DESIGN EVALUATION AND OPTIMIZATION OF A NOZZLE USED IN DIESEL ENGINE

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Abstract

The nozzle is used to convert the chemical thermal energy generated in the combustion chamber into kinetic energy. The nozzle converts the low velocity, high pressure, high temperature gas in the combustion chamber into high velocity gas of lower pressure and temperature. Nozzle is a device designed to control the rate of flow, speed, direction, mass, shape, and/or the pressure of the stream that exhaust from them.

Nozzles come in a variety of shapes and sizes depending on the mission of the rocket, this is very important for the understanding of the performance characteristics of rocket. Convergent divergent nozzle is the most commonly used nozzle since in using it the propellant can be heated in combustion chamber.

In this thesis the convergent divergent nozzle changing the different nozzle diameters and different fluids at different velocities. We modeled convergent divergent nozzle changing with different nozzle diameters and Analyzed the convergent divergent nozzle with different mass flow rates to determine the pressure drop, heat transfer coefficient, and velocity and heat transfer rate for the fluid by CFD technique.

1.INTRODUCTION

The nozzles on a diesel engine are responsible for taking the liquid fuel and atomizing it (breaking into small particles) so that it can burn. They need to deliver the proper amount of fuel to each cylinder for the load and horsepower demand.

They perform this job a countless number of times. Over the course of the life of the engine the inject cycles can be in the billions and possibly trillions. In addition, the nozzles are subjected to an extremely abusive environment — more than any other part of the engine.

The nozzles are exposed to temperature peaks of more than 2,550 F degrees on the outside while the internal pressure may exceed 30,000 psi. Though almost every manufacturer recommends servicing the nozzles to maintain proper atomization, these procedures are often neglected by the farmer and only addressed when a problem exists.

Preventive maintenance should be part of every diesel engine owners' plan if long life and trouble-free performance is desired.

When discussing diesel engines many refer to the part that delivers fuel to the cylinder as an injector. To a diesel expert the injector is the nozzle holder assembly but over time it has been used to describe the actual nozzle.

This has become complicated by the different fuel system designs that are employed on diesel engines. There are now mechanical unit injectors (MUI), electronic unit injectors (EUI) and hydraulic actuated electronic unit injectors (HEUI) that became popular on light-duty designs with the Ford Power Stroke engine.

The common complaint that prompts the injectors to be removed is blue/black smoke at idle, missing under load, poor idle quality, a decrease in power and an increase in fuel consumption along with hard starting.

There are brand specific variations in the nozzles from different manufacturers but the basic function, service procedures and maintenance tips all apply.

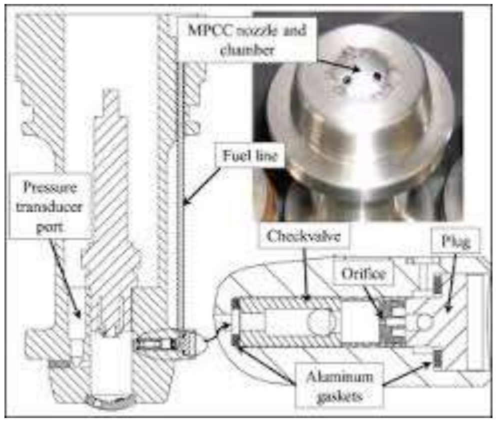
To complicate matters, within the mechanical category there are many different designs of nozzles that in some instances share operating characteristics but not in every case.

Hydraulic injectors are usually classified by the nozzle design. There is poppet, pintle, multi-orifice and electro-hydraulic styles. With each design category there are often subsets of styles such as those used strictly with in-direct injection (IDI) or direct injection (DI) applications.

Regardless of the design, a mechanical injector that contains no electronic parts can and needs to be serviced. Electronic enhanced injectors in light-duty applications are traditionally not serviceable and need to be replaced as a unit.

EFFECTS OF DISEL NOZZLE

The four-stroke direct-injection diesel engine typical was measured and sculptured by Bakar et al victimization GT-POWER machine model and has explored of diesel performance result based mostly on engine speeds. GT-POWER is the leading engine simulation tool employed by engine and vehicle manufacturers and suppliers and is appropriate for analysis of a large vary of engine problems.



The details of the diesel style vary considerably over the engine performance and size vary. specifically, completely different combustion chamber geometries and fuel injection characteristics area unit needed to deal effectively with major diesel engine style drawback achieving sufficiently speedy fuel-air commixture rates to complete the fuel-burning method within the time out there.

2.LITERATURE REVIEW

In 2016, Fuying Xue , Fuqiang Luo, Huifeng Cui, Adams Moro, Liying Zhou[1] Here in this paper, mathematical theory and model associated with the cavitation and turbulence is presented. The turbulence flow pattern and cavitation evolution for nozzle holes of an asymmetric multi-hole diesel injector were replicated using the multi-phase two fluid flow approach where the effect of injection conditions on bubble number density was considered. The fuel flow characteristics in each nozzle hole were simulated and the effect of cavitation and turbulence were analyzed. The cavitation holes evolution varied significantly. It was observed that the nozzle angles and needle lifting process influenced the cavitation, mass flow rate and flow velocity. In 2016, F.J. Salvador, D. Jaramillo, J.-V. Romero, M.-D. Rosello[2] In this paper, the behaviour of the internal nozzle flow and cavitation phenomenon are numerically studied for non-conventional Diesel convergent-divergent nozzles in order to assess their potential in terms of flow characteristics. The used nozzles differs each other in the convergence-divergence level of the orifices but all of them keep the same diameter at the middle of the nozzle orifice. The calculations have been performed using a code previously validated and able to simulate cavitation phenomenon using a homogeneous equilibrium model for the biphasic fluid and using a RANS method. For the simulations, one injection pressure and different discharge pressures were used in order to assess the characteristics of nozzles for different Reynolds conditions involving cavitating and non-cavitating conditions. In 2016, F.J. Salvador, J. De la Morena. Martínez-López. Jaramillo [3] in this paper, an investigation of the compressibility effects in nozzle flow simulations has been carried out for injection pressures up to 250 MPa. To do so, the fluid properties (including density, viscosity and speed of sound) have been measured in a wide range of boundary conditions. These measurements have allowed to obtain correlations for the fluid properties as a function of pressure and temperature. Then, these equations have been incorporated to a CFD solver to take into account the variation of the fluid properties with the pressure changes along the computational domain. The results from these simulations have been compared to experimental mass flow rate and momentum flux results, showing a significant increase in accuracy with respect to an incompressible flow solution. In 2016, V. Lazarev, G. Lomakin, E. Lazarev [4] Perfection of output parameters of diesel engines is considered as a result of the rail-pressure increase and modernization of nozzle tribosystems represented at high (up to 300 MPa) values of the fuel pressure. The nozzle with the modified design and additional (bottom) precision guiding interface is used and hydrodynamic parameters of injection are analyzed. The computational fluid-dynamic (CFD) modeling for estimation of hydrodynamic parameters of the fuel flow and force distribution in the “needle – nozzle body” system is used. The results of the injection modeling and contact parameters for the modified design of nozzle precision interfaces are established and discussed. The ways of increasing the stability of needle position in the nozzle body with perfection of parameters of fuel injection are presented. In 2016, Tao Qiu , Xin Song, Yan Lei, Hefei Dai , Chunlei Cao , Hui

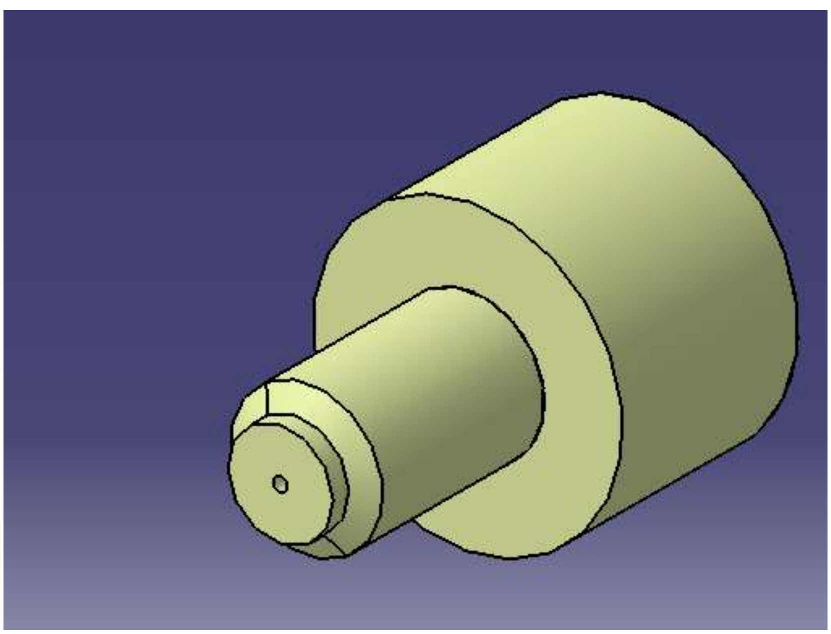
Xu , Xiang Feng [5] This work investigates the impacts of the injection back pressure on the nozzle inner cavitation developing, especially the flow characteristic during choking process. The following are the main observations: As the back pressure drops, the cavitation process is divided into 3 periods. During choking period, the back pressure has little effect on the mass flow.– During choking period, the discharge coefficient declines as the back pressure drops.– During choking period, the interface between the liquid and mixing section is constant.– During choking period, the outlet velocity increases as the back pressure drops.– In 2015, Hengzhou Wo , Karl D. Dearn , Ruhong Song , Enzhu Hu , Yufu Xu , Xianguo Hu [6] biomass oil/diesel blend was prepared using an emulsion method and combusted in a diesel engine. An injector was then removed and the morphology, composition, and structure of the carbonaceous deposits on the pintle type nozzle were characterized using a combination of HRTEM, SEM/EDAX, Raman and XRD. Results showed that the carbon deposition of the emulsified fuel with high crystallinity was greater than that of diesel. The agglomerated particulate diameters of the deposited carbon from diesel and emulsified fuel were approximately 10–30 μm and 50 μm, respectively. The carbon deposition mechanism from the emulsified fuel was attributed to the high oxygen content of the groups leading to increased polymerization and subsequent condensation on the nozzle surfaces that was then carbonised.

3.MODELING AND ANALYSIS

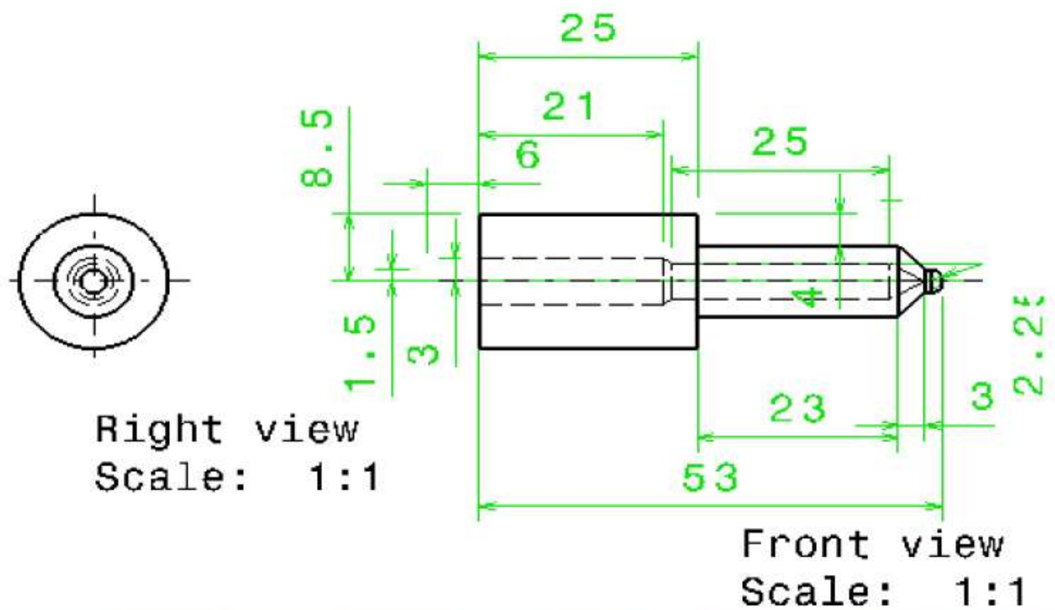
CATIA is an acronym for Computer **A**ided **T**hree-dimensional **I**nteractive **A**pplication. It is one of the leading 3D software used by organizations in multiple industries ranging from aerospace, automobile to consumer products.

CATIA is a multi platform 3D software suite developed by Dassault Systems, encompassing CAD, CAM as well as CAE. Dassault is a French engineering giant active in the field of aviation, 3D design, 3D digital mock-ups, and product lifecycle management (PLM) software. CATIA is a solid modeling tool that unites the 3D parametric features with 2D tools and also addresses every design-to-manufacturing process. In addition to creating solid models and assemblies, CATIA also provides generating orthographic, section, auxiliary, isometric or detailed 2D drawing views. It is also possible to generate model dimensions and create reference dimensions in the drawing views. The bi-directionally associative property of CATIA ensures that the modifications made in the model are reflected in the drawing views and vice-versa.

3d Model of Nozzle



2D Drawing

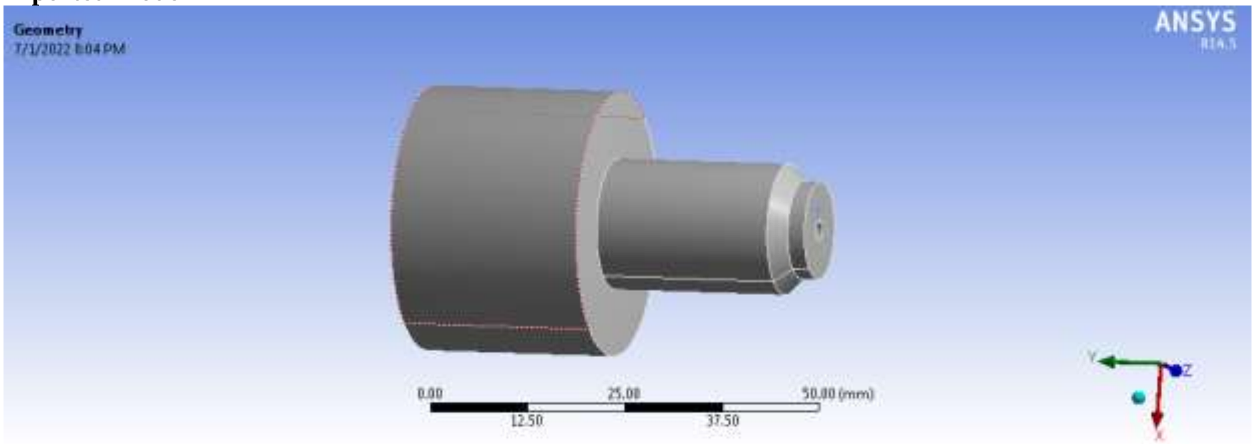


Finite element analysis is a method of solving, usually approximately, certain problems in engineering and science. It is used mainly for problems for which no exact solution, expressible in some mathematical form, is available. As such, it is a numerical rather than an analytical method. Methods of this type are needed because analytical methods cannot cope with the real, complicated problems that are met with in engineering. For example, engineering strength of materials or the mathematical theory of elasticity can be used to calculate analytically the stresses and strains in a bent beam, but neither will be very successful in finding out what is happening in part of a car suspension system during cornering.

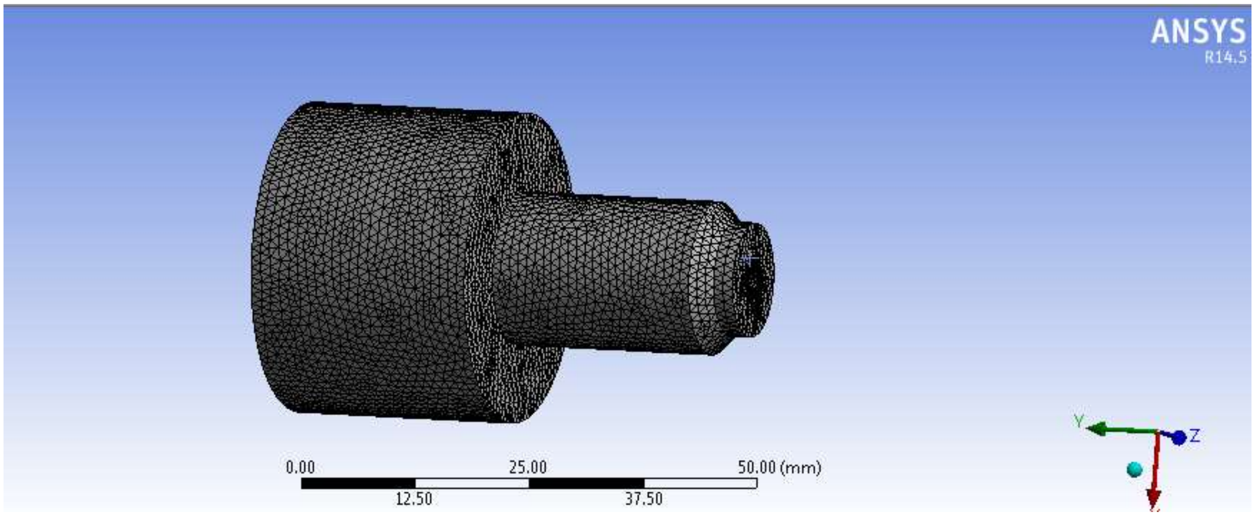
Computational fluid dynamics, usually abbreviated as CFD, is a branch of fluid mechanics that uses numerical methods and algorithms to solve and analyze problems that involve fluid flows. Computers are used to perform the calculations required to simulate the interaction of liquids and gases with surfaces defined by boundary conditions. With high-speed supercomputers, better solutions can be achieved. Ongoing research yields software that improves the accuracy and speed of complex simulation scenarios such as transonic or turbulent flows. Initial experimental validation of such software is performed using a wind tunnel with the final validation coming in full-scale testing, e.g. flight tests.

4. CFD ANALYSIS OF DIESEL ENGINE NOZZLE

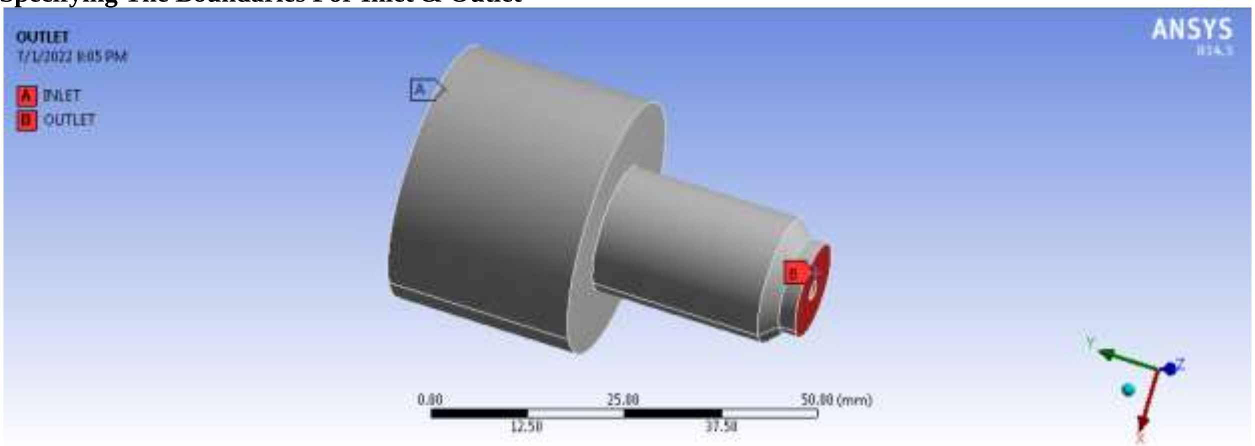
Imported Model



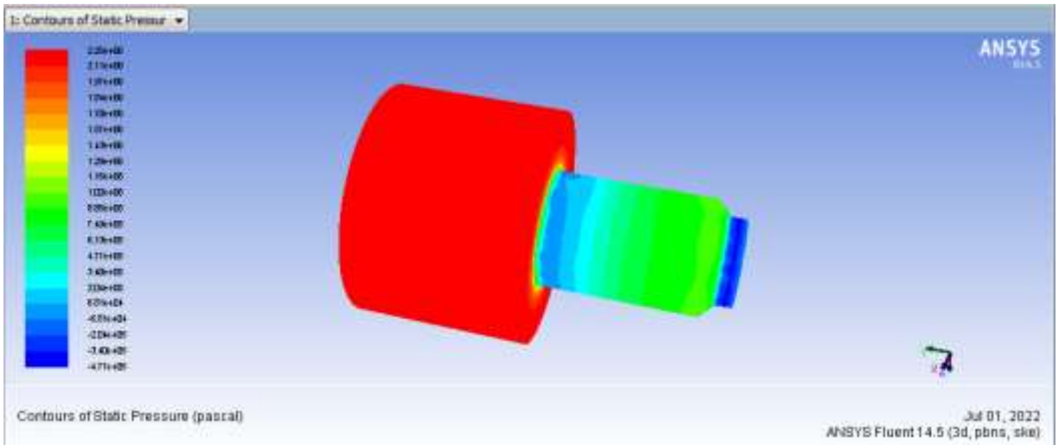
Meshed Model



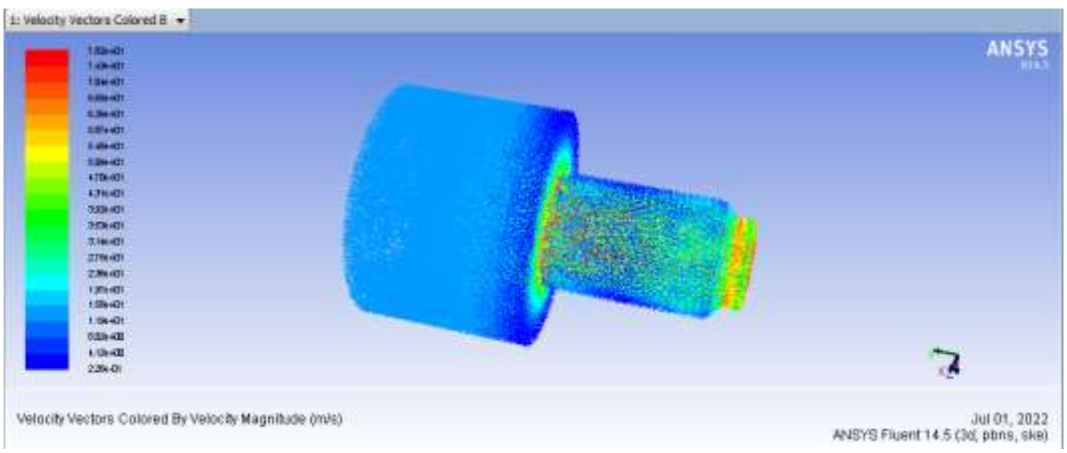
Specifying The Boundaries For Inlet & Outlet



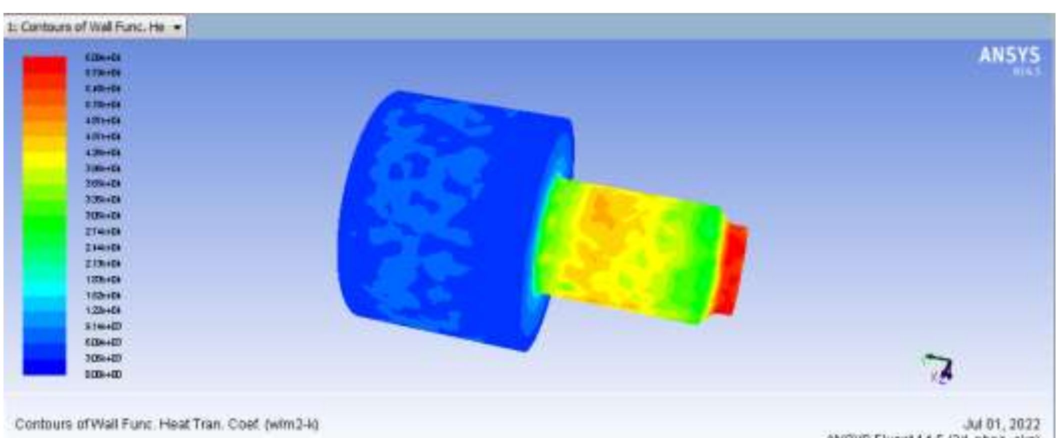
Pressure Plot



Velocity



Heat Transfer Coefficient



Mass Flow Rate

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      Mass Flow Rate                  (kg/s)
-------------------- --------------------
               inlet            5.1545849
  interior-partbody           -2.7459452
              outlet           -5.1530056
       wall-partbody                    0
  ------------------ --------------------
                 Net         0.0015792847
```

Results tables

Angle	Inlet velocity(m/s)	Pressure (pa)	Velocity (m/s)	Heat transfer coefficient	Mass flow rate (kg/sec)
45	**15.5**	2.25e+06	7.82e+01	6.09e+04	0.00157
	25.5	5.37e+06	1.37e+02	8.32e+04	0.00115
	35.5	1.24e+07	1.92e+02	1.00e+04	0.0704
60	**15.5**	3.34+06	1.05e+02	4.9e+04	0.012572
	25.5	8.77+06	1.72e+02	7.30e+04	0.0281
	35.5	1.63e+07	2.42e+02	9.75e+04	0.040214
75	**15.5**	4.19e+06	1.24e+02	6.51e+04	0.01485
	25.5	1.02e+07	2.00e+02	9.37e+04	0.006624
	35.5	2.26e+07	2.77e+02	1.86e+05	0.04163

CONCLUSION

Nozzles come in a variety of shapes and sizes depending on the mission of the rocket, this is very important for the understanding of the performance characteristics of rocket. Convergent divergent nozzle is the most commonly used nozzle since in using it the propellant can be heated in combustion chamber.

In this thesis the convergent divergent nozzle changing the different nozzle diameters and different fluids at different velocities. We modeled convergent divergent nozzle changing with different nozzle diameters.

By observing the CFD analysis of diesel engine nozzle the pressure, velocity, heat transfer rate and mass flow rate values are increases by increasing the inlet velocities and increasing the nozzle angle.

So it can be concluded the diesel engine nozzle efficiency were more when the nozzle angle 75 deg.

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