

DESIGN AND OPTIMIZATION OF AUTOMOTIVE MUFFLER FOR NOISE AND VIBRATION REDUCTION

Submitted in partial fulfillment of the requirements for the award
of Bachelor of Engineering degree in Mechanical Engineering

By

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**DEPARTMENT OF AUTOMOBILE ENGINEERING
SCHOOL OF MECHANICAL ENGINEERING**

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

Accredited with Grade "A" by NAAC

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March 2021



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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of L.DEEPAK RAJ (37860006), V.GOKUL (37860011), YALLA KRISHNA SAI DURGA SRINIVAS (37860042) who carried out the project **"DESIGN AND OPTIMIZATION OF AUTOMOTIVE MUFFLER FOR NOISE AND VIBRATION REDUCTION"** under my supervision from November 2020 to April 2021.

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ABSTRACT

The main purpose of a muffler in an automobile is to reduce the engine noise produced by combustible products when passing through the exhaust system. An automotive muffler is designed and modified to achieve impoverishment and backpressure targets. Today's exhaust systems are developed to deliver minimum noise, emissions, maximum durability, packaging, safety, flow rates, lower system restriction, high-temperature compatibility, Corrosion resistance, easy serviceability, and cost-effectiveness. The exhaust system has various attributes, including vibration, acoustics, thermal distribution, durability, flow, power loss, in addition to its interface with the vehicle.

To achieve maximum noise reduction with the minimum pressure drop is very difficult. The main objective of the project is to reduce the noise level of the muffler using CFD techniques. In this study, an automobile muffler is taken for noise study, in which total pressure drop and back pressure are studied existing and proposed muffler. Modeling will be created using CATIA, CFD analysis will be conducted using ANSYS Fluent.

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CHAPTER 1

INTRODUCTION

Silencer is also termed as the muffler. The muffler is used for reducing the noise emitted by the exhaust of an internal combustion engine, which is the main source of noise pollution. It becomes a much vital concern when used in residential areas or areas where noise creates a hazard. Generally, a noise level of more than 80-90 dB is harmful to a human being.

The major sources of noise in an engine are divided into two parts, the first is the exhaust noise, and the second is the noise produced because of the friction from different parts of the engine.

The engine exhaust noise is the most presiding. Noise is reduced at the most effective way of using a muffler in the engines. The level of noise reduction depends upon the design, construction, and working procedure of mufflers.

Suppose a car is running without a muffler, then the noise level is unbearable. Most of the advances in acoustic filters and exhaust mufflers came out in the last four decades. Hence, the muffler's good design should give the best noise reduction and offer optimum backpressure for the engine.

Backpressure is the extra static pressure exerted by the engine's muffler through the restriction in the flow of exhaust gases. The insertion loss is the difference in the acoustic power radiated without and with the muffler fitted.

By that, We decided to analyze over muffler to reduce the natural frequency by using making vibration analysis over the muffler.

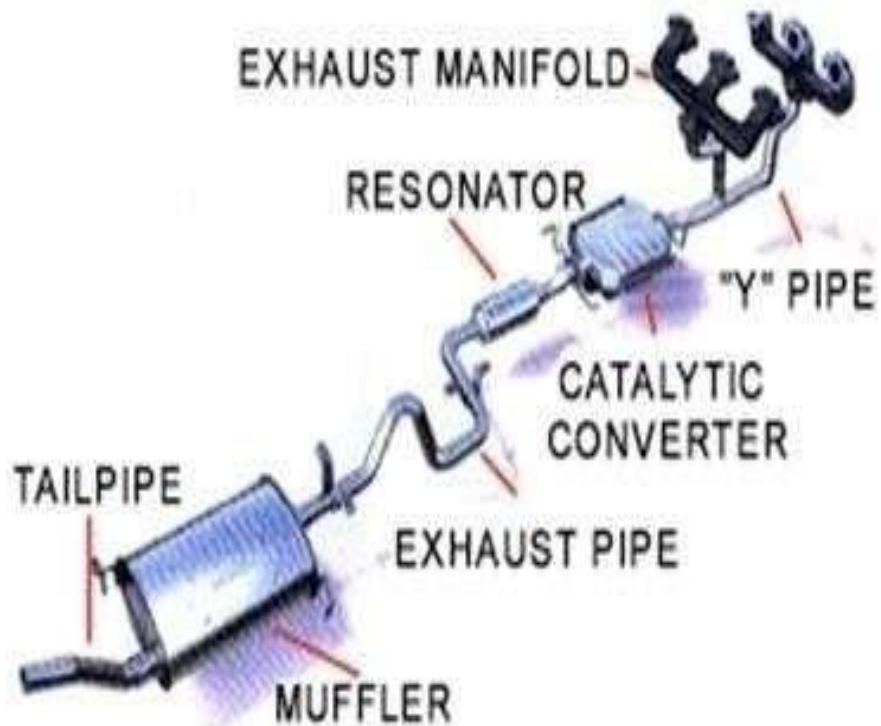


Fig: 1.1: Exhaust system

Exhaust System Schematic

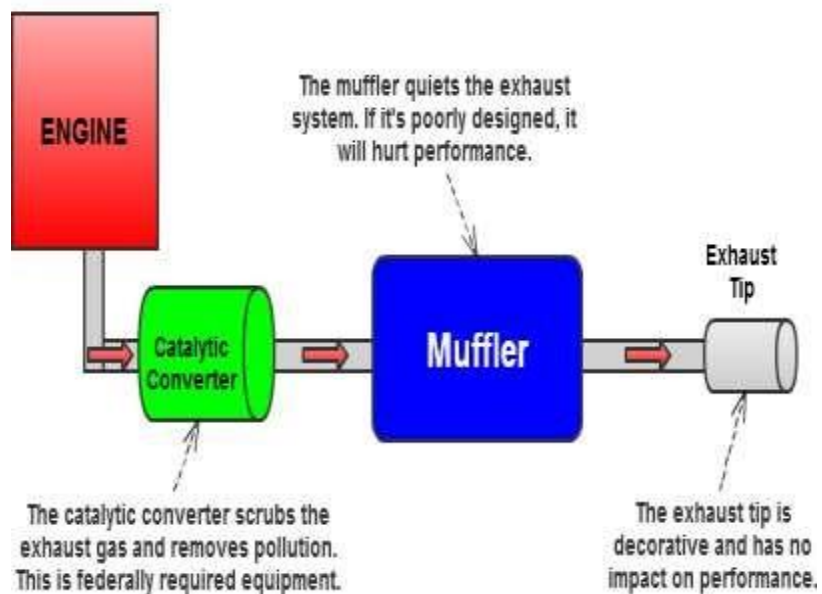


Fig: 1

In some designs, the muffler's outer shell is made oval in shape to permit adequate clearance with the ground. Many of the mufflers' outer shells are made up of steel coated by lead-tin alloy or aluminium to prevent corrosion, which the exhaust condensate has caused.

Most of the mufflers are designed with small drain holes in the outside shell to drain out the condensate in the exhaust gases and resist corrosion.

1.1. TRANSMISSION LOSS

Transmission loss has a key role in the effectiveness of mufflers for engineering applications. It indicates the sound energy is prevented from traveling through a muffler. Transmission loss is the difference in sound power level between incident wave entering and transmitted wave exiting muffler when muffler termination is anechoic. It is the property of the muffler only. Few calculation methods are the transfer matrix method, finite element method, boundary element method, and computational fluid dynamics.

1.2. INSERTION LOSS

The insertion loss of sound pressure level difference at a point usually outside the system without and with muffler present though insertion loss is more helpful to the industry, the calculation not only depends on muffler geometry but also depends on source impedance and radiation impedance.

1.3. NOISE TARGET

The noise target for different vehicles is mentioned in table 1. The allowable noise target in India for two-wheelers of 110 cm³ is 77 dB (A).

Table 1.1: Noise limit value of vehicle in India

Type of vehicle	Noise LimitsdB(A)
1) Two-wheeler	
Displacement up to 80 cm ³	75
Displacement of 80 cm ³ -175 cm ³	77
Displacement more than175 cm ³	80
2) Four-wheeler	
Displacement up to 175cm ³	77
Displacement more than175 cm ³	80

1.4 PROBLEM STATEMENT

Though noise reduction is the main purpose of the muffler, it increases the engine's backpressure. Directly this backpressure depends on pressure drop. So minimizing pressure drop will reduce backpressure. And this can be achieved by varying some parameters like porosity, the shape of pipes, and the position of baffle plates.

1.5 TYPES OF MUFFLERS

There are two main types of muffler designs commonly used

are,1.5.1Reactive or Reflective muffler

1.5.2Absorptive or Dissipative muffler

1.6 THE REACTIVE OR REFLECTIVE MUFFLER

It uses the phenomenon of destructive interference to reduce noise. It means those have been designed so that an engine's sound waves are canceled out in the muffler partially. For complete destructive interference to happen, a reflected pressure wave of equal amplitude and 180 degrees out of phase needs to be collide with the transmitted pressure wave.

Reflections occur where there is a change in geometry or an area discontinuity.

As shown in the figure below, a reactive muffler generally consists of a series of resonating and expansion chambers designed to reduce the sound pressure level at certain frequencies. The inlet and outlet tubes are normally offset and have holes that allow sound pulses to scatter out in various directions inside a chamber resulting in destructive interference.

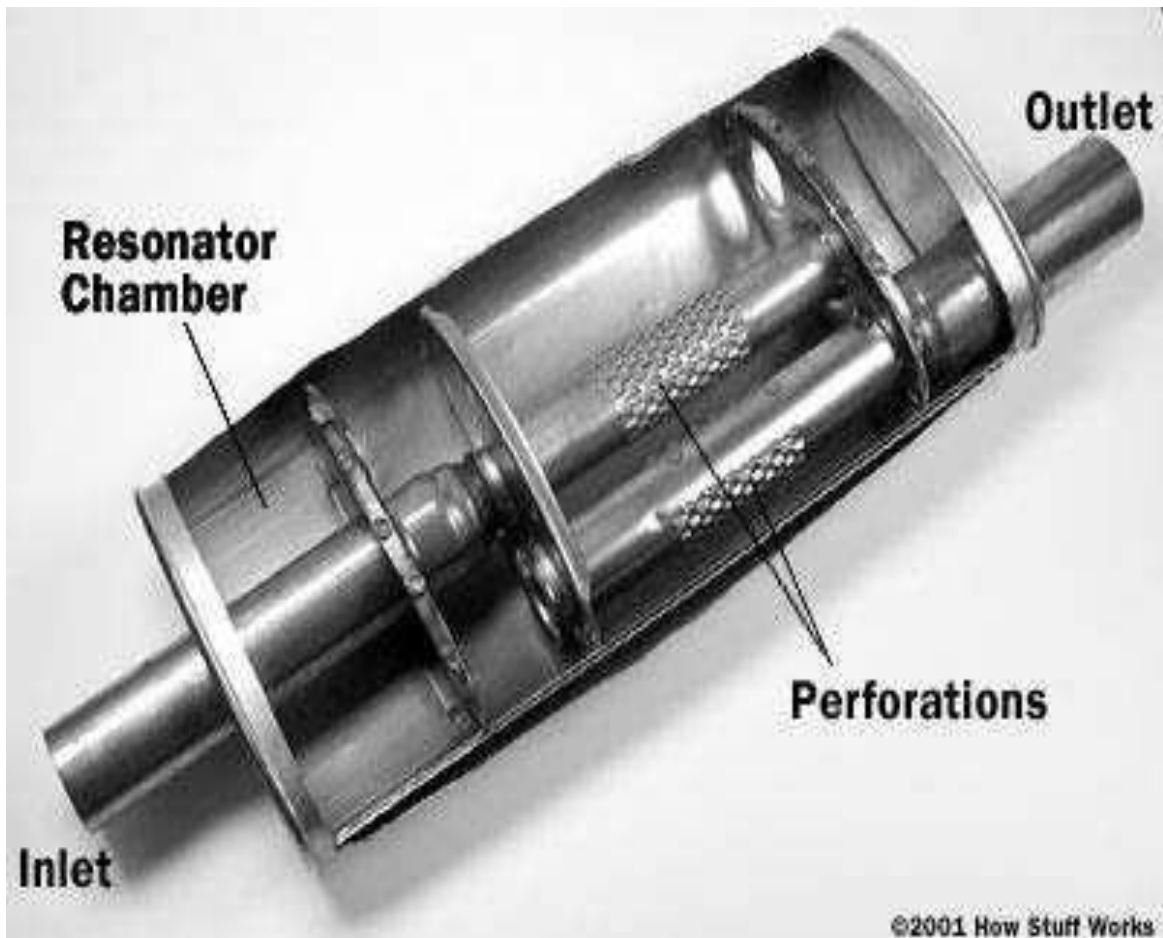
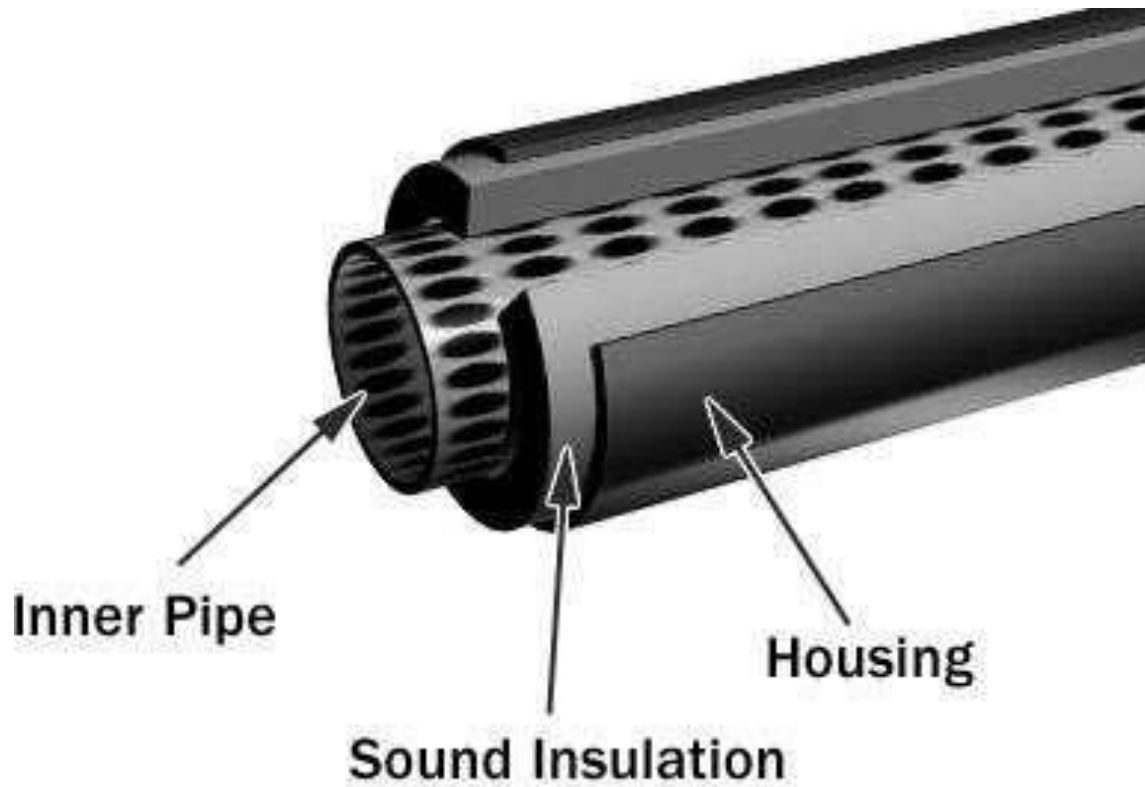


Fig: 1.3: Typical reactive automotive muffler

1.7 AN ABSORPTIVE OR DISSIPATIVE MUFFLER

As shown in the figure below, it uses absorption to reduce sound energy. The sound waves have reduced as their energy is converted into heat in the absorbent material. A typical absorptive muffler consists of a straight, circular, and perforated pipe encased in a larger steel housing, between the perforated pipe and the casing in a layer of sound absorptive material that absorbs some pressure pulses.

Absorptive mufflers create less backpressure than reactive mufflers. However, they do not reduce noise as well.



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Fig: 1.4: An Absorptive or Dissipative Muffler

CHAPTER 2

LITERATURE SURVEY

“Vijay M Mundhe, Eknath R Deore Did “Design and analysis of perforated muffler in Automobile Exhaust System”

This Page summarizes that muffler is a vital part of an engine device utilized in exhaust devices to lessen exhaust fueloline noise. Muffler geometry, extension in inlet and outlet valves, the quantity of complete perforation, and its diameter are the elements that impact noise from engines. The goal of this observe is to lessen the exhaust fueloline noise stage. The overall performance of the muffler is classified through studying stress variation, exhaust fueloline float patterns, duration of enlargement chamber, transmission loss. Finally, they concluded that its miles found while float has bifurcated in 1/3 chamber quantity of growth in perforations reasons extra transmission loss.

- **Sujit Kumar Jha and Ajay Sharma Did “Optimal Automobile Muffler Vibration and Noise Analysis”**

The muffler is the primary part of the Automobile Exhaust System, such as fibrous and porous substances to take in noise and vibrations. This paper aims to decide the frequencies that seem on the modes that have the extra destructive impact throughout the operation of the vehicle. An effect check has carried out by using the pressure, the usage of a tough headhammer, and information generated for plotting a graph of the switch capabilities of the usage of MATLAB. Finally, they concluded the muffler layout might be modified primarily based totally on the device's resonant frequencies. MATLAB has been used to decide the resonance frequency and devise a graph of the switch capabilities for every information factor labeled at the muffler. The resonance frequencies may be minimized by including damping to the device.

- **Vaibhav D. Prajapati, Ankit J. Desai did “Design and Analysis of Automotive Muffler.”**

This Page summarizes that Muffler is a completely vital part of the automobile exhaust device to lessen the noise produced through engine flammable merchandise while passing thru the exhaust device. To acquire most noise discounts with the minimal stress drop could be very hard. A traditional muffler of Maruti-Suzuki WagonR has taken as reference and relying upon parameters, a new muffler is designed and modeled in a software program, and evaluation may be finished numerical codes. Comparison of traditional muffler and proposed designed muffler is primarily based totally on the quantity of noise discount, stress drop, and muffler life. In the experimental setup stress drop was calculated through the water manometer tube, and good depth was measured through Sound Level Meter (SLM) device.

The simulation shows that the modified layout is a long way higher in stress loss, so with better stress loss, there may be extra noise discount. But advantage and demerit are usually collectively growth in stressloss will growth returned stress which isn't precise for the engine.

- **Pradyumna Saripalli, K. Sankaranarayana did “CFD Analysis on Flow through a Resistance Muffler of LCV Diesel Engine.”**

This Page summarizes that the exhaust pollutants have ended up one of the vital troubles of surroundings pollutants with programs in the vehicle industry. The exhausted muffler has paid interest to enhance the overall performance of engines. The venture document simulates the sphere through a numerical approach with Cosmos Flow and analyses the impact which the inner float discipline has on the overall performance of the muffler. With this approach, the stress distribution withinside the muffler has been simulated and the stress loss is expected for the shape modification. The test consequences confirm that the overall meeting performance of the muffler changed is higher than the authentic muffler. Finally, one-of-a-kind fashions of a muffler have been designed for the engine output of an LCV diesel engine and the float has simulated the usage of ANSYS FLUENT. The float traits

Received thru the simulation have been promising. On evaluating the consequences and performances of the two fashions, we study that eleven though each of the fashions have equal comparable layout parameters, the second version became extra powerful in lowering the exhausting stress than the second due to its inner baffle arrangement.

- **Swetha Baruah and Sushovan Chatterjee did “CFD Analysis on an Elliptical Chamber Muffler of a C.I Engine”**

This Page summarizes that the elliptical chamber muffler version of a MAHINDRA C.I. engine is studied primarily based totally on CFD evaluation of the exhaust fueloline float thru the muffler chamber. Two designs for the fore mentioned muffler are analyzed, one in every of which includes a perforated inlet, outlet, and primary pipes. If applied in real exercise, it ought to result in higher and progressed sound attenuation. Transmission loss has been calculated for each of the muffler fashions primarily based totally on stress distribution received from CFD evaluation consequences. As such, it may be concluded that the perforated muffler version genuinely achieves higher sound attenuation compared to the non-perforated version on the value of a small quantity of growth in stress that's nice with inside the allowable range.

CHAPTER 3

AIM AND OBJECTIVE

AIM:

To observe the layout and optimization of automobile muffler for noise and vibration reduction.

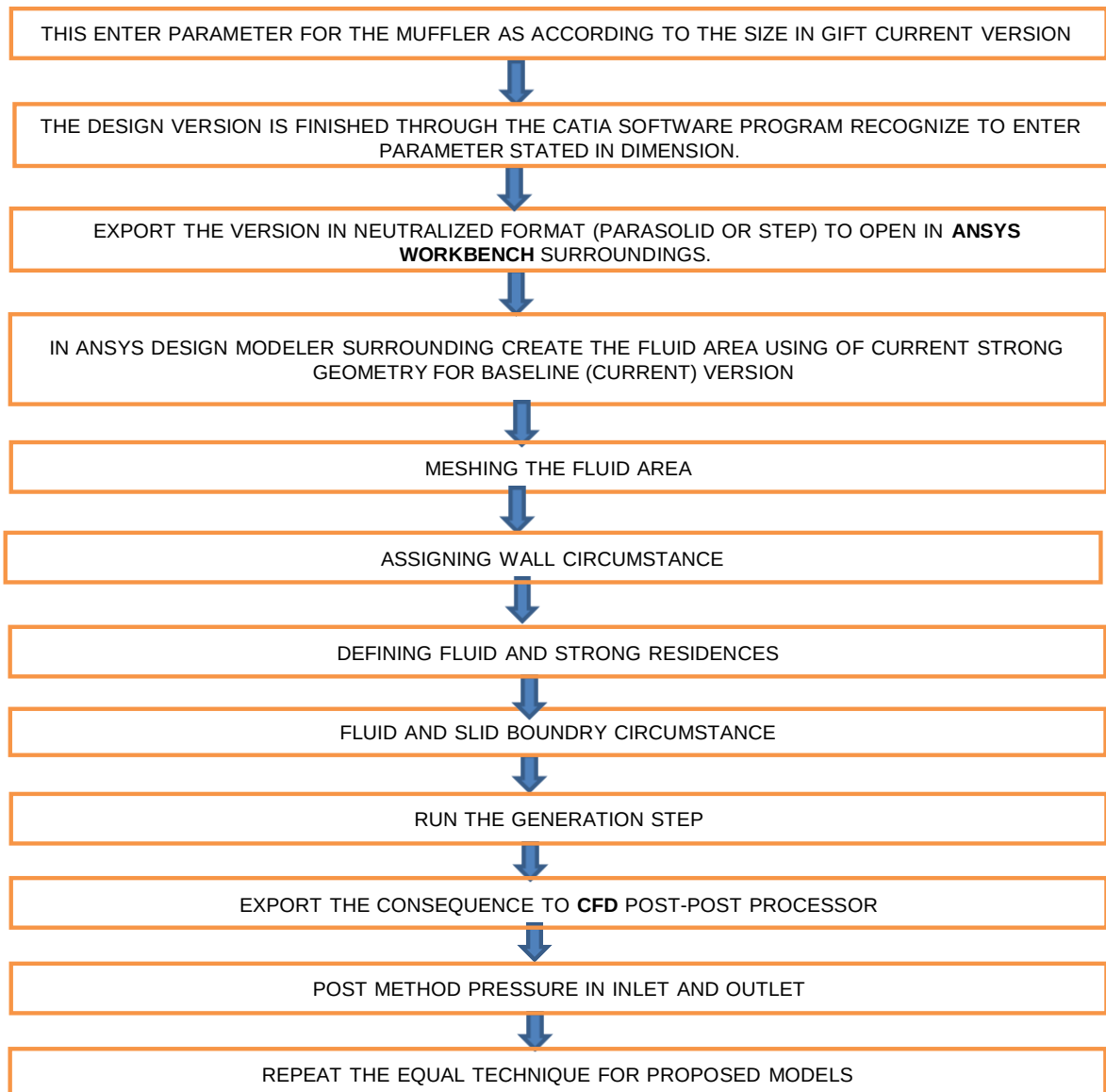
OBJECTIVE:

- i) The most important goal of the venture is to lessen the noise stage of muffler the usage of CFD techniques. This observed vehicle muffler has taken for noise observe, In which overall stress drop and returned stress are studied current and proposed muffler.
- ii) Comparison of traditional muffler and proposed designed muffler is primarily based totally on the quantity of noise reduction, stress drop.

CHAPTER 4

METHODS, MODELING AND DESIGN METHODOLOGY

4.1. METHODS



MODELING

4.2. INTRODUCTION TO MODELING

Throughout our industrial society, many inventions have patented and evaluation of new technologies. If in case of the single development is impacted on manufacturing and significantly than any previous technology in the digital computer. These computers are being used increasingly for both design and detailing of engineering components in the drawing office.

4.3. COMPUTER-AIDED DESIGN

Computer-aided design (CAD) is defined as applying computers and graphics software to help or improve the product design from conceptualization to documentation. Computer-aided design is most commonly associated with the use of an interactive computer graphics system, referred to as a CAD system. Computer-aided design systems are powerful tools and in the mechanical design and geometric modeling of products and components.

There are numerous precise motives for the usage of a CAD device to assist the engineering layout function:

- To grow the productiveness
- To enhance the fine of the layout.
- To uniform layout requirements
- To create a production information base.
- To dispose of inaccuracies as a result of hand-copying of drawings and inconsistency among drawings.

4.4. BASIC REQUIREMENT OF MUFFLER DESIGN

Various requirements should have considered when designing a muffler for an automotive application. Such functional requirements may include adequate insertion loss, backpressure, size, durability, desired sound, cost, weight, compact shape, and style. Some of the requirements has given in detail below.

4.5. ADEQUATE INSERTION LOSS (I.L.):

An effective muffler will reduce the sound pressure of the noise source to the required level. In the case of an automotive muffler, the noise in the engine's exhaust system is to be reduced. A muffler's performance or attenuating capability has generally defined in terms of insertion loss or transmission loss. Insertion loss is defined as the difference between the acoustic powers radiated without and with a muffler fitted. The transmission loss is defined as the difference (in decibels) between the sound power incident at the entry to the muffler that is transmitted by the muffler. The muffler designer must determine the required insertion loss to have a suitable type of muffler designed for the automotive application.

4.6. SELECTION OF LENGTH:

The silencer's proper selection and sizing are of utmost importance to ensure that pressure drop, acoustical performance, and other specific design criteria are met. The correct type of engine exhaust silencer is selected as determined by the type of engine, the engine's end-use, and the degree of silencing required. Also, the silencer size selected must accommodate the specified volume of exhaust gas flow keeping the back pressure within limits specified. The available space has a great influence on the size and type of muffler that may be used. A muffler may have its geometry designed for optimum attenuation. However, if it does not meet the space constraints, it is useless.

4.7. BACKPRESSURE:

Backpressure represents the extra static pressure exerted by the engine's muffler through the restriction inflow of exhaust gasses. Generally, the better a muffler is at attenuating sound and the more back pressure is generated. In a reactive muffler where good attenuation is achieved, the exhaust gasses are forced to pass through numerous geometry changes. A fair amount of backpressure may be generated, which reduces the engine's power output. Backpressure should be kept to a minimum to avoid power losses especially for better performance of the vehicle.

4.8. COST AND WEIGHT:

Generally, the larger a muffler is, the more it weighs and the more it costs to manufacture. For a performance vehicle, every gram saved is crucial to its performance. Effectively supporting a muffler is always a design issue, and the larger a muffler is the more difficult it is to support. A Muffler's mounting system needs to support the weight of the muffler. It needs to provide vibration isolation so that the exhaust system's vibration is not transferred to the chassis and then to the passenger cabin. This vibration isolation is usually achieved with the use of hard rubber inserts and brackets that isolate or dampen vibration from the muffler to the chassis. Therefore, small lightweight muffler is desirable.

- **CAD Model OF Baseline Muffler**

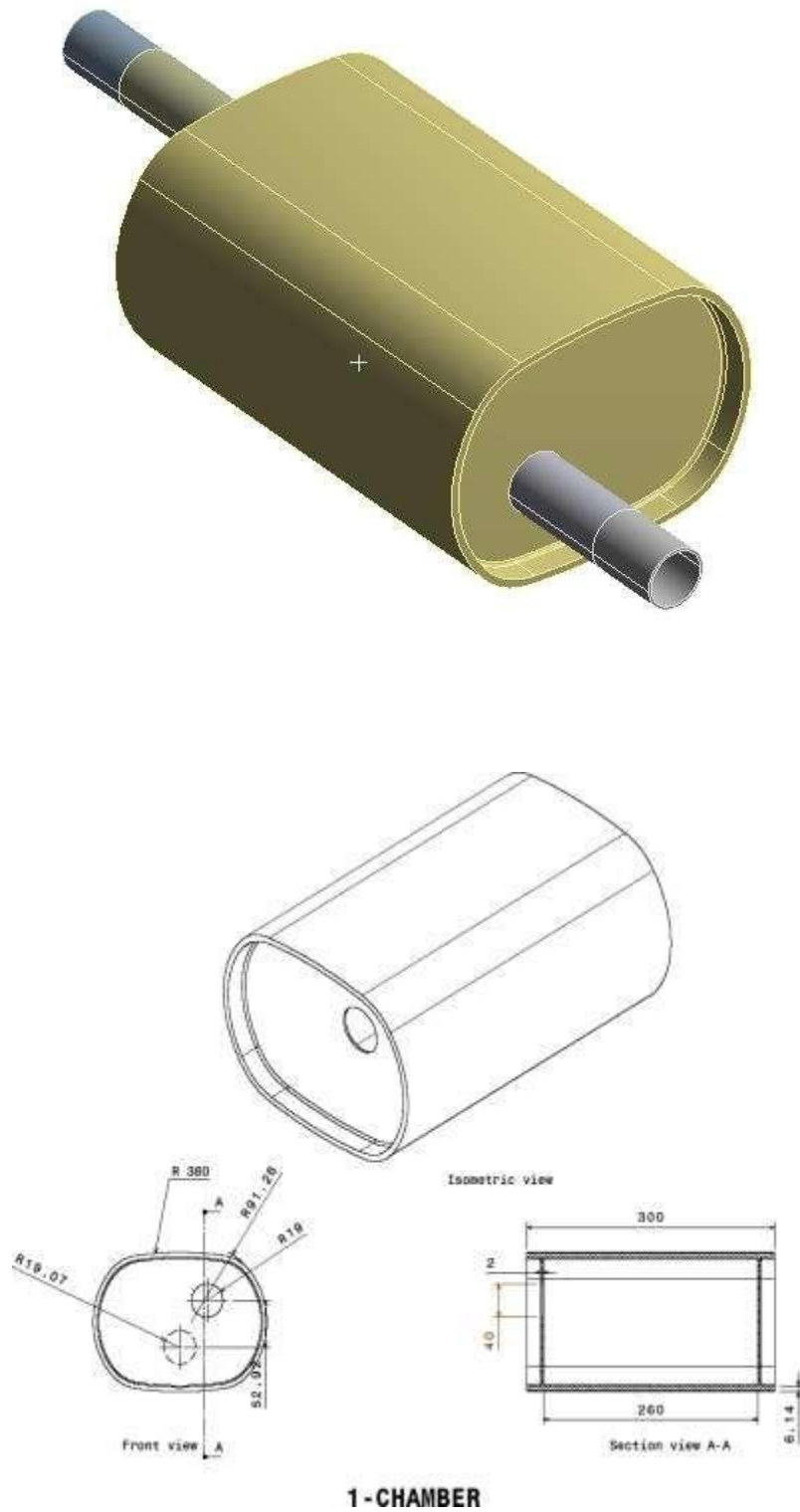
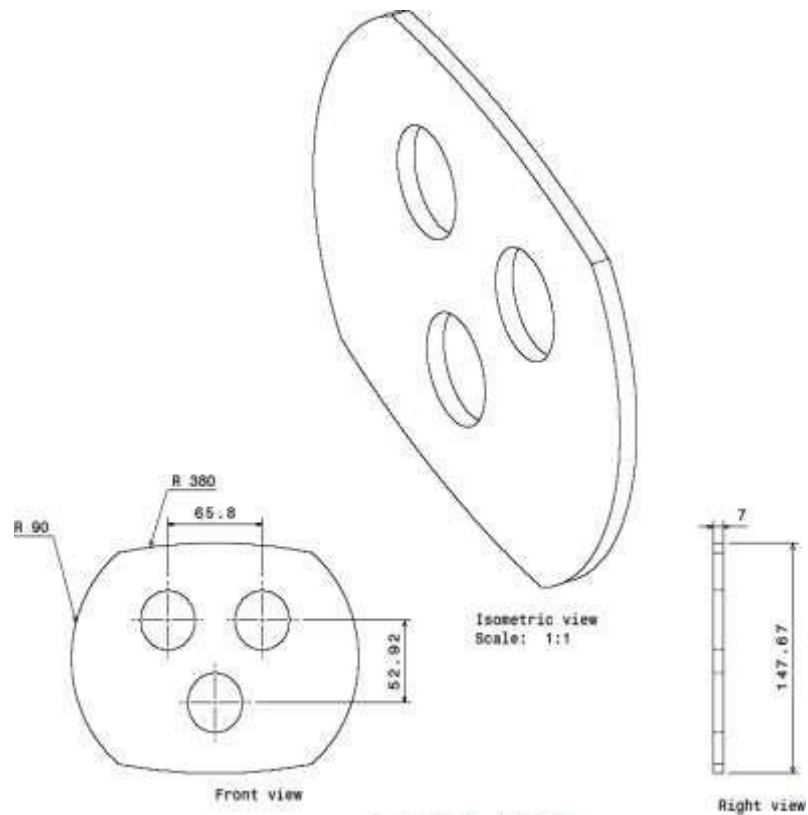
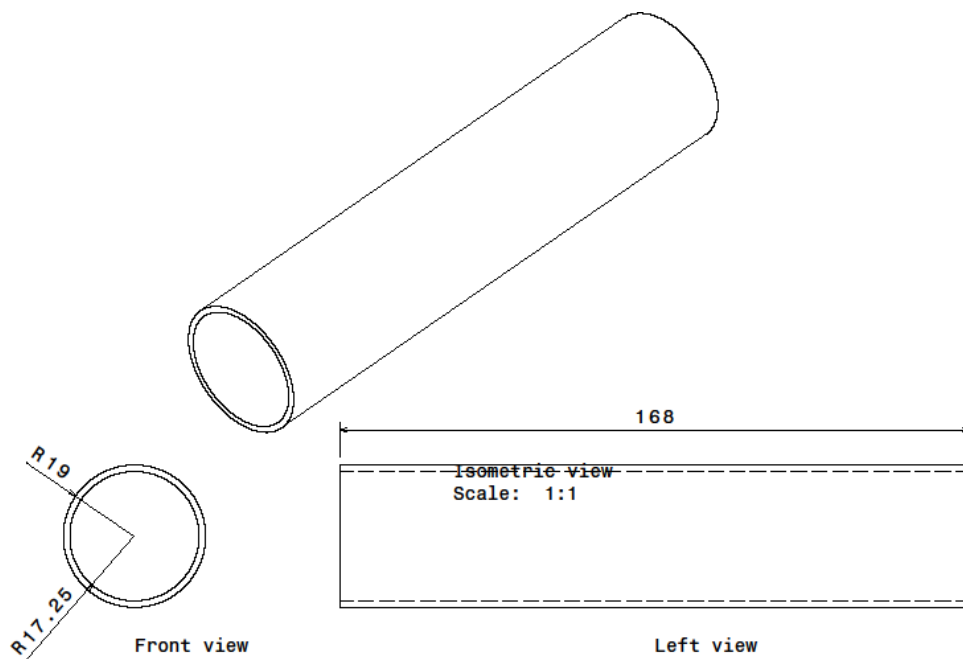


Fig: 4.1: CAD Model of baseline muffler



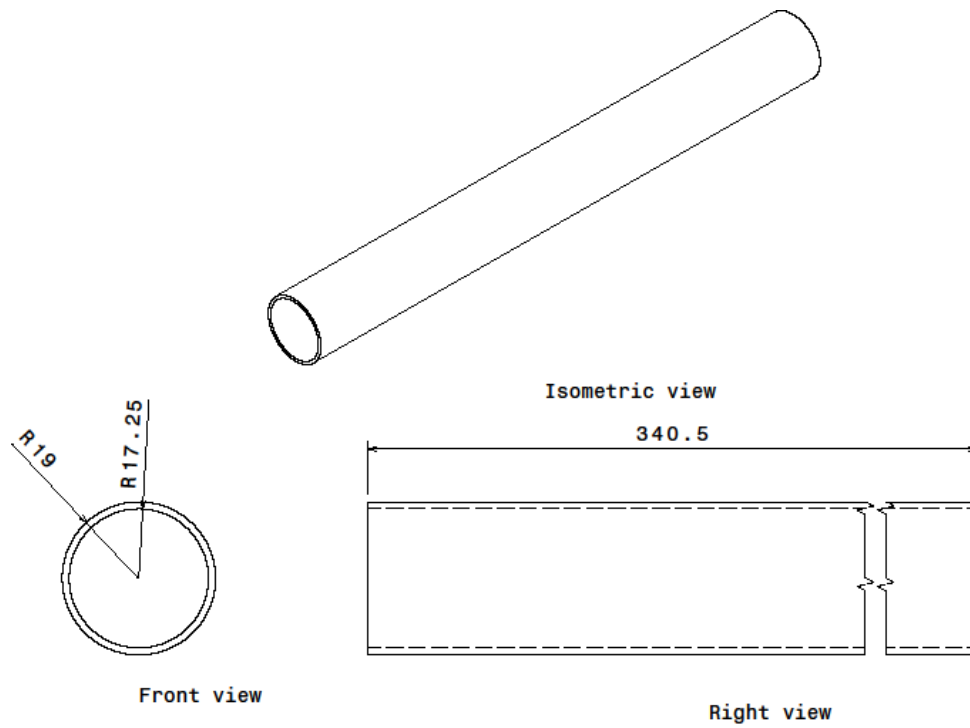
2-BULK HEAD

Fig: 4.2: Bulk Head



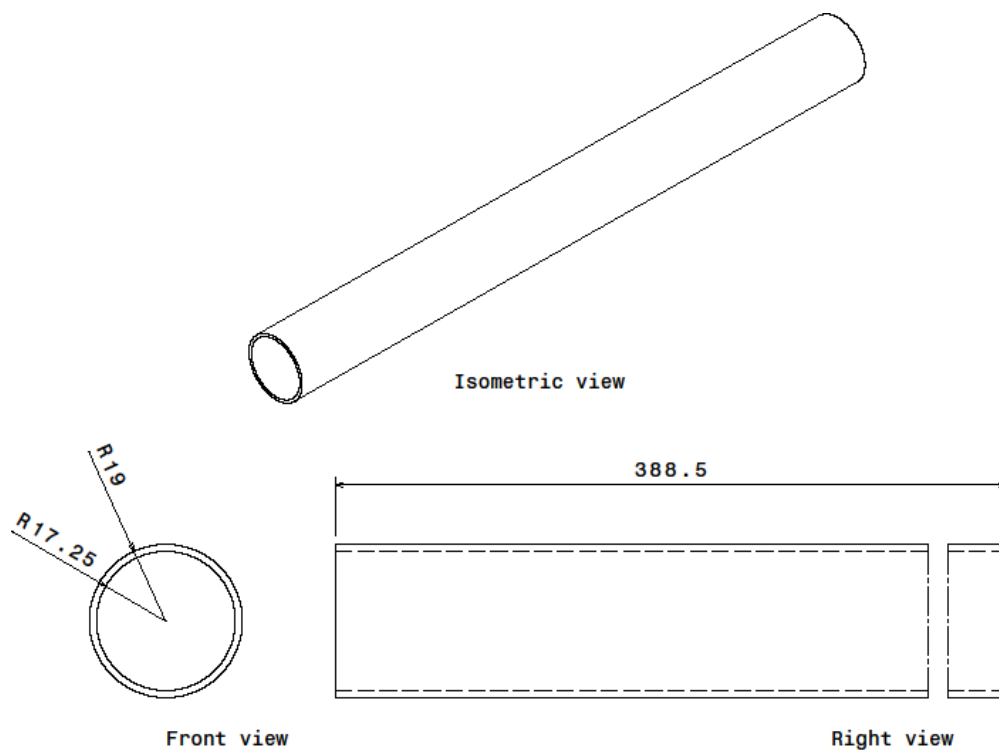
3- PERFORATED TUBE

Fig: 4.3: Perforated Tube



4- INLET TUBE

Fig: 4.4: Inlet Tube



5-OUTLET TUBE

Fig: 4.5: Outlet Tube

4.9 CAD MODEL OF DESIGN 1

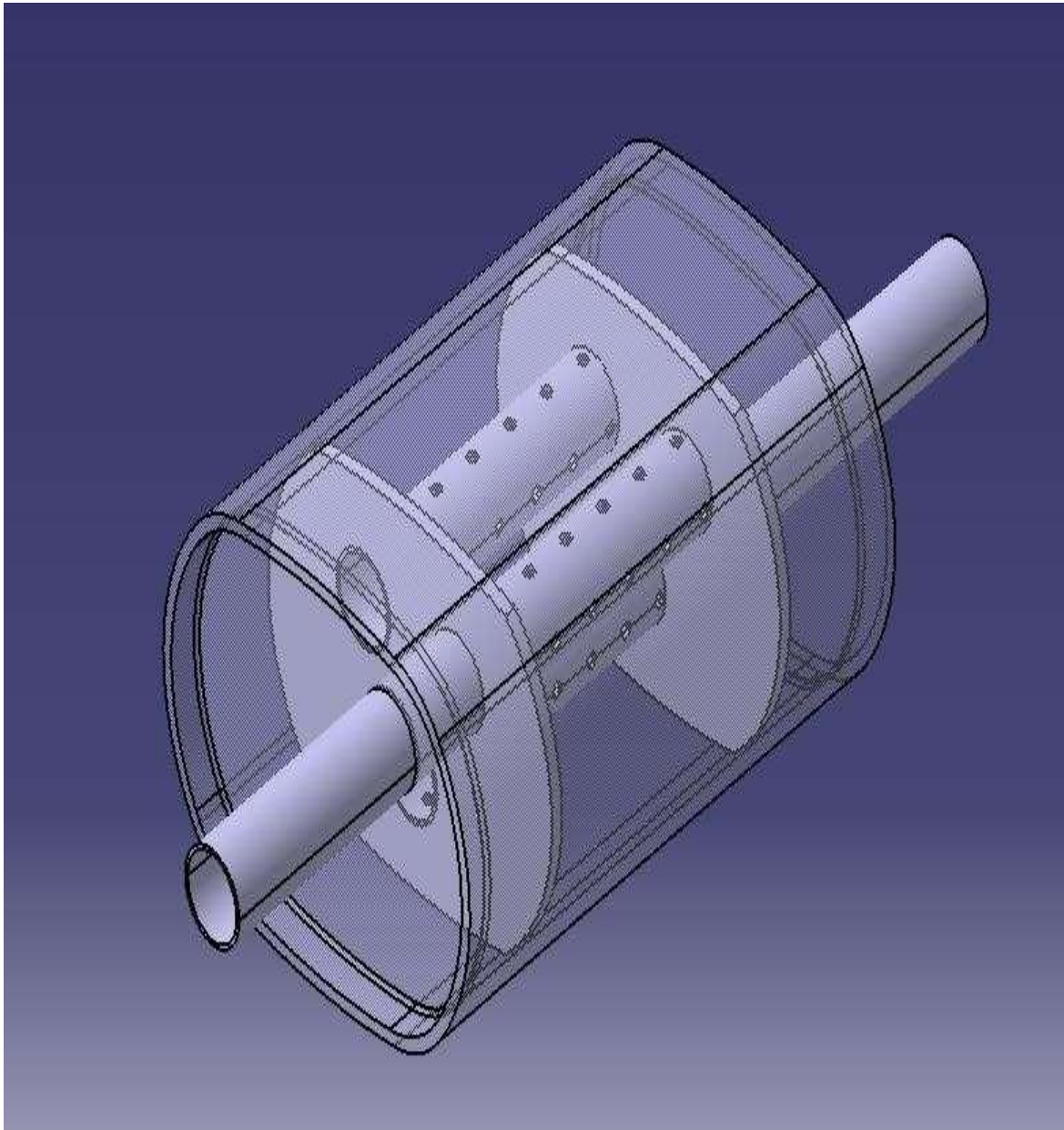


Fig: 4.6:CAD MODEL OF DESIGN 1

The design of the muffler is with the same volume as the existing muffler. The muffler's internal structure is changed by adding two baffles with four perforated holes, as shown in the figure above. And it is investigated the clashes for Analysis.

4.10 : CAD MODEL OF DESIGN 2

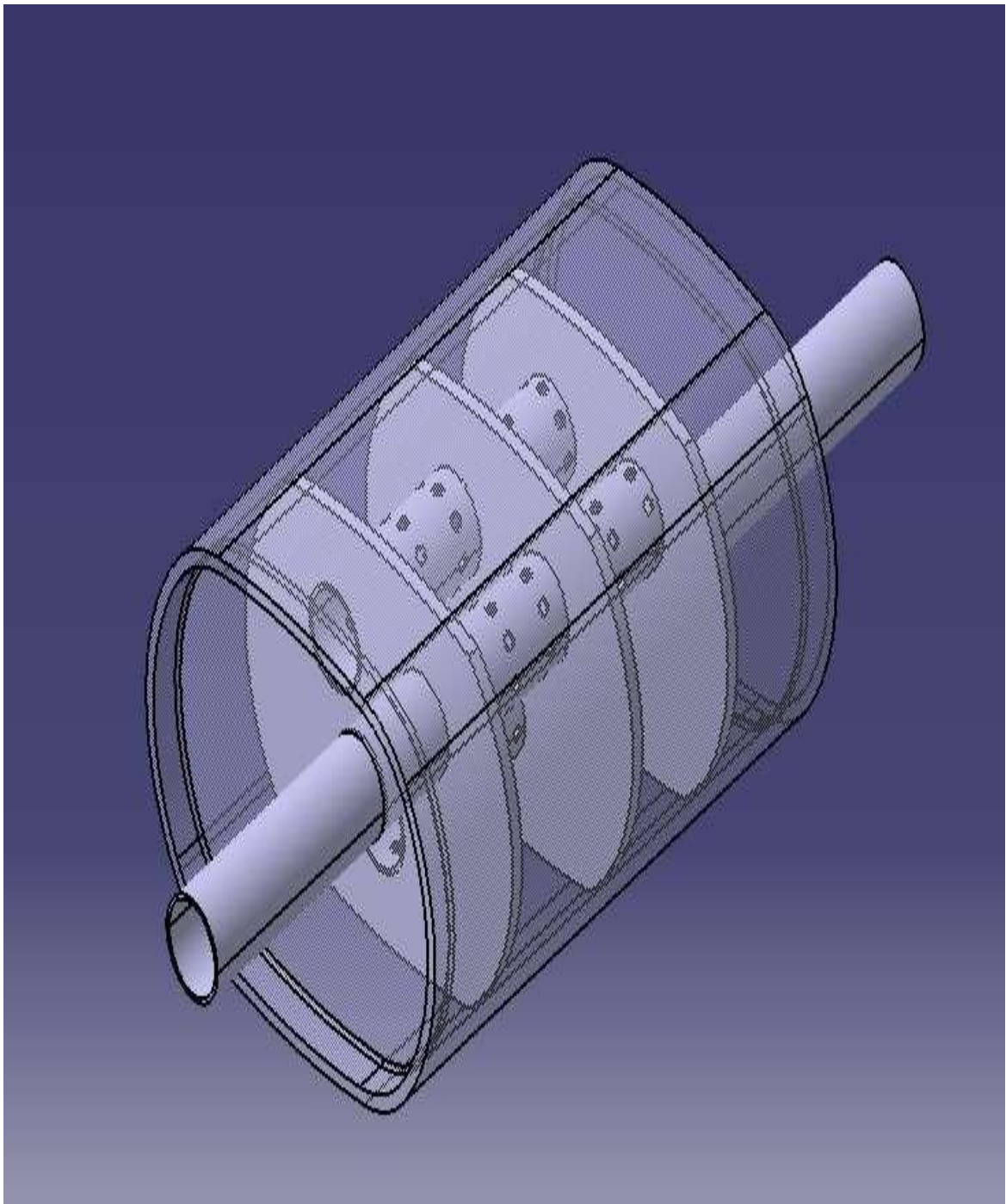


Fig: 4.7: CAD MODEL OF DESIGN 2

The design of the muffler is with the same volume as the existing muffler. The muffler's internal structure is changed by adding three baffles with eight perforated holes, as shown in the figure above. And it is investigated the clashes for Analysis.

CHAPTER 5

ANALYSIS AND RESULTS

5.1. ANALYSIS

Computational Fluid Dynamics (CFD) is one of the parts of fluid mechanics that utilizes mathematical techniques and calculations to examine and tackle the issues that include fluid flows. Computational Fluid Dynamics (CFD) has become an integral part of the engineering design. CFD analysis reduces the development time and increases the reliability of the designs. It makes it possible to evaluate and predict the working parameters such as velocity, pressure, and temperature throughout the solving process. The fundamental basis of any CFD problem is the Navier Stokes equations, which define any single-phase fluid flow. It works by solving the fluid flow equations over a region of interest, with the predetermined known conditions on the boundary of that region.

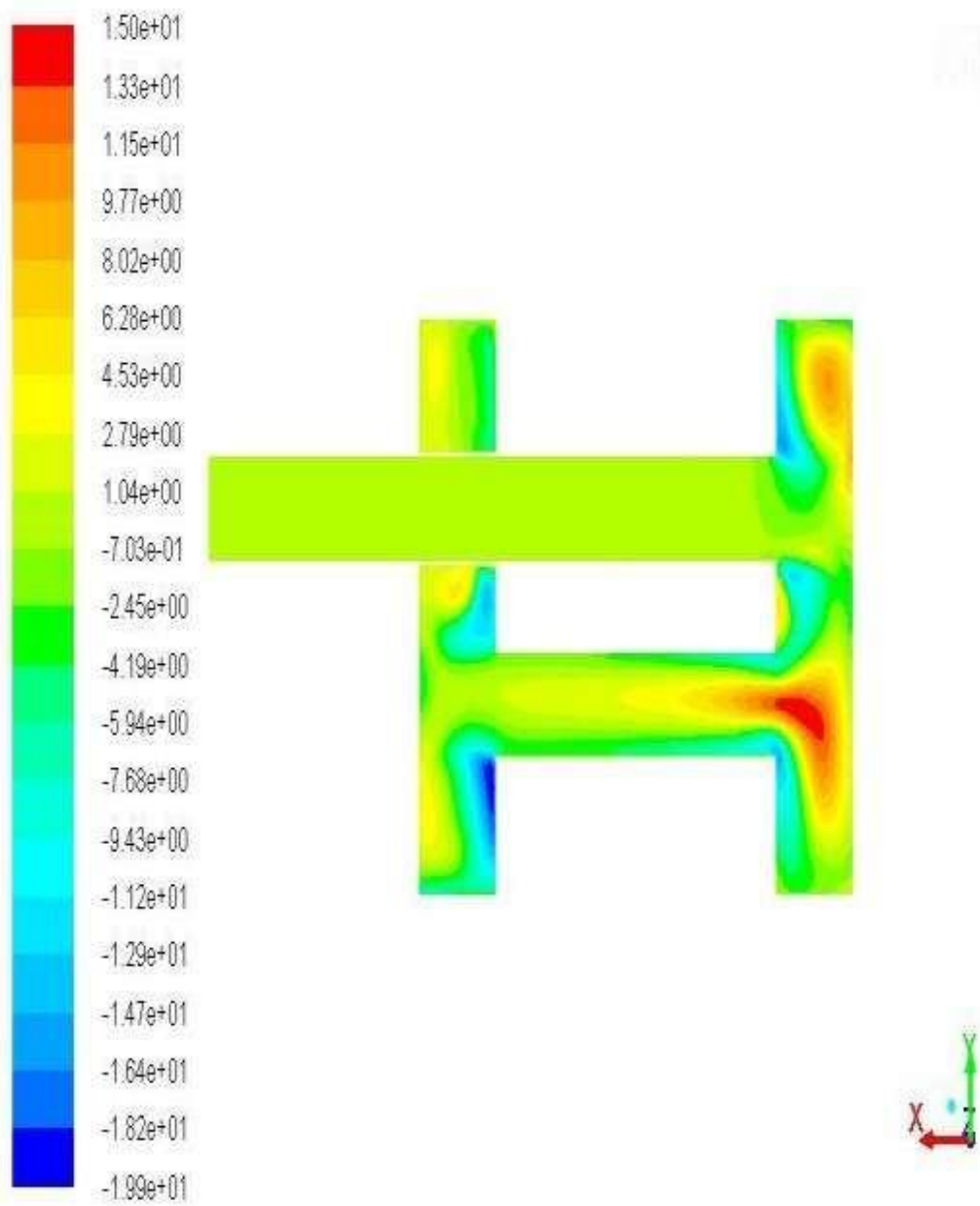
5.2. FLOW SIMULATION

Flow Simulation is capable of calculating the flow of fluids of different types in the same Analysis, but walls must separate fluids of various types. Mixing of fluids may be considered only if the fluids are of the same kind. Flow Simulation has an integrated database containing properties of several liquids, gases, and solids. Solids are used in conjugate heat conduction analysis. For each analysis maximum of ten liquids or gases can be chosen. It can analyze various flows: turbulent flows, Laminar flows,, and Laminar or Turbulent flows. The turbulent equations can be disregarded only if the flow is entirely laminar. It will analyze and simulate fluid flow, heat transfer, and related forces on immersed or surrounding components.

5.3 BASELINE MODEL :

Table: 5.1. : BASELINE MODEL

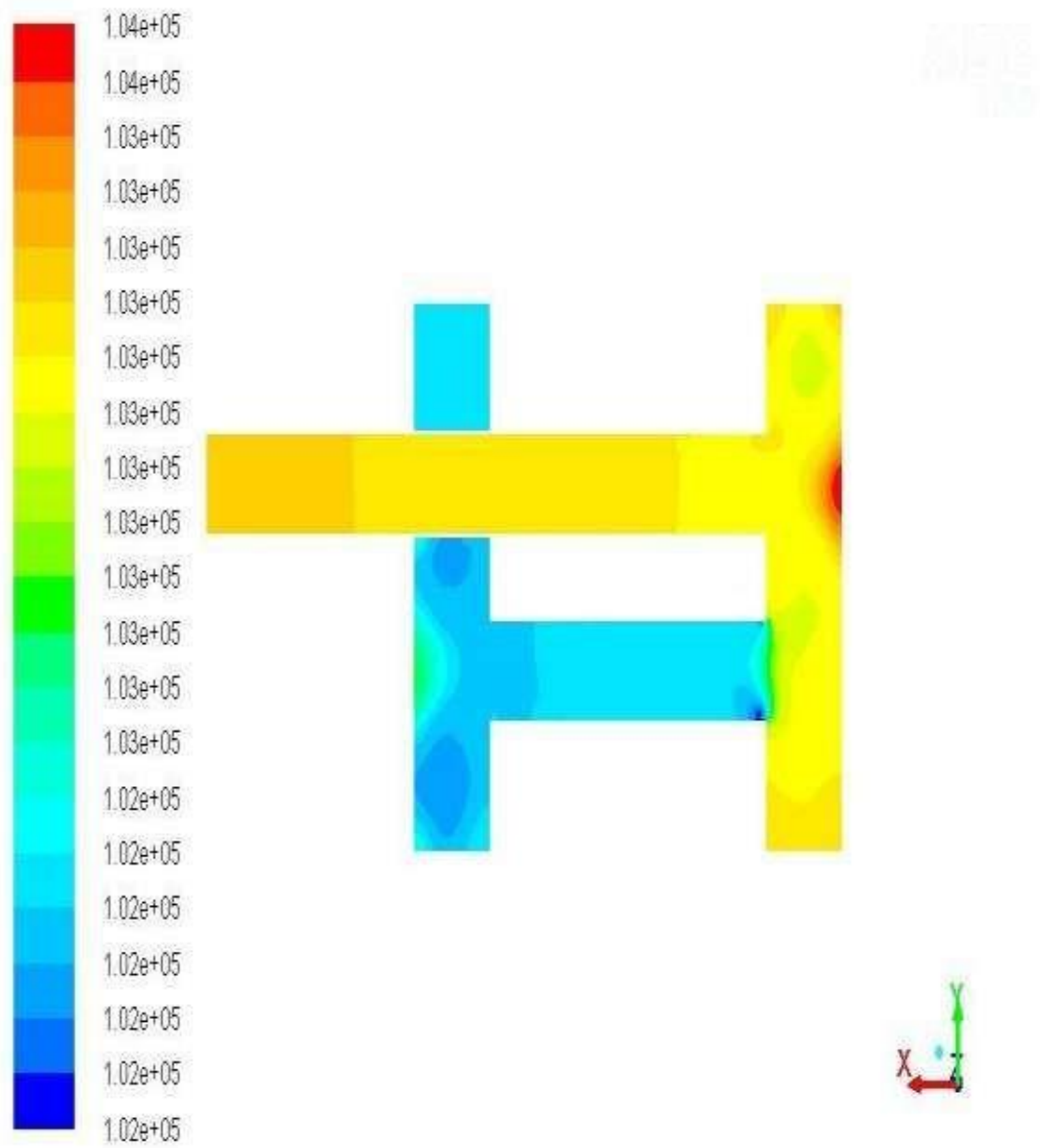
Mass Flow Rate (kg/s)	
inlet	0.017181803
outlet	-0.017179064
Net	2.7381554e-06
Mass-Weighted Average abs_total_presure	
inlet	103614.09
outlet	101737.72
Net	102675.98



Contours of Axial Velocity (m/s)

Feb 06, 2021
ANSYS Fluent 15.0 (3d, pbns, ske)

Fig: 5.1: Velocity Contour



Contours of abs_static_pressure

Feb 06, 2021
ANSYS Fluent 15.0 (3d, pbns, ske)

Fig: 5.2: Contour Static Pressure

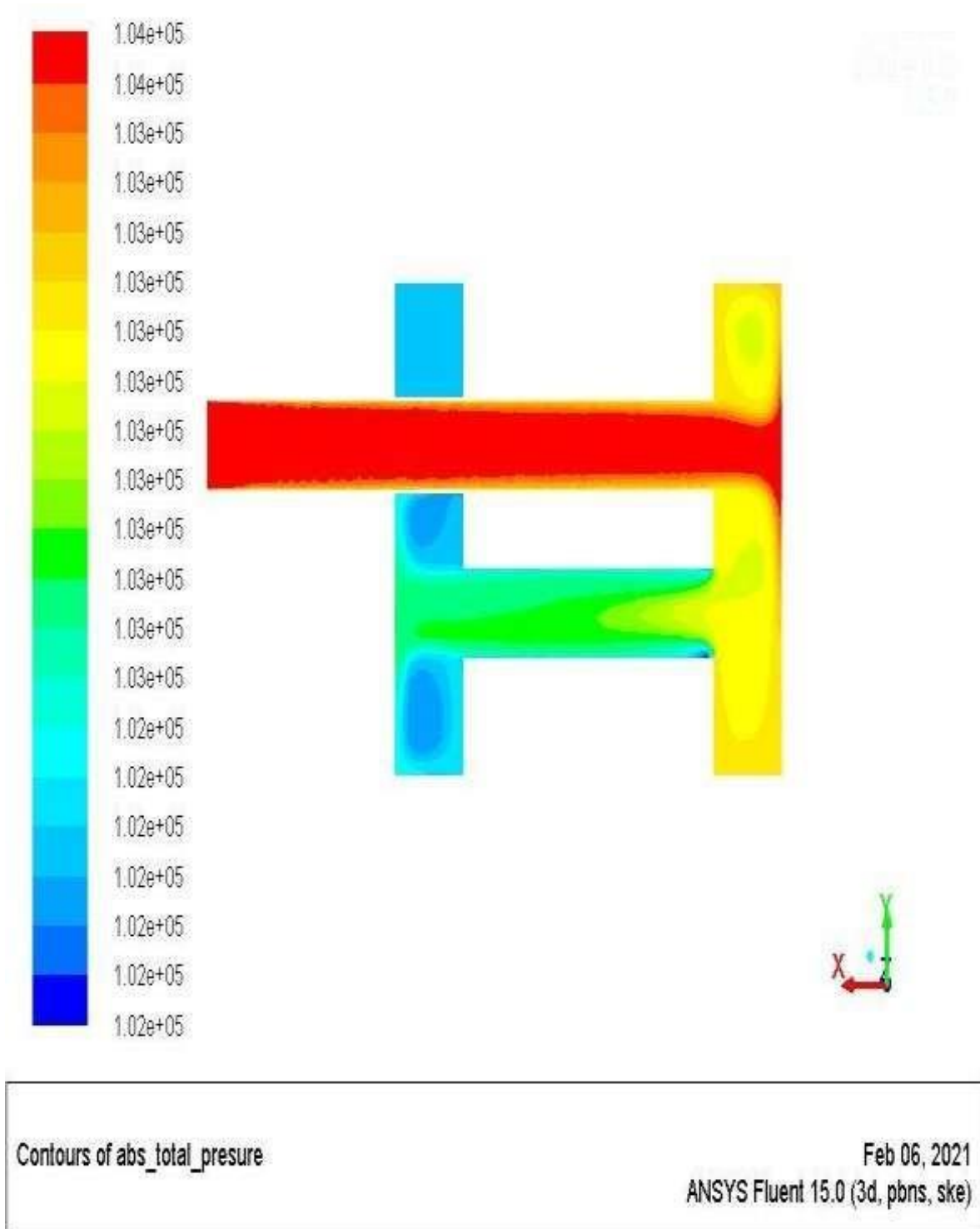


Fig: 5.3: Contour Total Pressure

- The 3D model of the current version of muffler is finished through CATIA, and evaluations has taken through the Ansys software program through CFD evaluation from this evaluation.

- The current version layout has returned stress, stress drop, and static stress
- which is proven withinside the above evaluation of the current version.
- In this evaluation, the stress drop is up to 1876.37.

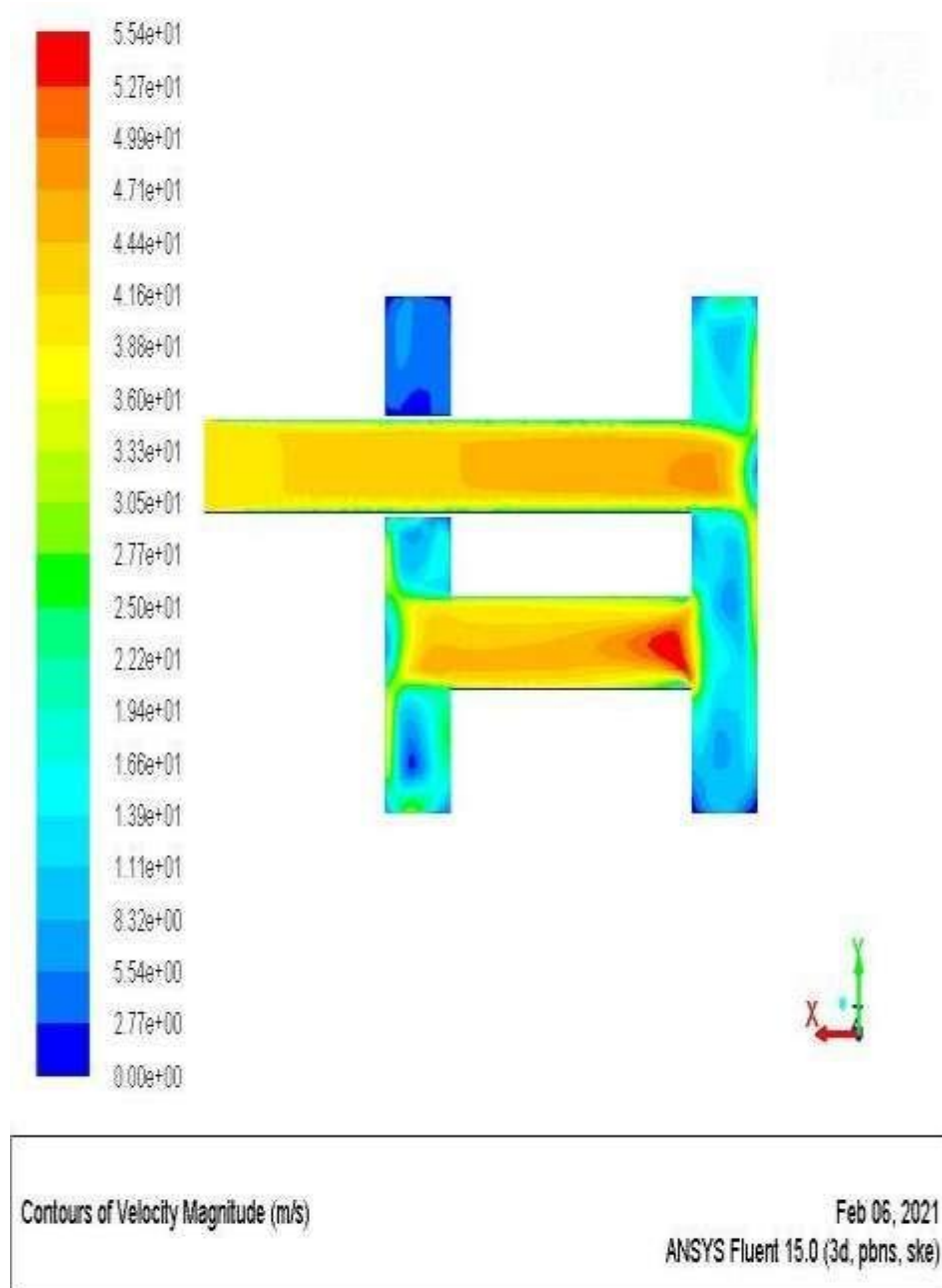


Fig: 5.4: Contour Velocity

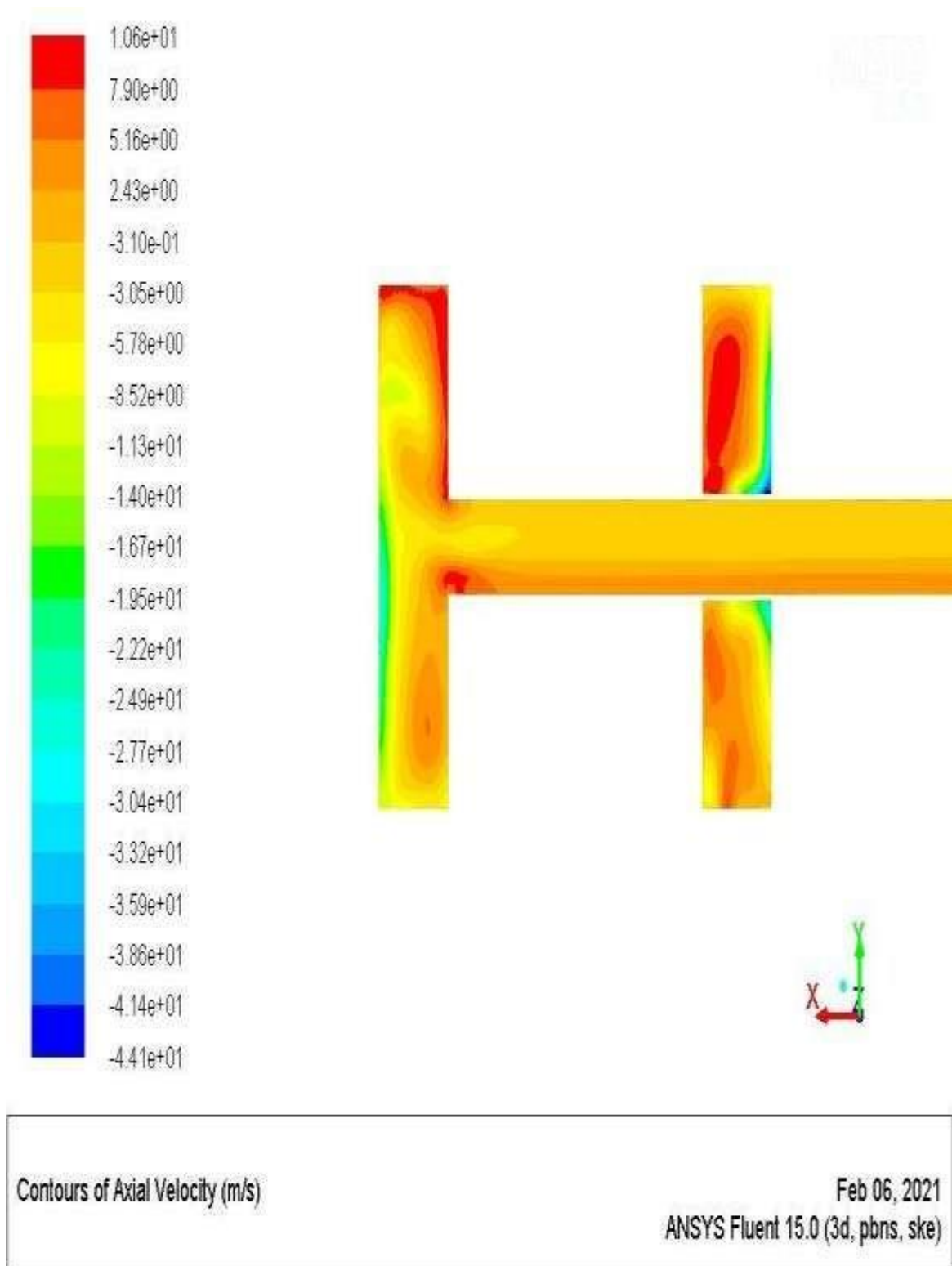


Fig: 5.5: Countours of Axial Velocity

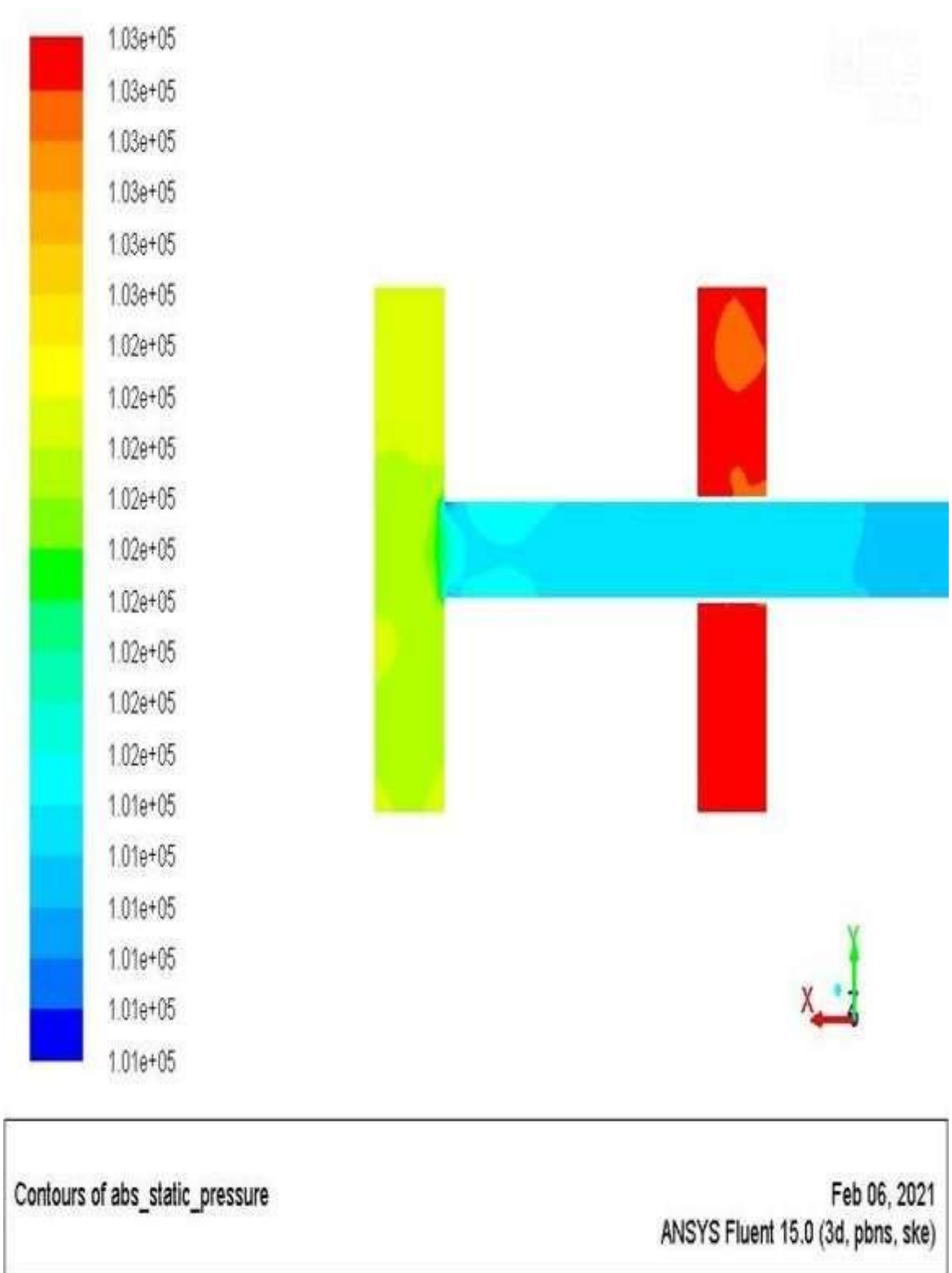


Fig : 5.6: Contours Of ABS Static Pressure

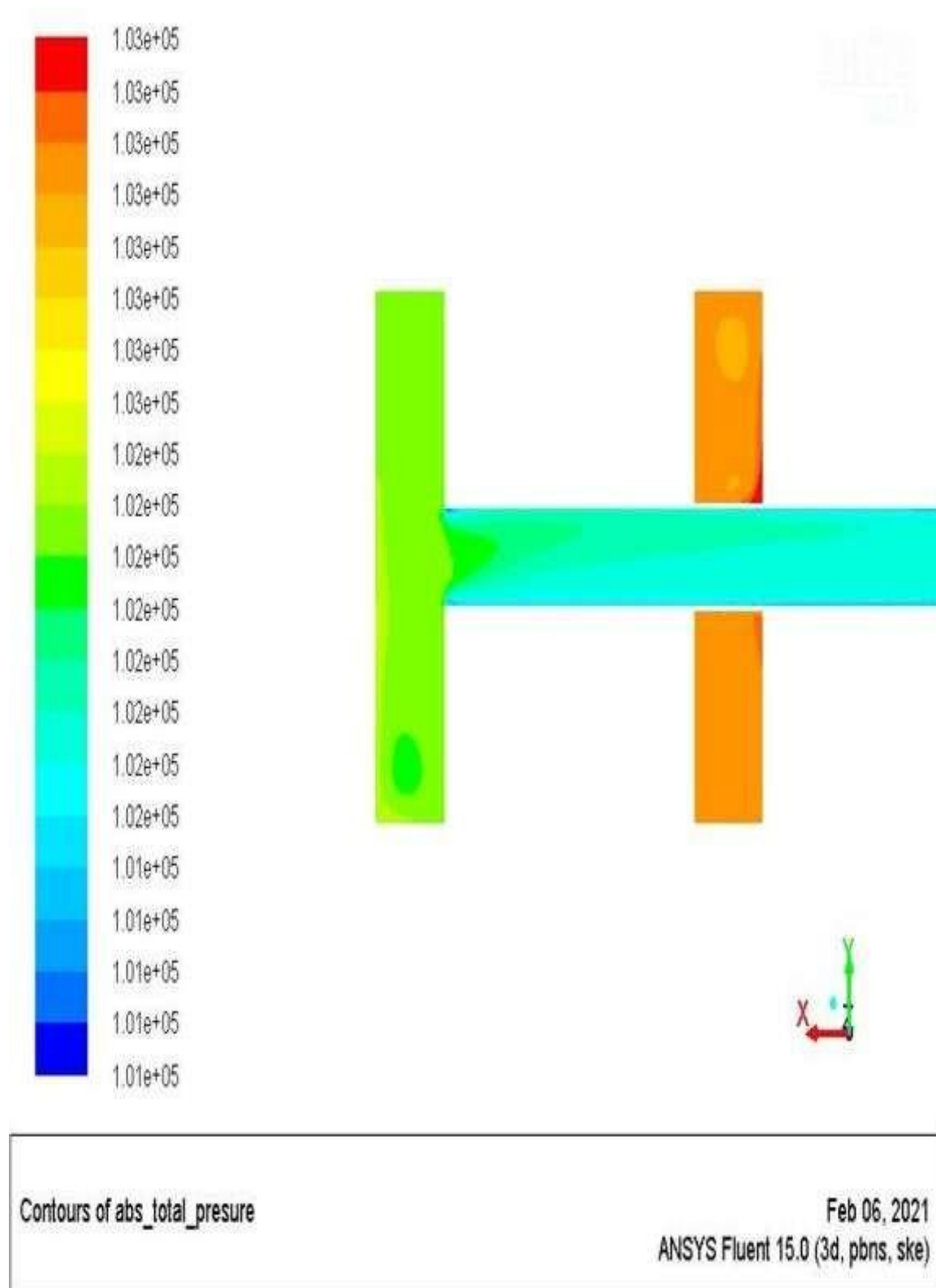
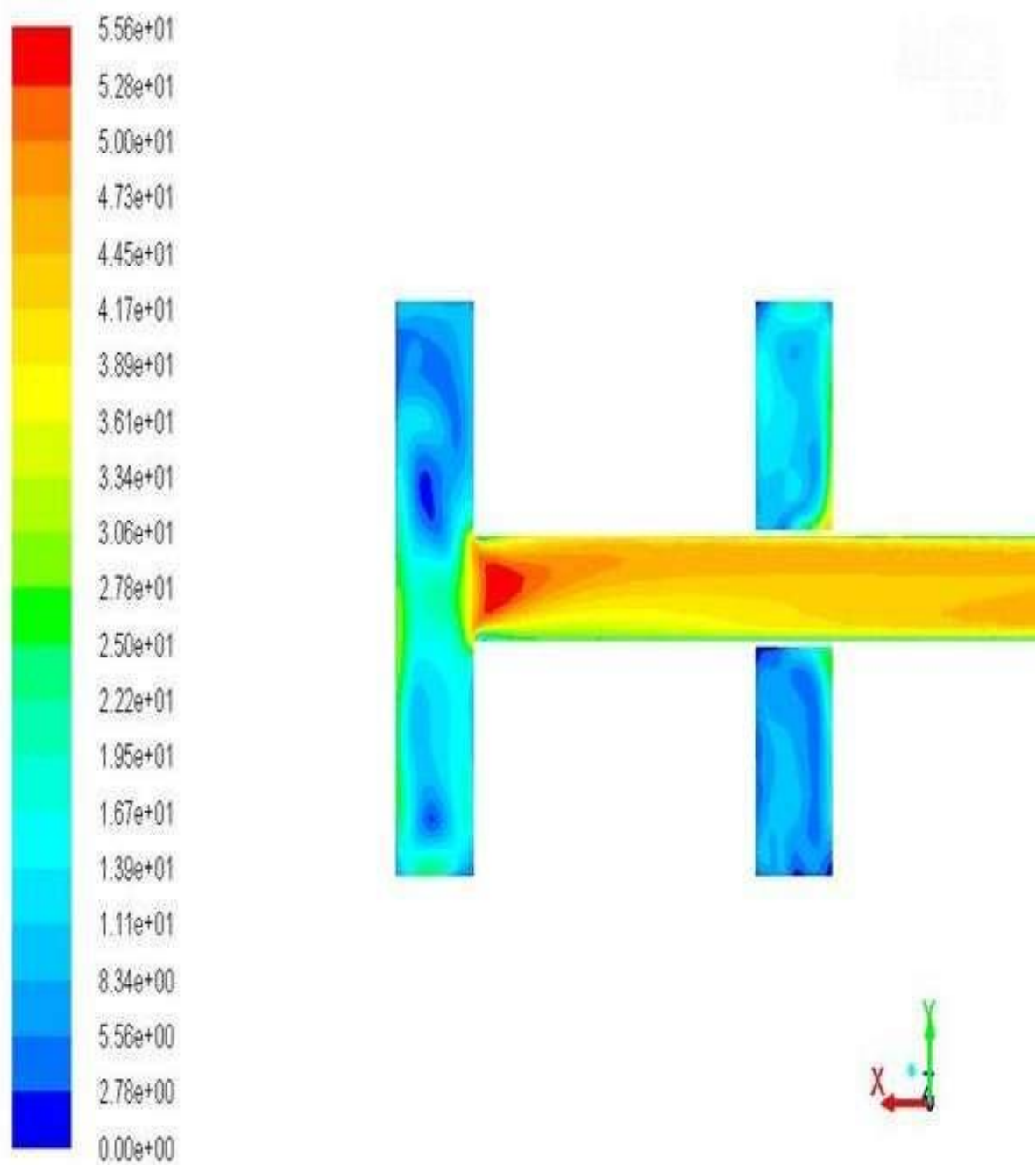


Fig: 5.7: Contours of ABS Total Pressure



Contours of Velocity Magnitude (m/s)

Feb 06, 2021
ANSYS Fluent 15.0 (3d, pbns, ske)

Fig: 5.8: Contours of Velocity Magnitude

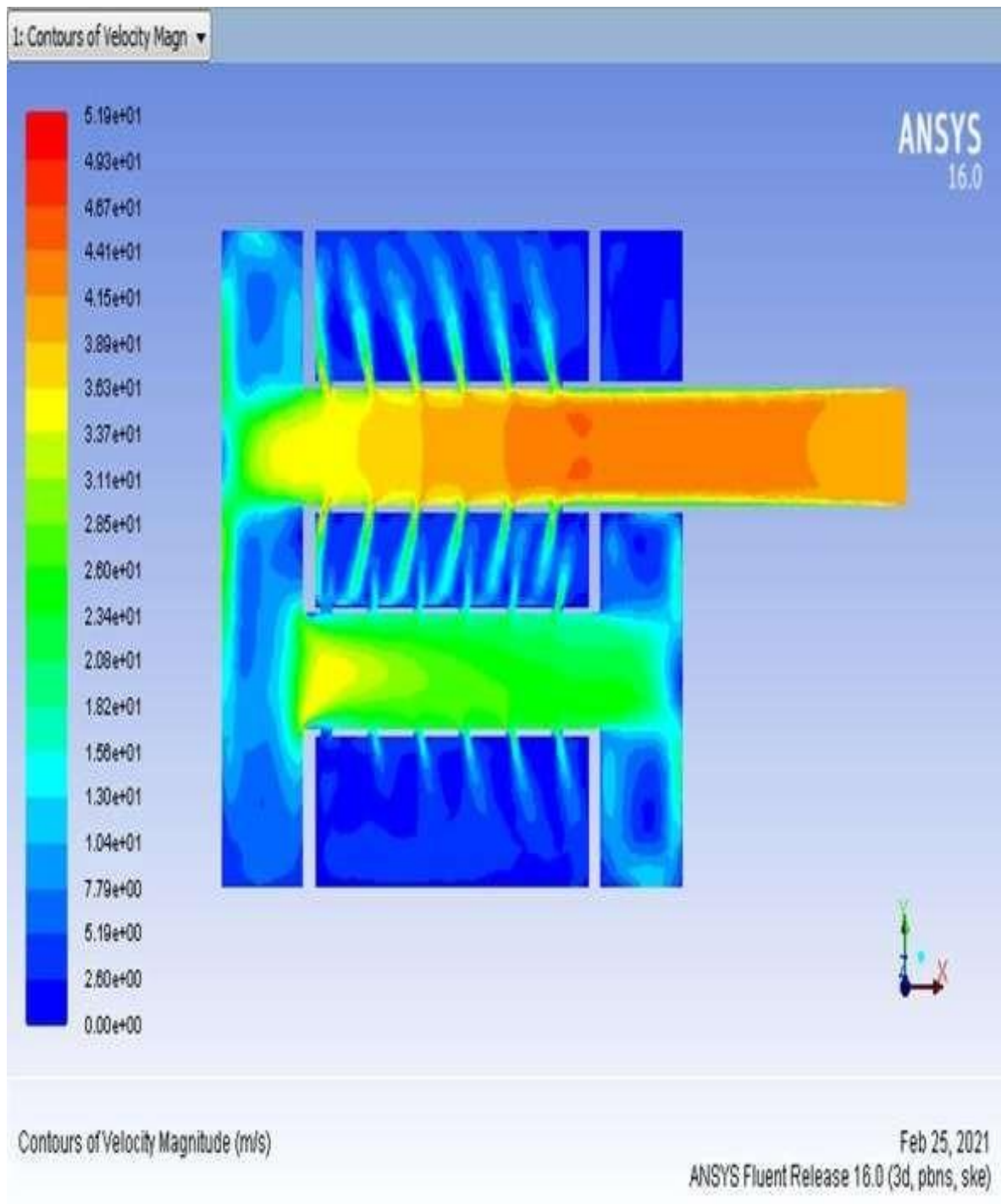


Fig: 5.9: Contours of Velocity Magnitude

5.4 DESIGN 1 ANALYSIS :

Table : 5.2: DESIGN 1:

Mass-Weighted Average abs_static_pressure		

	inlet	102346.72
	outlet	101325

	Net	101835.85
Mass-Weighted Average abs_total_presure		

	inlet	102709.88
	outlet	101729.66

	Net	102219.76
Area-Weighted Average abs_static_pressure		

	inlet	102346.72
	outlet	101325

	Net	101837.64
Area-Weighted Average abs_total_presure		

	inlet	102709.88
	outlet	101714.2

	Net	102213.78

|

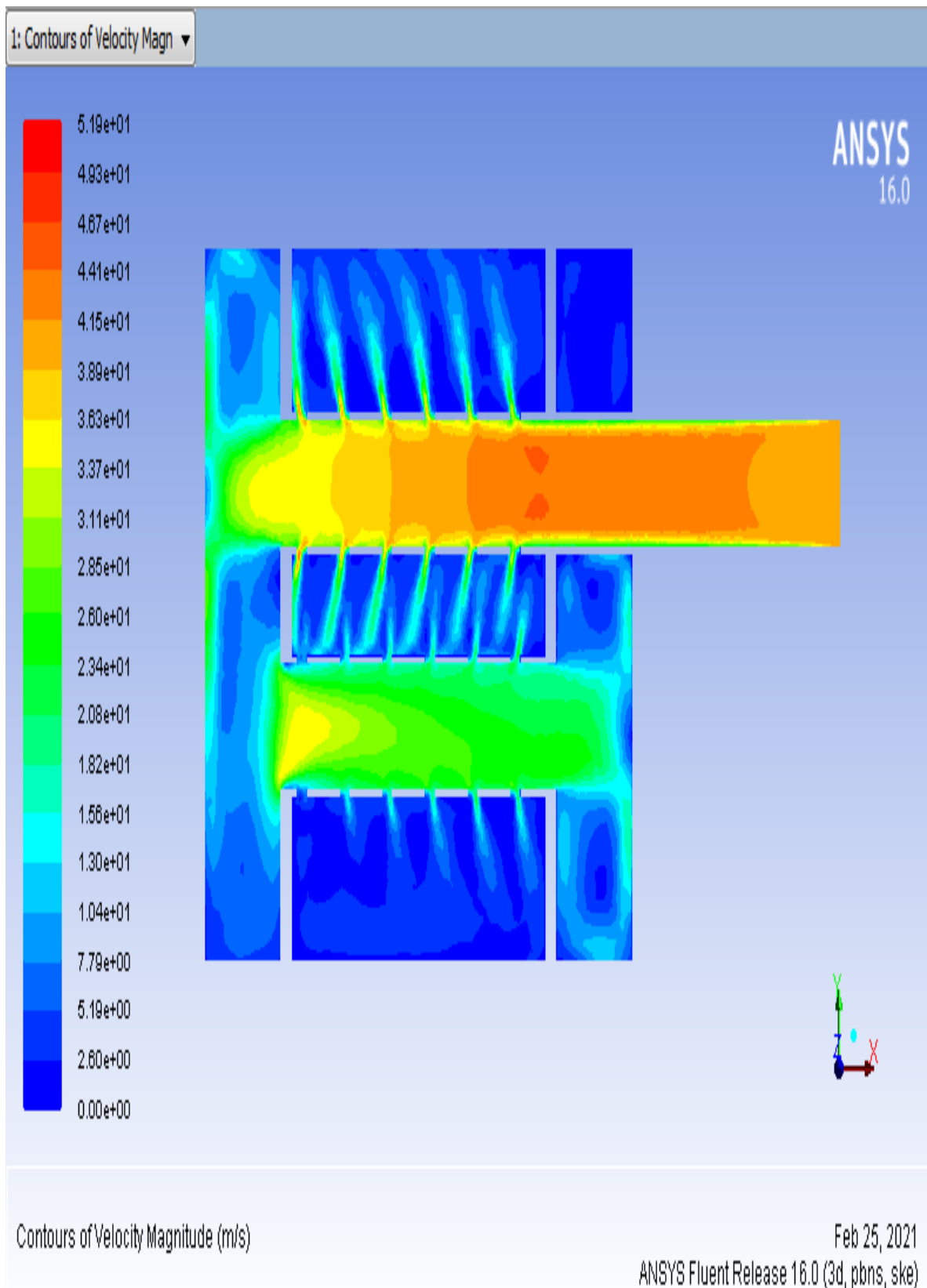


Fig: 5.10: Contours of Velocity Magnitude

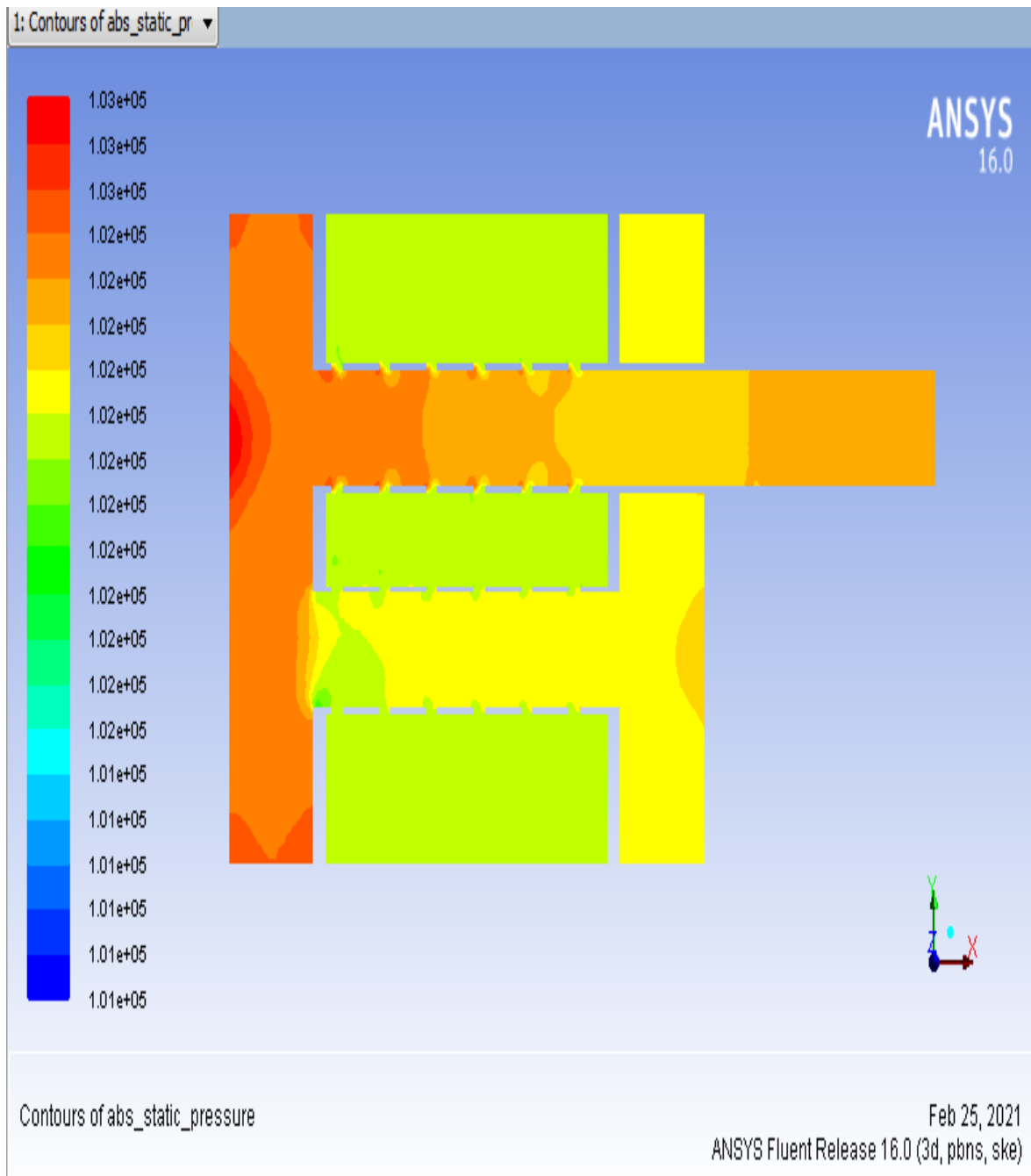


Fig: 5.11: Contours of ABS Static Pressure

5.4 DESIGN 1:

The 3D model is done using CATIA software, and evaluation is finished through the Ansys software program. Layout 1 likewise has an equal foundation with as in comparison to the existing version. It has extra perforated tube holes. it's miles lowering the stress drop up to 995.6

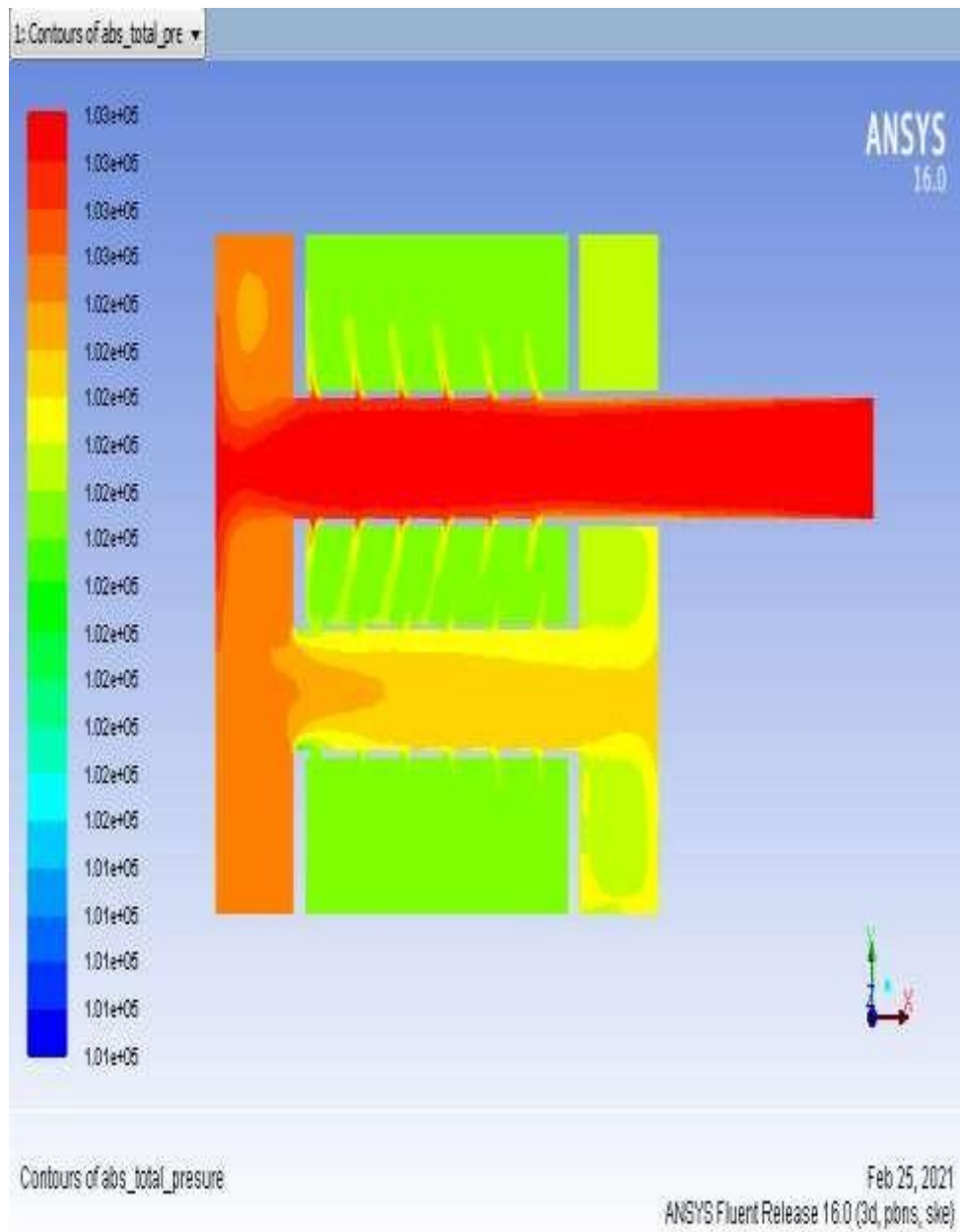


Fig: 5.12: Contours of ABS Total Pressure

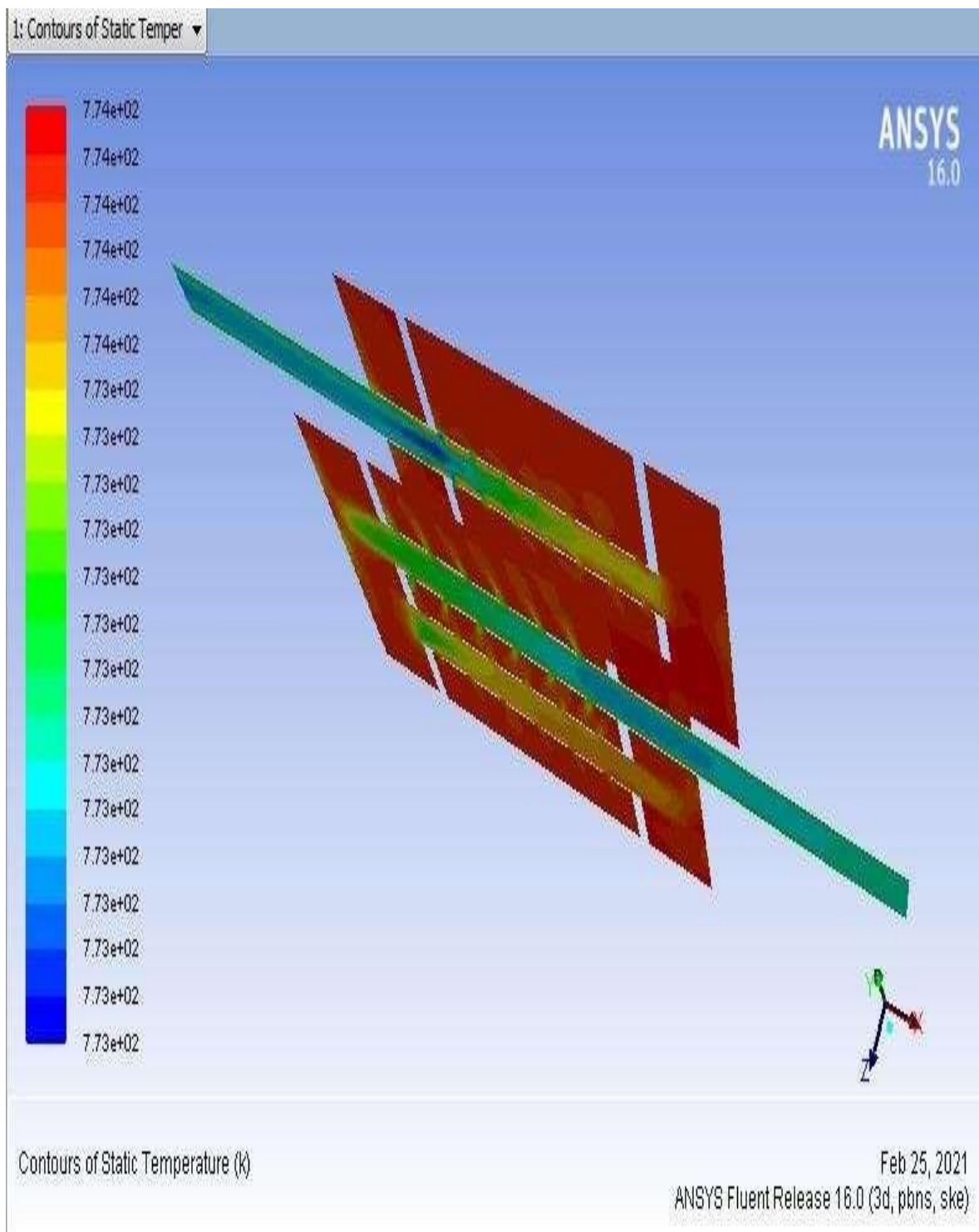


Fig: 5.13: Contours of Static Temperature

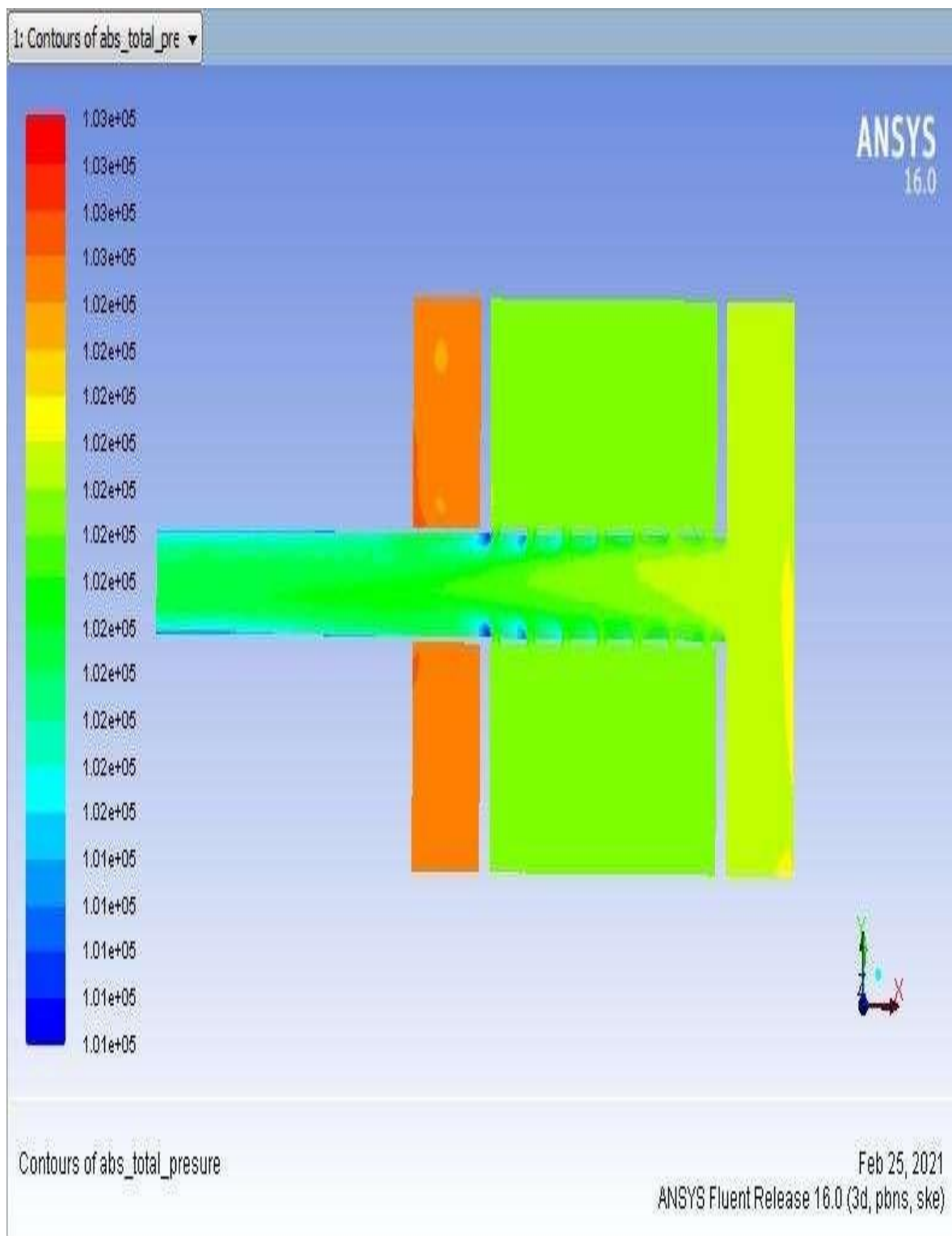


Fig: 5.14: Contours of ABS Total Pressure

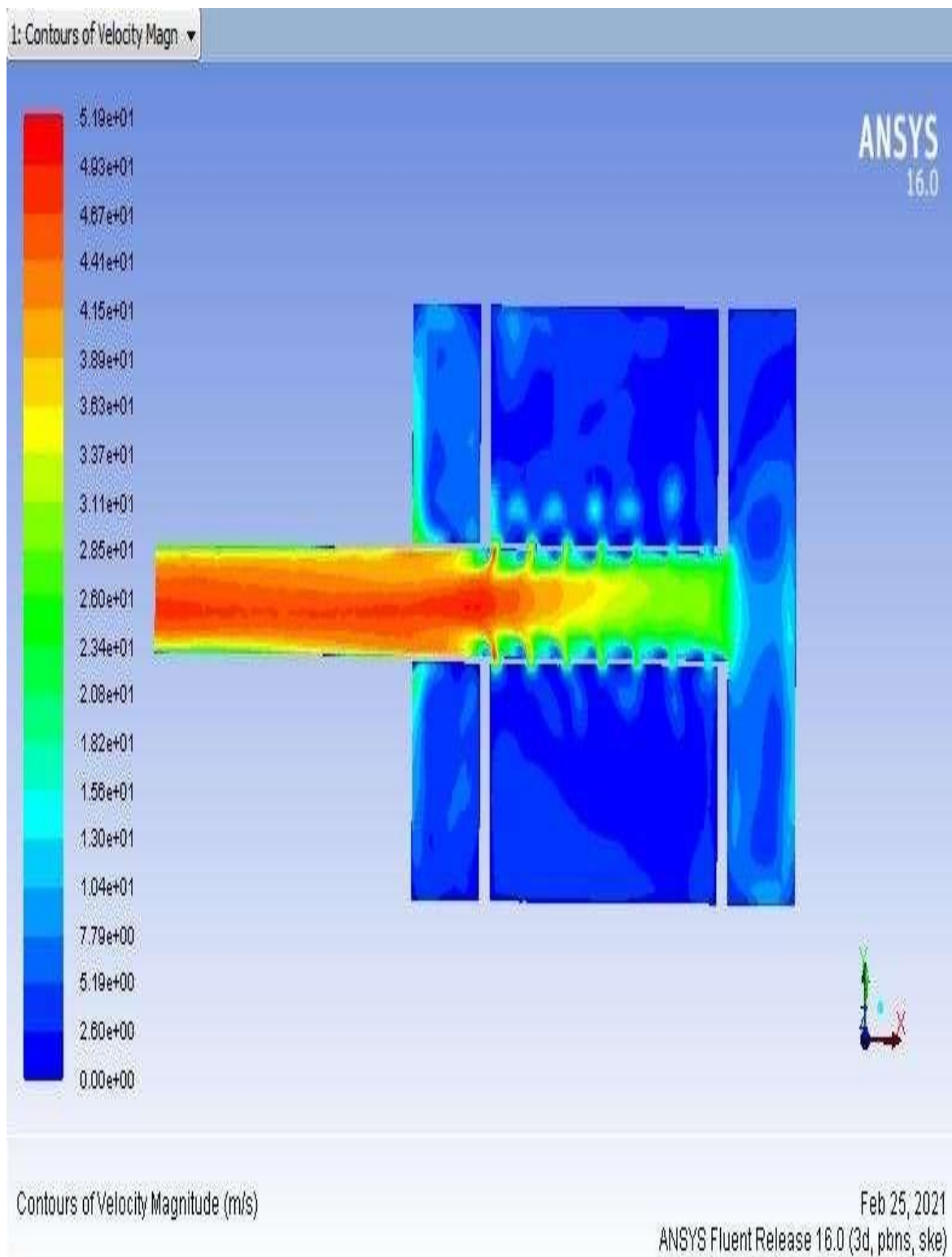


Fig: 5.15: Contours of Velocity Magnitude

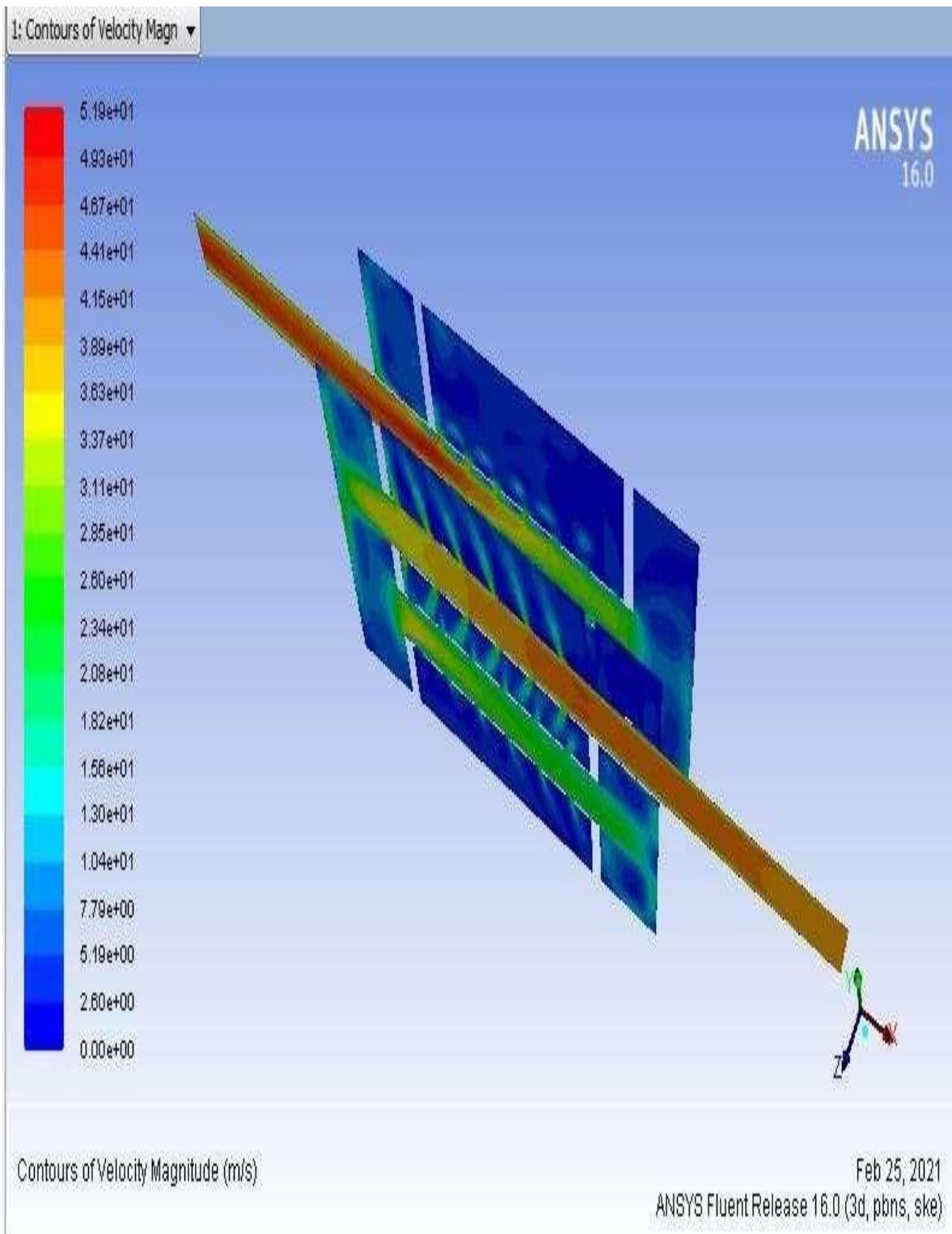


Fig: 5.16: Contours of Velocity Magnitude

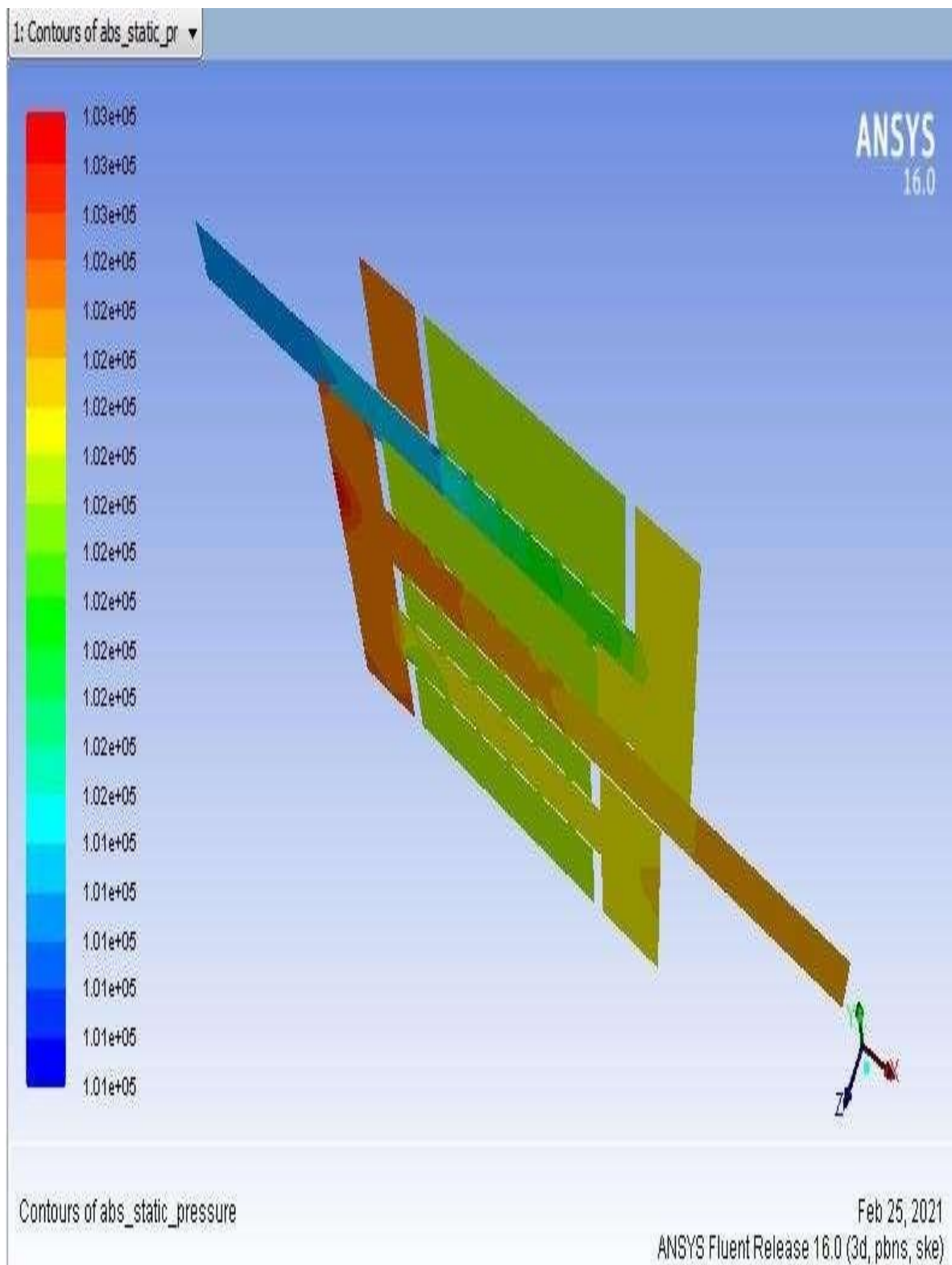


Fig: 5.17: Contours of ABS Static Pressure

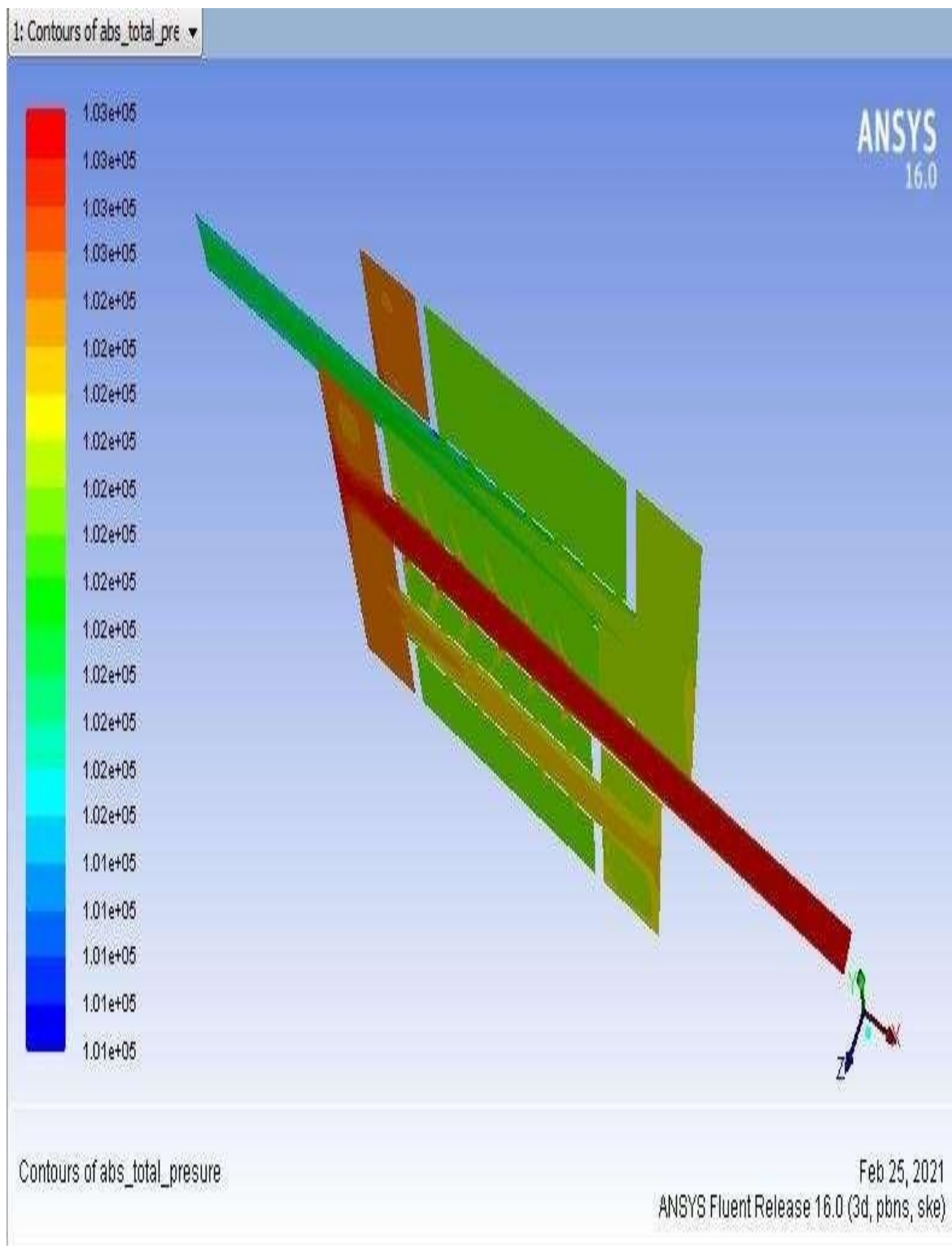


Fig: 5.18: Contours of ABS Total Pressure

DESIGN 2 ANALYSIS

Table: 5.3: DESIGN-2 :

Mass-Weighted Average abs_static_pressure		

inlet		102161.82
outlet		101325

Net		101743.41
Mass-Weighted Average abs_total_presure		

inlet		102524.4
outlet		101742.78

Net		102133.59
Area-Weighted Average abs_static_pressure		
=====		
inlet		102161.82
outlet		101325

Net		101744.94
Area-Weighted Average abs_total_presure		

inlet		102524.4
outlet		101716.83

Net		102122.09

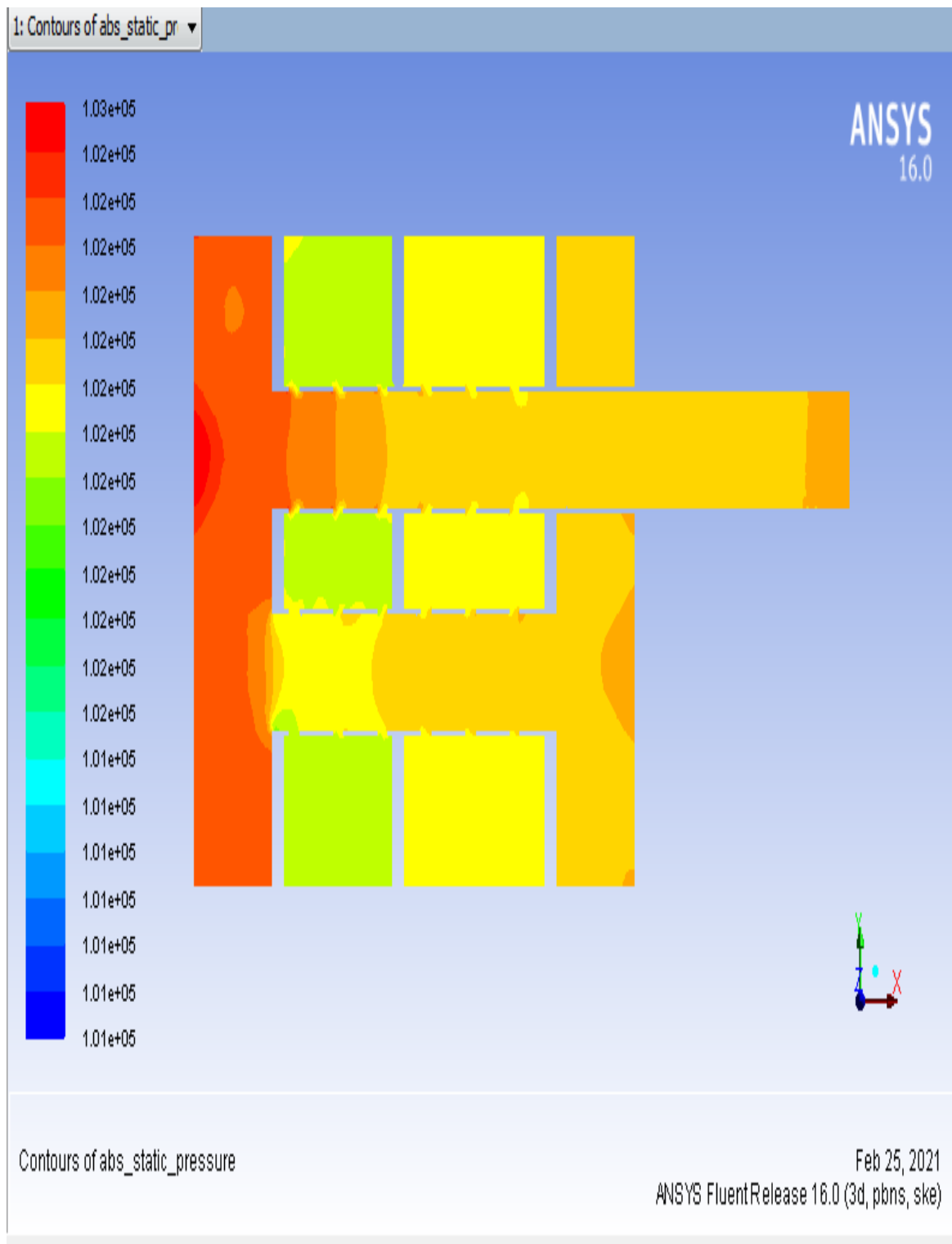


Fig: 5.19: Contours of ABS Static Pressure

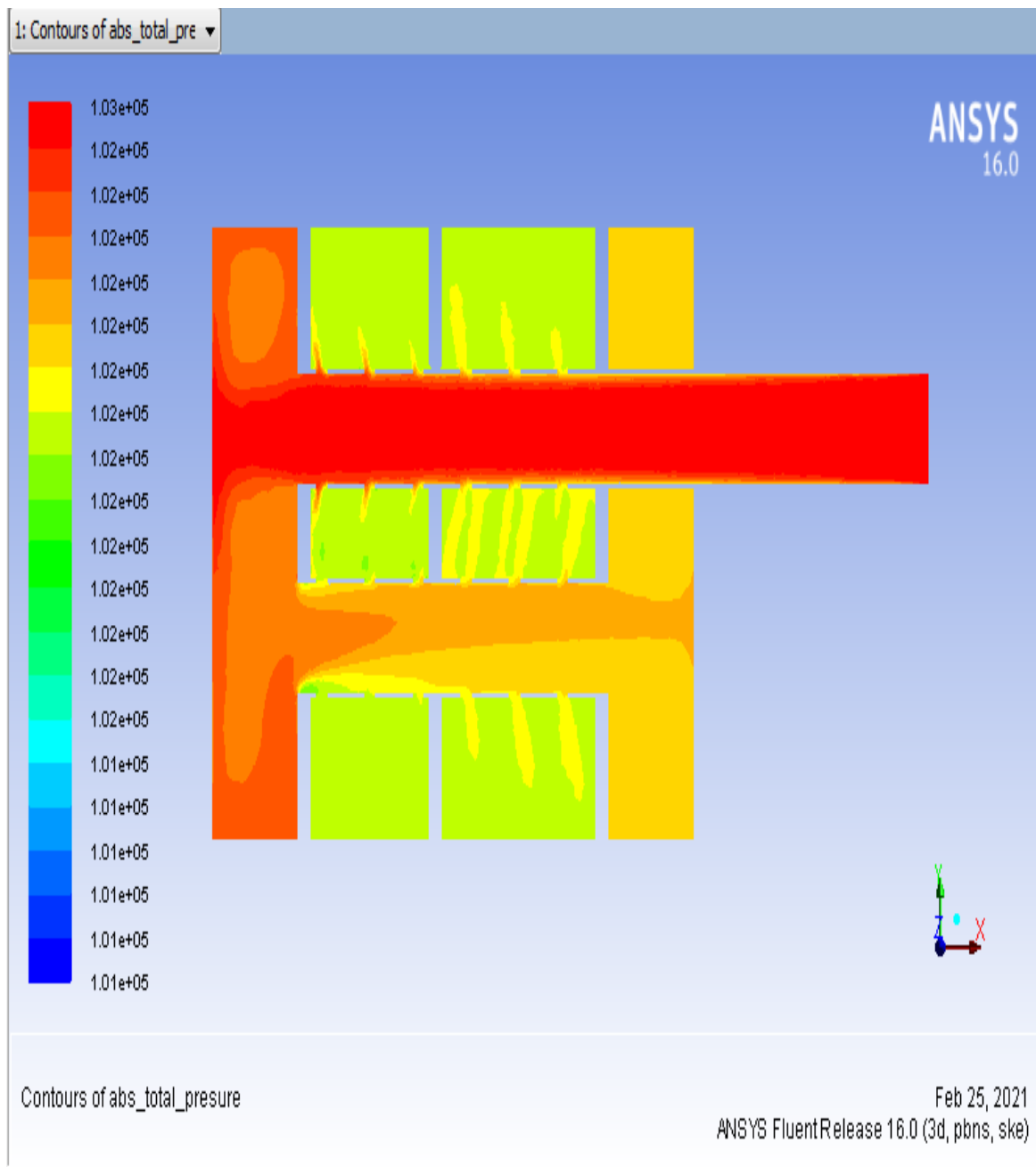


Fig: 5.20: Contour of total pressure

5.5 DESIGN 2:

The layout 2 version has three baffle plates with perforated tubes, right here CFD evaluation is finished through Ansys, and 3D model is done using CATIA software from the above fig, it truly displaying the stress drop and returned stress on the usage of 3

baffle plates, it lowers the noise and vibration. In this evaluation, layout 2 has stress drop up to 807.57. So it lessens the vibration and noise examination to layout 1 and the current version.

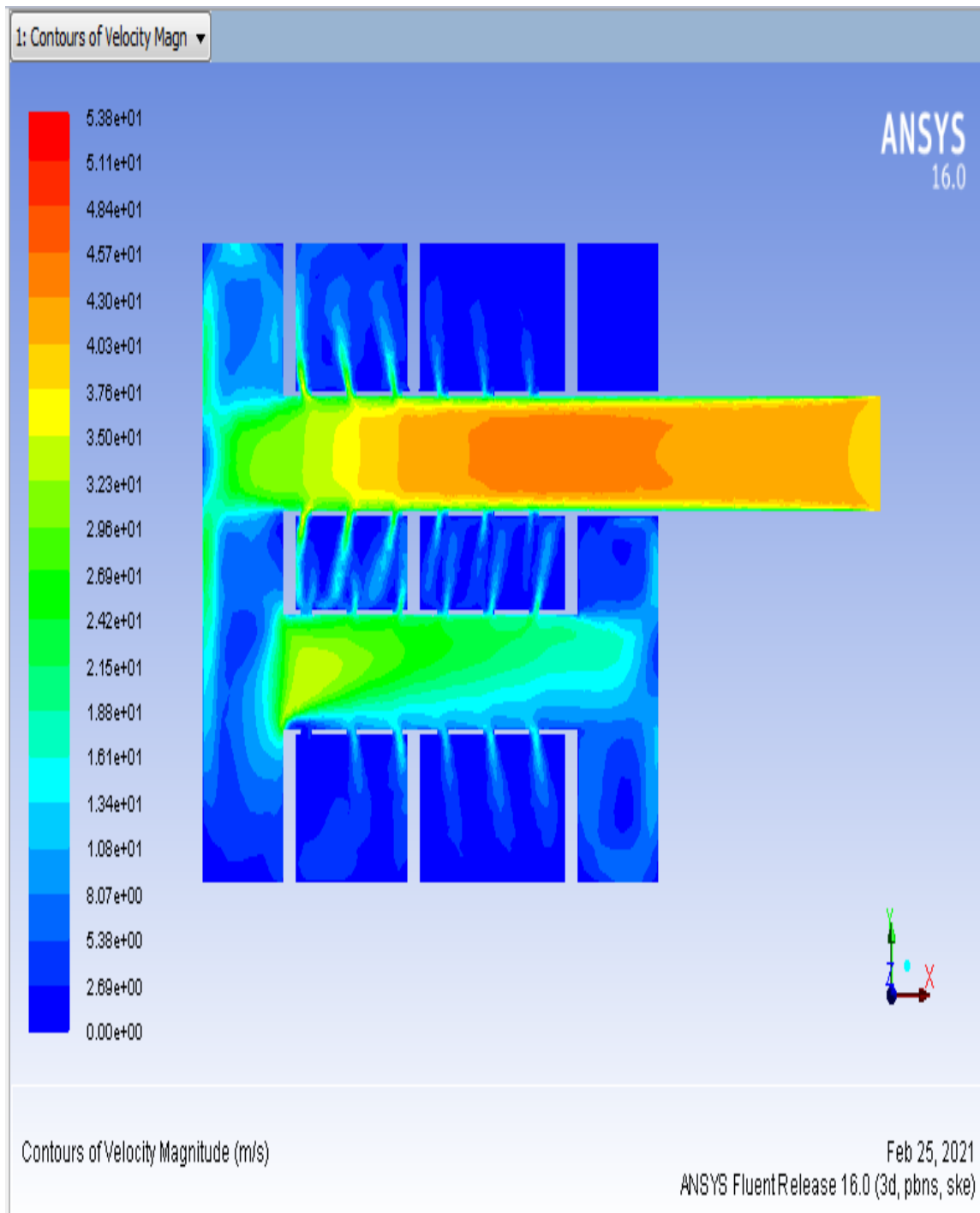


Fig: 5.21: Contours of Velocity Magnitude

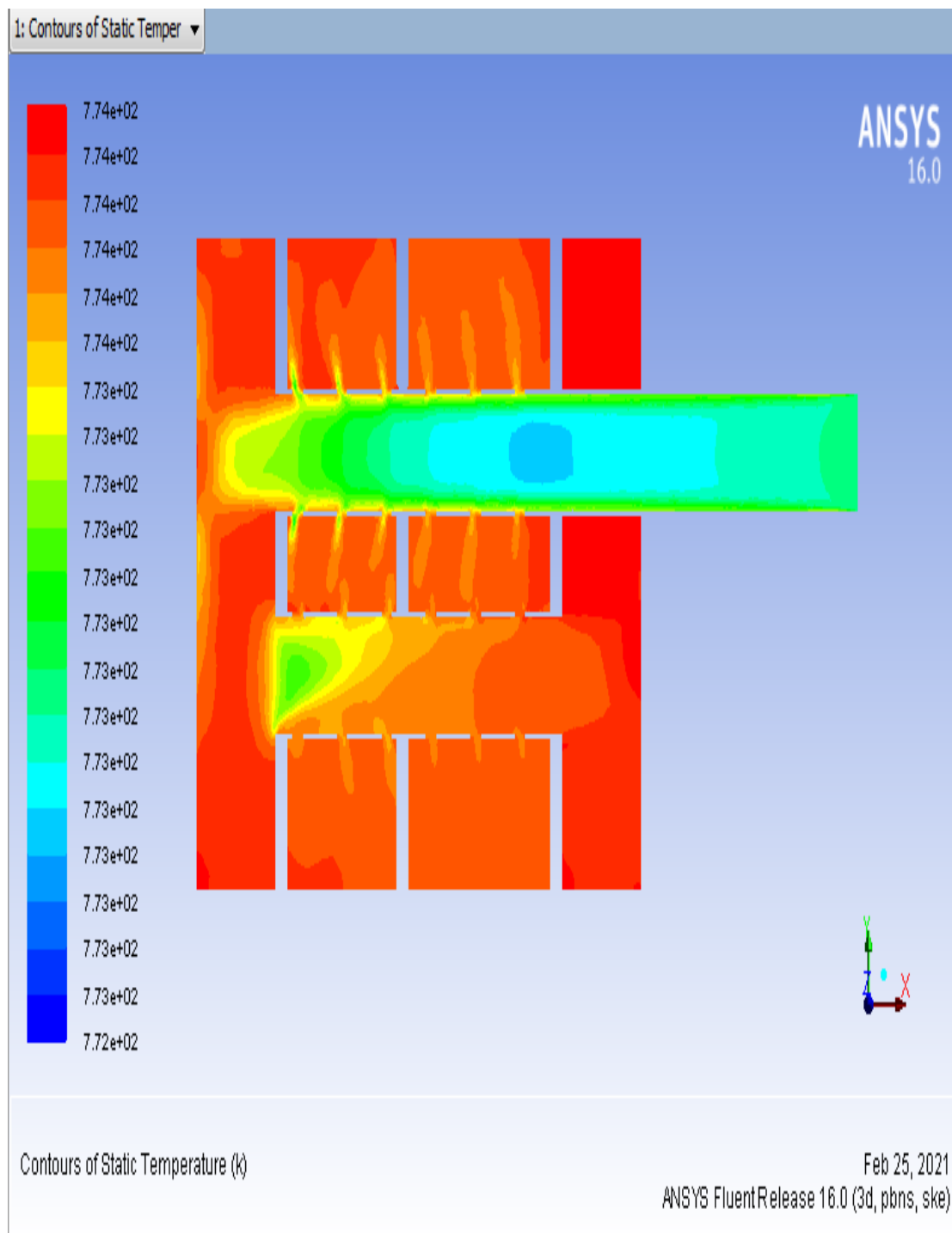


Fig: 5.22 Contours of Static Temperature

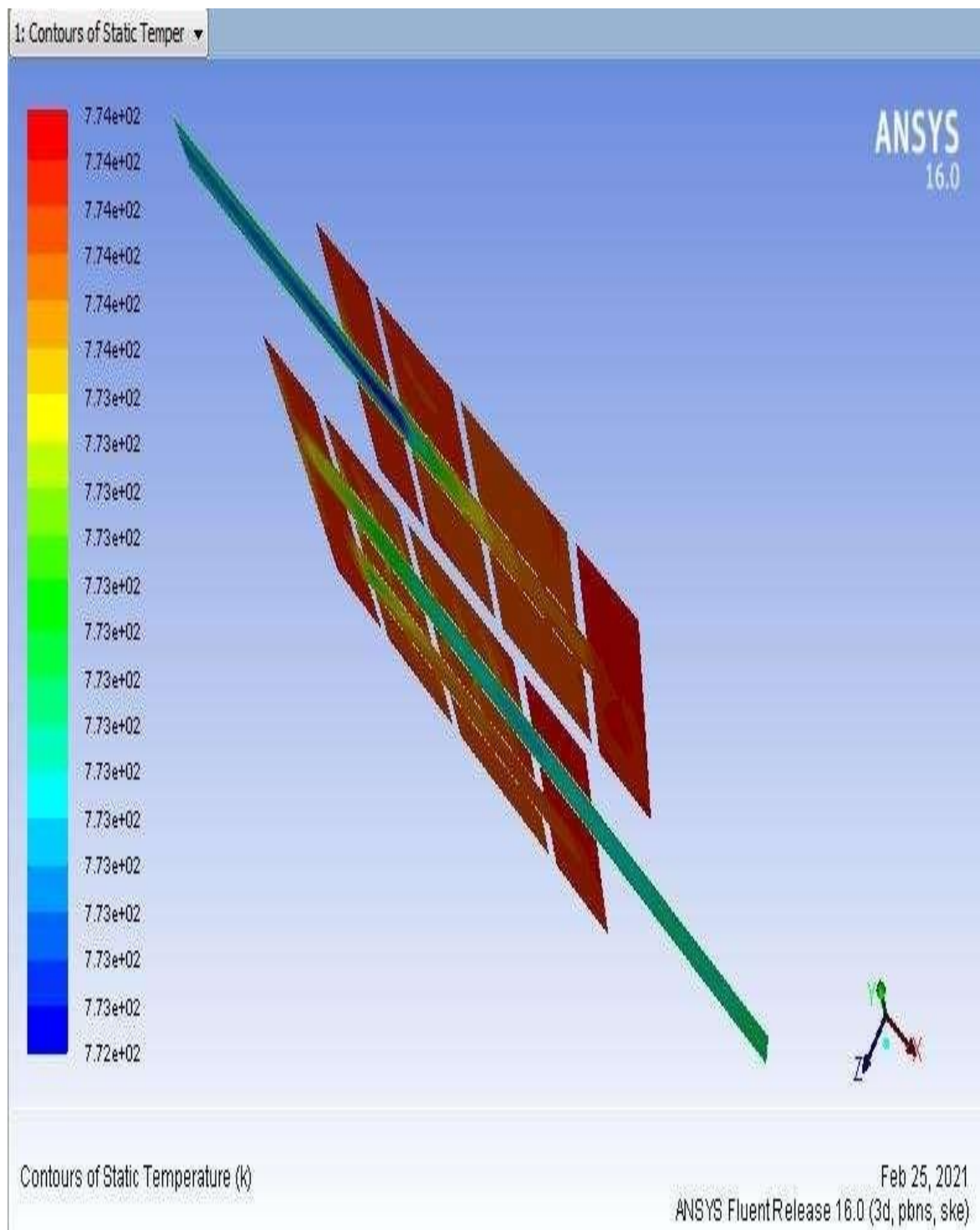


Fig: 5.23: Contours of Static Temperature

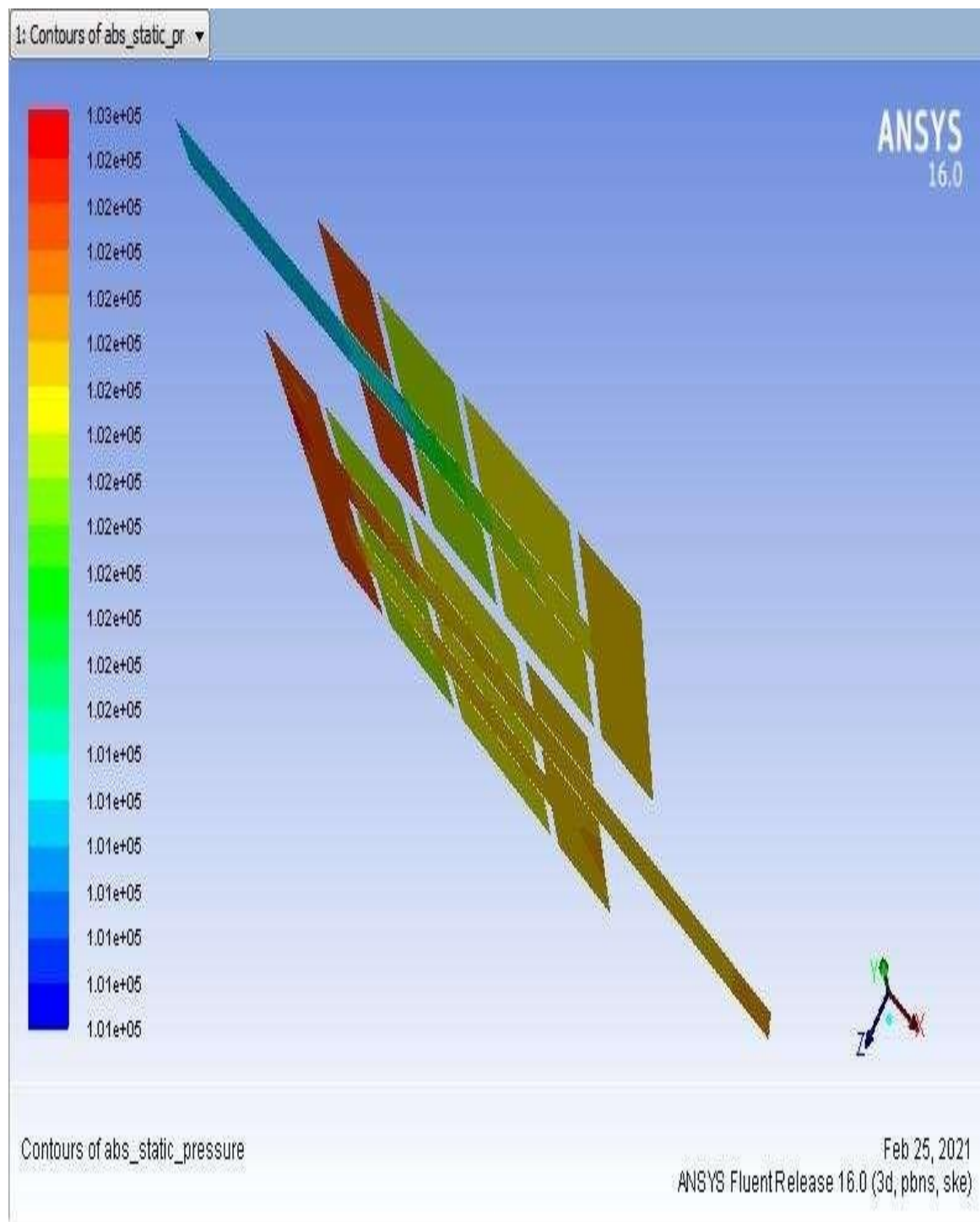


Fig: 5.24: Contours of ABS Static Pressure

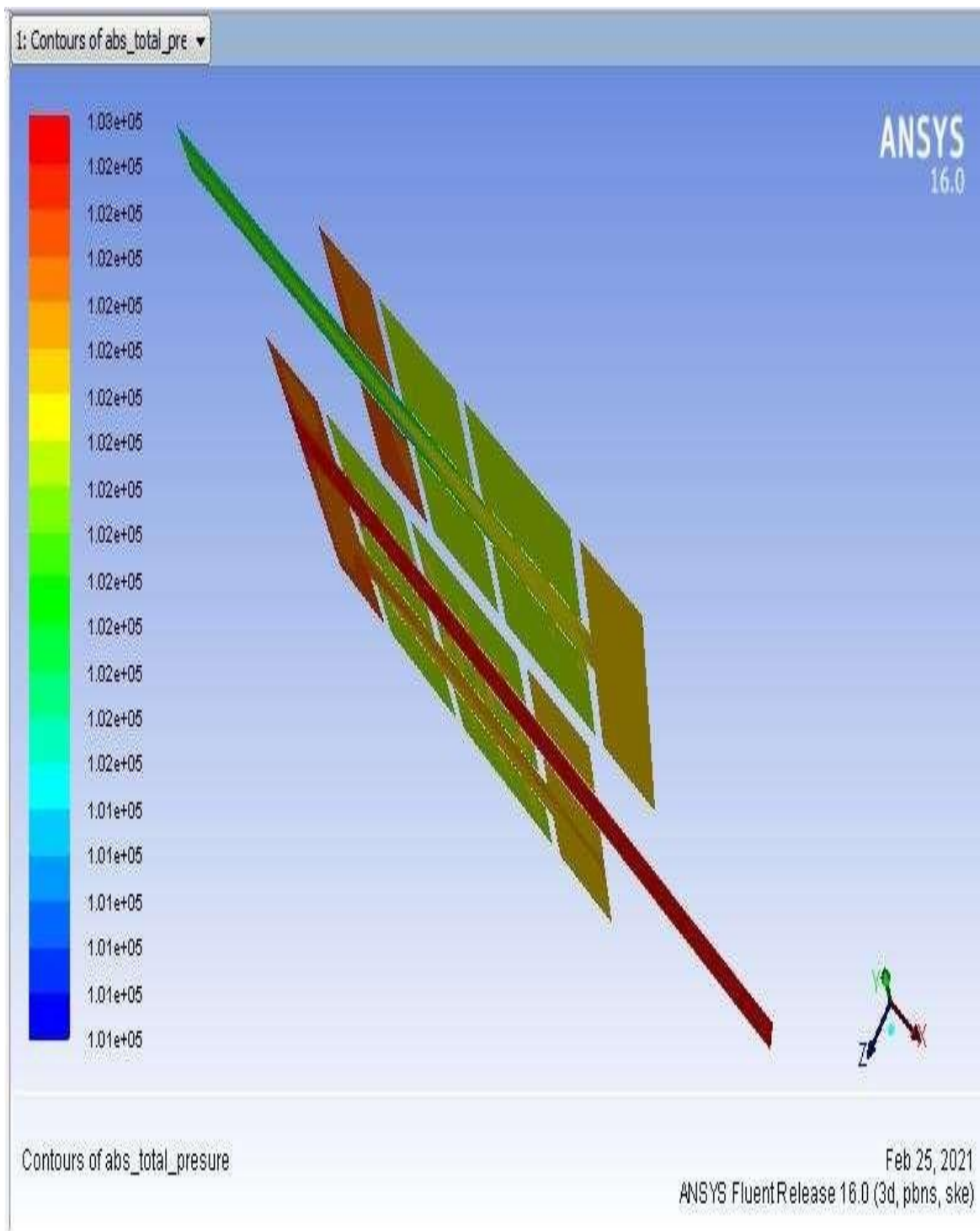


Fig: 5.25: Contours of ABS Total Pressure

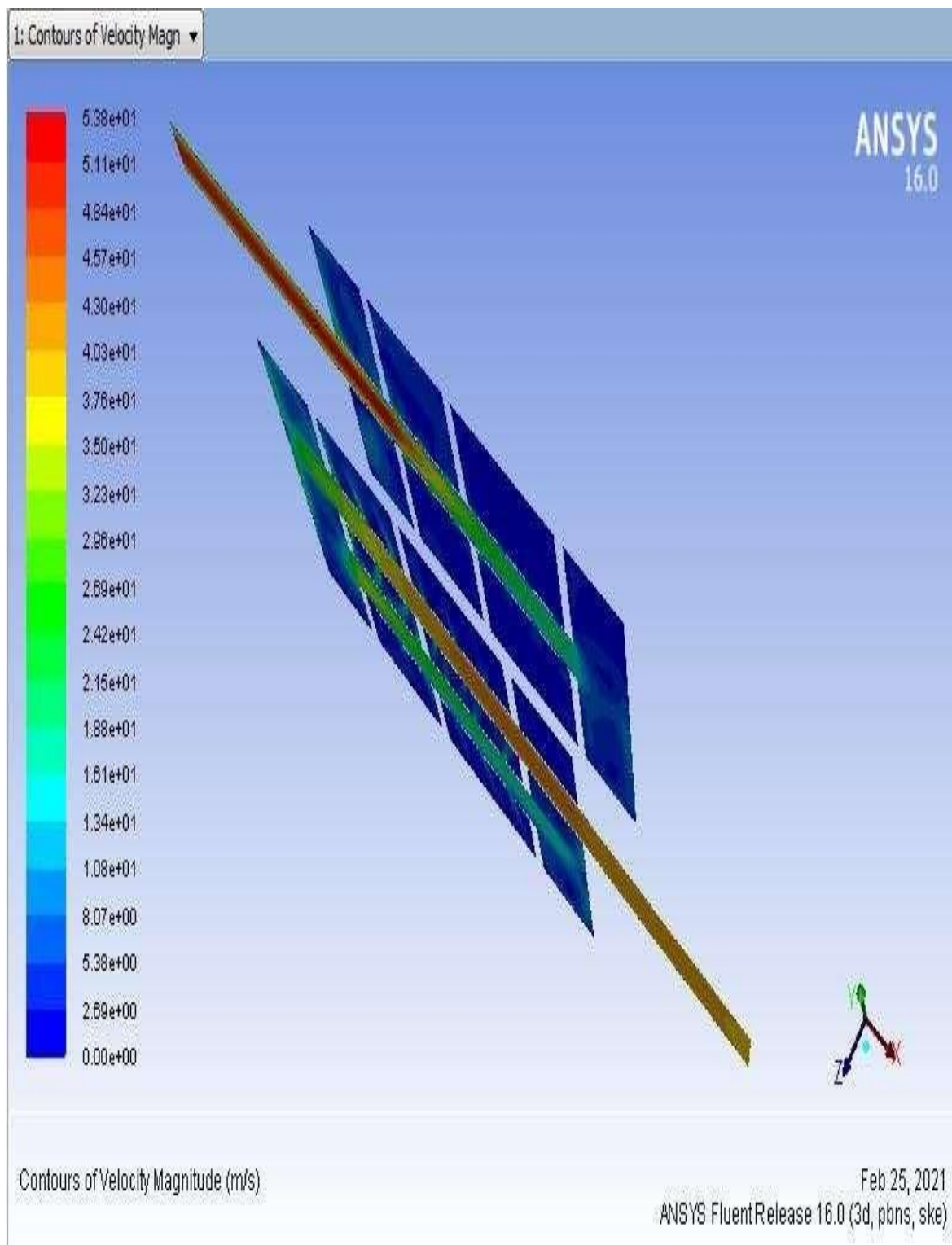


Fig: 5.26: Contours of Velocity Magnitude

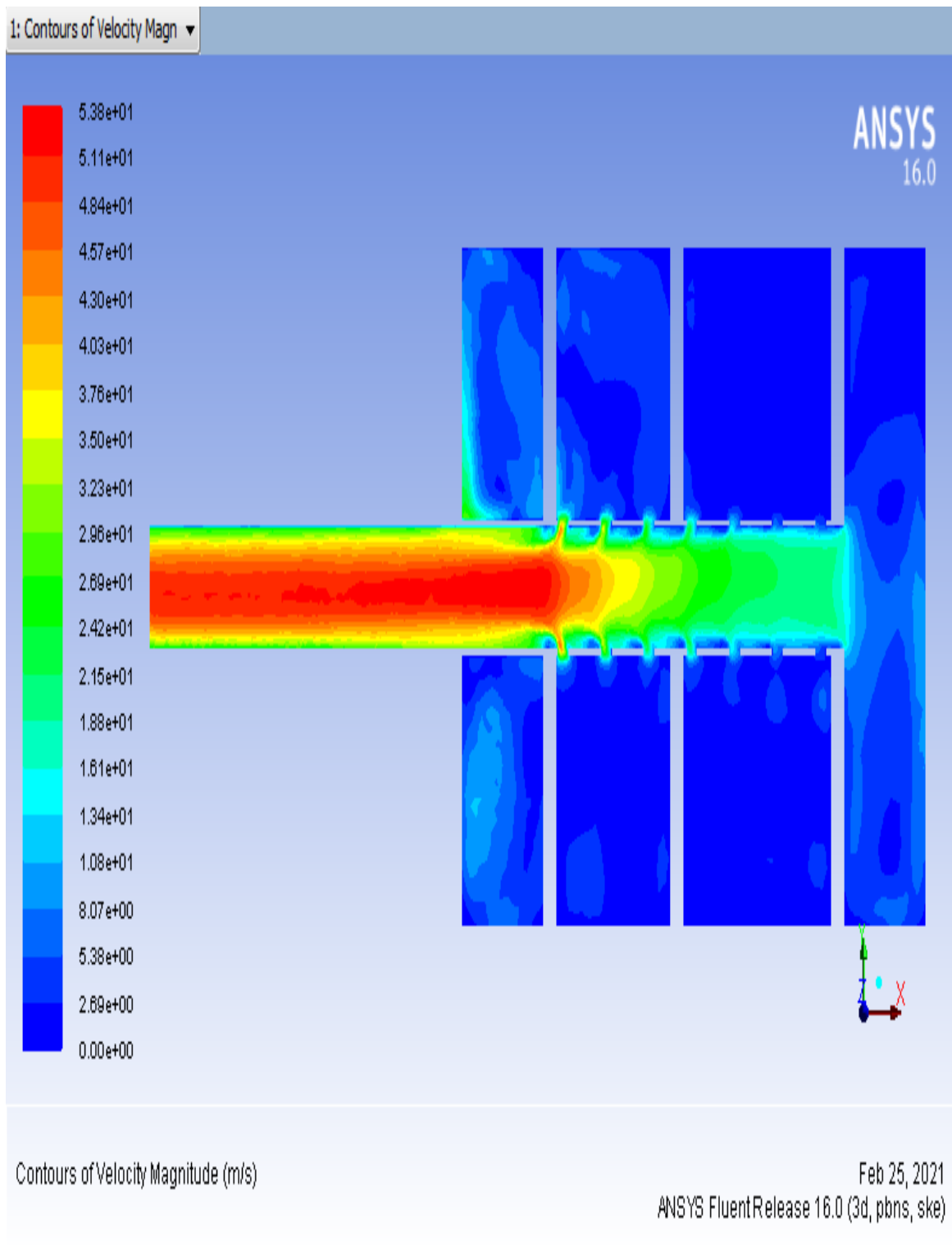


Fig: 5.27: Contours of Velocity Magnitude

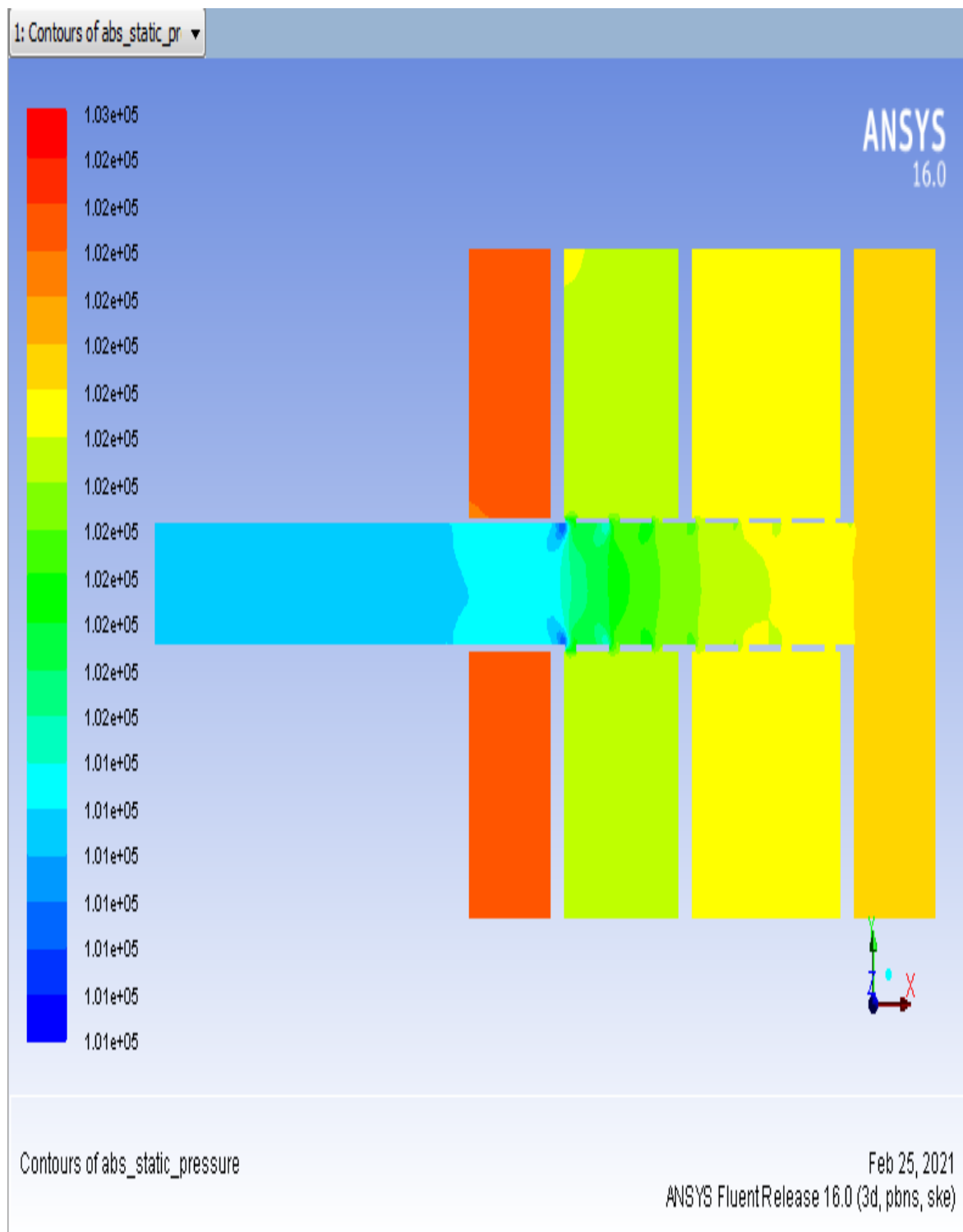
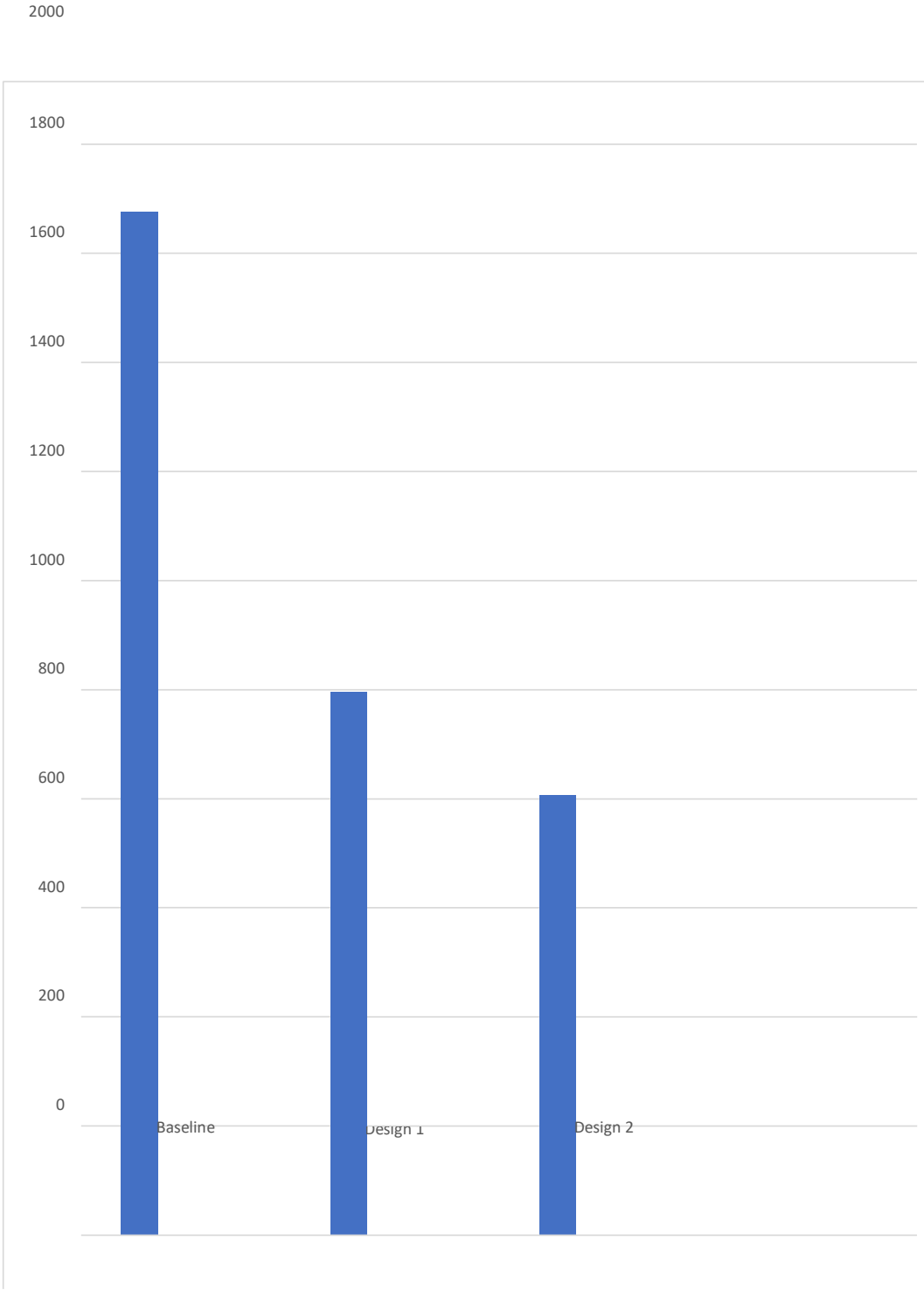


Fig: 5.28: Contours of ABS Static Pressure

MUFFLER GRAPH



GRAPH: 5.5: MUFFLER GRAPHICAL CHART:

Table: 5.4: Pressure Drop :

DESIGN	INLET PRESSURE	OUTLET PRESSURE	PRESSURE DROP
MODEL DESIGN	103614.09	101737.72	1876.37
DESIGN 1	102709.88	101714.2	995.68
DESIGN 2	102524.4	101716.83	807.57

**Table: 5.5: Comparson of Pressure Drop For Baseline, Design 1 & Design 2
Model:**

S.NO	MODEL	VALVE DROP
1.	BASELINE	1876.87
2.	DESIGN 1	995.68
3.	DESIGN 2	807.57

5.6 RESULT

From the results of all mufflers graph as shown in the figure above, It shows that design 2 having maximum pressure loss (807.57) because of 3 baffles present in design which gives more noise reduction than others. But more the pressure loss tends to more back pressure which affects the performance of the engine.

CHAPTER – 6

CONCLUSION

Various designs are created in comparison to the existing muffler and simulated in software. The simulation concluded that design 2 is far better in pressure loss, so with higher pressure loss,, there is more noise reduction. So for more sound attenuation we can prefer design 2.

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