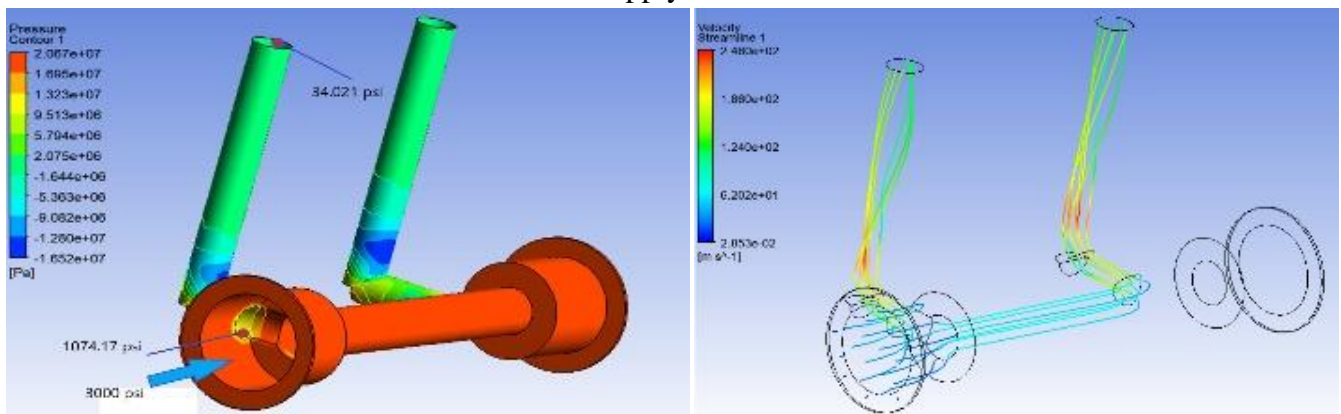**Fig.8: Proof load (Supply line)**
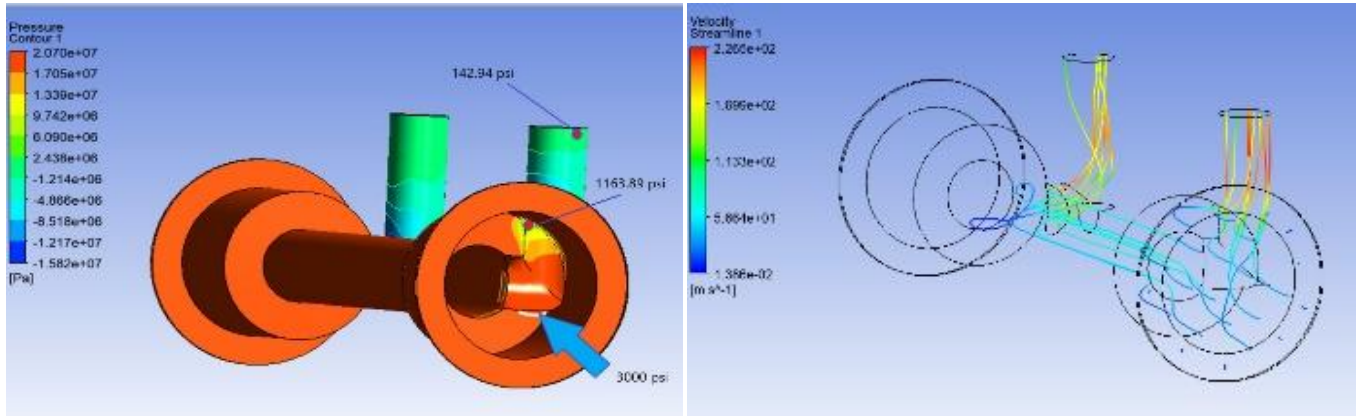
Return Line

Pressure contour   velocity streamline
Fig.9.Proof load (Return line)

3.2.3Burst load (3000 psi)

Supply Line

Pressure contour   velocity streamline
Fig.10: Burst load (Supply line)

Return Line

Pressure contour   **velocity streamline**

Fig.11: Burst load (Return line)

4. Advantages and Applications

Advantages:

The main advantages in using a manifold system are:

- Minimizes leak paths
- Reduces the number of connections
- Simplifies hose installation and system design
- Designs accommodate multiple industries
- Standard porting options
- Compact design for both low- and high-pressure applications

Using additive manufacturing for fabrication has the following advantages:

- The overall wastage of material in this process is very less and so it saves more money and also it saves energy
- It is very easy to fabricate the products with more complex design structures
- This process allows us to make more customized and personalized products for all scales of production

Applications:

Hydraulic manifolds are seen in a variety of situations.

- Heavy-duty building machinery
- Farm machinery
- Applications in the marine environment
- Aerospace and defense industries
- Material processing and storage facilities
- Quarrying machinery
- Uses of bionic engineering-quadruped robots

Conclusion and future work

The benefit of this layer-by-layer fabrication is we can modify the right-angled flow path into an angled passage and the sudden change in geometry can be converted into a tapered flow path. Finally, it results in the reduction of weight and improvements in the performance of the manifold. As of now we have dealt with the supply and return flow lines inside the manifold and the three pressure conditions that have to be performed for the same AL6061 material. To enhance the quality of this manifold, we are going to carry on the following future works:

- Re-designing of the hydraulic manifold
- Perform the pressure analysis and flow analysis for the same under the given three pressure conditions for AL 6061- T6
- To reduce the flow loss, we are creating the curved bend in place of the L bend and instead of the flow path with change in diameters, to be converted into the tapered path to reduce the major and minor losses in the fluid.
- Perform the same previous steps for SS316 material.

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