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Paper Authors

Mohd Ghouse Ahmed, Dr.M.Subburaj, Mohd Mohiuddin

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PARAMETRIC RAM AIR CHANNEL MODEL FOR FLOW OPTIMIZATION

1. Mohd Ghouse Ahmed, M.tech in cad/cam, SCET, JNTUH, TS, IND.
2. Dr.M.Subburaj, professor of Mechanical Engineering Dept, SCET, JNTUH, TS, IND.
3. Mohd Mohiuddin, Associate Professor of Mechanical Engineering Dept, SCET, JNTUH, TS, IND.

Abstract : In an aircraft, ambient air is directed via ram air channels or NACA channels for a variety of uses, including pressurising the cabin, cooling heat exchangers, and other uses like cooling coolant. Even aerodynamical aspects ought to be taken into consideration during design to guarantee that it supplies the required quantity of ambient air for the various activities that have been described. In the past, it was common practice to first design built prototypes, then carry out experiments to improve the design and provide forecasts that were accurate and easy to understand. Before finishing the prototype, certain new mathematical approaches were added in an effort to prevent the use of these methods, which may result in significant resource and time loss and increase the likelihood of receiving the erroneous results. Prior to the prototype stage, the calculation stage includes a few more processes, namely computer-aided simulations. These simulations may approach the accuracy rate required before the prototype stage and can be as exact as real-time simulations. The goal is to create a Ram air channel tool chain that increases flow and delivers the heated refrigerant from the avionics systems to heat exchangers to cool it. The applications for which the heat exchanger is used and the temperature range that needs to be cooled determine its specifications. The Ram air channel's shape is designed in CAD to maintain the required mass flow rate for the heat exchanger's performance after first estimating the heat exchanger's size for the required performance. In order for the final model to achieve flow optimization for a heat exchanger, these two components are finally incorporated into the simulation loop.

Index Terms : *NACA, CAD, Ram air channel, aerodynamical*

1. INTRODUCTION

The estimation of the aircraft's total drag is one of the requirements for a simulation of an aviation system's Environmental Control Systems (ECS). The system's largest surface aperture, the ram air channel, significantly contributes to this drag. The supply of sufficient mass flow from the air surrounding the heat exchanger is the primary function of the ram air channel. During the calculations of the design phase, it is particularly challenging to predict the drag produced by the NACA channel or ram air channel without specific geometry. Objective: Using the extremely simplified NACA channel or ram air channel model, the primary objective of this study is to develop a tool chain for calculating air flow in the NACA channel, heat transfer in the heat exchanger, and (approximately) drag contribution. In this instance, the design parameters used are the W/D ratio across the NACA channel, ramp angle, pipe area, heat exchanger frontal area, and NACA channel lip configurations. Constraints included the pressure recovery at the NACA channel and the pressure drop over the heat exchanger. Solid works are used to create the entire geometric model of the NACA Inlet's heat exchanger (HEX), exit tube, and post-HEX pipe. The heat exchanger's volume, frontal area, and pressure drop across it are all computed using MATLAB. For the purpose of modeling heat transfer, the airflow is manually calculated. After that, the computational analysis (CFD) uses the NACA channel to calculate the characteristics of the air flow. Following the import of the flow as an input parameter into the simulation model, an iteration loop is constructed for further model correction analysis.

The following requirements must be met in order to create a Ram air channel: 1. Flight Mission, which offers a variety of operating speeds at various altitudes. 2. Application use, such as pressurising the cabin or cooling avionics. 3. Space domain, such as the NACA channel's volume limitation and the HEX installation 4. The range of cooling temperatures and the refrigerant coolant. First, the available flying mission, application selection, and heat exchanger performance all influence the heat exchanger's capacity. the estimation. The frontal area and the Ramp angle are used to calculate the W/D ratio of the NACA air channel for the pipe that contains the heat exchanger and the NACA air channel.

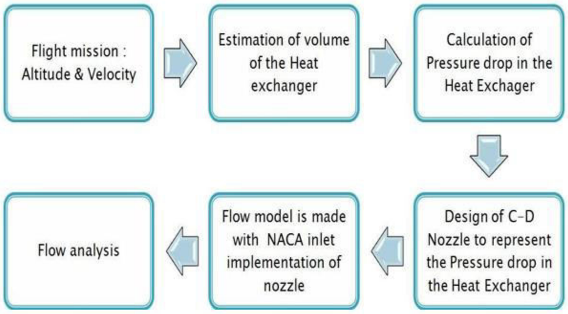


Fig 1 Flow chart

The Ram air channel design procedure and final flow model are shown in the figure. 1. The flying mission is the first step in the method. MATLAB is used to use additional data from that mission to figure out the heat exchanger's size that will work under all of the flight mission's parameters. The pressure drop that occurs through the heat exchanger is then calculated. The pressure drop over the heat exchanger is replaced by a simplified Convergent-Divergent nozzle, also known as a C-D Nozzle, which makes computational system analysis simpler. The incorporation of this C-D Nozzle and a NACA air channel into the model, which also checks the pressure difference, produced the flow analysis model. Utilizing the iteration loop for the analysis, the flow analysis model generates the final flow model (fig. 20). This method aims to speed up the process without sacrificing the accuracy of the data used to calculate drag at the very end. Finally, it is automated by linking multiple tools together in a chain.

2. LITERATURE SURVEY

MODELING AND SIMULATION OF AN AIRCRAFT ENVIRONMENTAL CONTROL SYSTEM

In this memoir we address the task of modeling Bombardier's CSeries 300 aircraft environmental control system (ECS) based on flight data. That is, flight data and dimensional analysis is used to model the system main components. The function of the ECS is to supply optimal cabin conditions to the passengers' cabin (ventilation, pressurization, temperature control and best possible humidity) using bleed air coming from the engines. The system components comprise four heat exchangers, a fan, a compressor, a turbine, control valves, cabin heat sources and sinks and the interconnecting piping. For each component analogous to a mechanical machine, the performance parameters were adimensionalized and their respective performance maps were built. When tridimensional reliable maps were required, flight data was augmented with smoothing assumptions. By doing so, a regularized optimization problem could be solved. The ECS network was built and solved with Flowmaster® software (FM). In fact, the software allows for customized scripts and performance maps to be easily imported to the model. The simulation of the final model was compared with flight data and converged to very similar results. Only simulations with very high humidity (HD and XHD cases) failed to converge to the expected temperature because Flowmaster's heat exchanger calculation neglected water latent heat. Nevertheless, code is suggested in this work to improve the software calculation method. For all the other cases (XCD, CD and ISA), the model is able to predict cabin conditions at any permitted altitude and aircraft speed. Moreover, the model and can be used as a design tool or analysis tool within Bombardier's support team.

ENTROPY GENERATION MINIMIZATION IN A RAM-AIR CROSS-FLOW HEAT EXCHANGER

This paper presents the constrained thermodynamic optimization of a crossflow heat exchanger with ram air on the cold side. The ram-air stream passes through a diffuser before entering the heat exchanger, and exits through a nozzle. This configuration is used in the environmental control systems of aircraft. In the first part of the study the heat exchanger is optimized alone, subject to fixed total volume and volume fraction occupied by solid walls. Optimized geometric features such as the ratio of channel spacings and flow lengths are reported. It is found that the optimized features are relatively insensitive to changes in other physical parameters of the installation. In the second part of the study the entropy generation rate also accounts for the irreversibility due to discharging the ram-air stream into the atmosphere. The optimized geometric features are relatively insensitive to this additional effect, emphasizing the robustness of the thermodynamic optimum.

A SURFACE PARAMETRIC CONTROL AND GLOBAL OPTIMIZATION METHOD FOR AXIAL FLOW COMPRESSOR BLADES

An aerodynamic optimization method for axial flow compressor blades available for engineering is developed in this paper. Bezier surface is adopted as parameterization method to control the suction surface of the blades, which brings the following advantages: (A) significantly reducing design variables; (B) easy to ensure the mechanical strength of rotating blades; (C) better physical understanding; (D) easy to achieve smooth surface. The Improved Artificial Bee Colony (IABC) algorithm, which significantly increases the convergence speed and global optimization ability, is adopted to find the optimal result. A new engineering optimization tool is constructed by combining the surface parametric control method, the IABC algorithm, with a verified Computational Fluid Dynamics (CFD) simulation method, and it has been successfully applied in the aerodynamic optimization for a single-row transonic rotor (Rotor 37) and a single-stage transonic axial flow compressor (Stage 35). With the constraint that the relative change in the flow rate is less than 0.5% and the total pressure ratio does not decrease, within the acceptable time in engineering, the adiabatic efficiency of Rotor 37 at design point increases by 1.02%, while its surge margin 0.84%, and the adiabatic efficiency of Stage 35 0.54%, while its surge margin 1.11% after optimization, to verify the effectiveness and potential in engineering of this new tool for optimization of axial compressor blade.

CFD ANALYSIS OF RAM AIR FLOW IN AN AIRCRAFT AIR CONDITIONING SYSTEM

Heat exchanger performance is directly related to flow distribution to the inlet. Maldistribution of flow can cause efficiency drops and in extreme cases can lead to exchanger failure. Commercial aircraft operate almost continuously throughout the year. With this high operation rate of the environmental control system (ECS) the heat exchanger packs undergo a large amount of work and are not maintained frequently (typically every 20 months). If problems caused by a maldistribution of flow such as increased fouling or thermal stress fatigue or certain channels then they may be unnoticed and lead to further issues. The aim of this research paper is to study the ECS system for an Airbus A320 aircraft and using computational fluid dynamics analyse the flow of RAM air through the inlet duct. A series of models were generated with three different duct designs to examine the effect of the duct shape on flow distribution. Each model was run using two different flow rate scenarios to simulate conditions of aircraft ground operations and in-flight (cruising) operations. It was found that a square duct with no curvature generated large maldistribution of flow to the heat exchanger, providing poor cooling rates for both scenarios. The two other models with curved outlets showed an increase in flow uniformity with the most uniform flow exhibited by model 1. Complete unification of flow was not achieved by any of the models suggesting further design modification is needed.

DESIGN AND OPTIMIZATION OF RAM AIR-BASED THERMAL MANAGEMENT SYSTEMS FOR HYBRID-ELECTRIC AIRCRAFT

Ram air-based thermal management systems (TMS) are investigated herein for the cooling of future hybrid-electric aircraft. The developed TMS model consists of all components required to estimate the impacts of mass, drag, and fuel burn on the aircraft, including the heat exchangers, coldplates, ducts, pumps, and fans. To gain a better understanding of the TMS, one- and multi-dimensional system sensitivity analyses were conducted. The observations were used to aid with the numerical optimization of a ram air-based TMS towards the minimum fuel burn of a 180-passenger short-range turboelectric aircraft with a power split of up to 30 electric power. The TMS was designed for the conditions at the top of the climb. For an aircraft with the maximum power split, the additional fuel burn caused by the TMS is 0.19. Conditions occurring at a hot-day takeoff represent the most challenging off-design conditions for TMS. Steady-state cooling of all electric components with the designed TMS is possible during a hot-day takeoff if a small puller fan is utilized. Omitting the puller fan and instead oversizing the TMS is an alternative, but the fuel burn increase on the aircraft level grows to 0.29.

3. METHODOLOGY

This chapter explains each component's qualities and function as well as the specific design details for each one. The Ram air channel framework is comprised of various parts that start with the NACA channel to increment strain prior to sending the air to the HEX for heat move and delivering the warmed air into the climate. The most continuous stockpiling areas are under the wing, underneath the gut fairing, or at a reasonable separation from the nose, which is more presented to air flows. Subsequently, a framework is developed between an airplane's outside and inside. The framework is made up of four key subparts:

1. The NACA Inlet
2. Inlet tube prior to HEX
3. Exchanger for heat
4. tube with post-HEX outlet

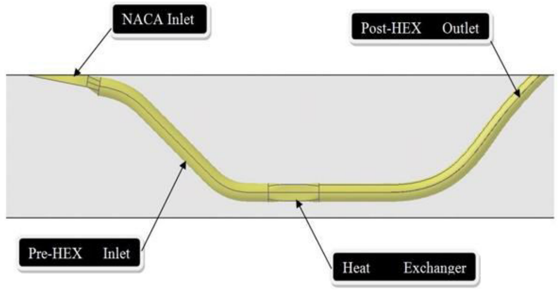


Fig 2 Ram air channel

NACA Inlet:

The essential roundabout cylinders with a round cross segment and roundabout scoops are two examples of the various types of inlets that provide or convey the surrounding air for various purposes. The intake required for this project must have appropriate mass flow rate while exhibiting pressure recovery characteristics. NACA Inlet, otherwise called flushed gulf, is a lowered pipe with a veering wall and a slope base. At low and high subsonic velocities, it has magnificent tension recuperation properties [1]. Pressure is expected to rise due to the particular profile of the separating wall. Some of the mathematical variables that influence the NACA bay tension recuperation qualities include the incline point, the viewpoint proportion between the NACA inlet's width and depth, and the length of the NACA inlet [2]. These inlets are located where the structure would be exposed to the majority of the air that surrounds it; Consequently, they are either side of or beneath the fuselage's interior. They can be used underneath the wing if the application is close to a wing, despite the fact that doing so may reduce the wing's lift.

Fig 3 NACA inlet

Heat Exchangers (HEX):

Since there is a restricted measure of room accessible in flying applications, little honeycomb heat exchangers are utilized for the intensity exchangers. Contingent upon the flying mission and the application, different intensity exchanger sizes are accessible [3]. It cools the engines, compresses the cabins, cools the electronics, and, most importantly, preheats the fuel in airplanes.

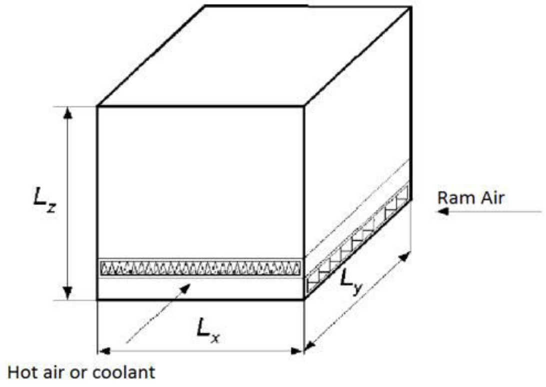


Fig 4 Heat Exchanger

Pre-HEX Inlet tube:

From the NACA inlet, encompassing air is supplied to the intensity exchanger via the Pre-HEX admission tube. In order to maintain the necessary strain for the intensity exchanger to function and the rate of the vital mass stream, the cylinder procedure needs to be constructed with the least amount of tension misfortune possible.

Post-HEX Outlet tube:

Similar to the Post-Hex leave tube, the Pre-Hex entry tube moves hot air from the intensity exchanger to the environment. To prevent counterflow, its design calls for a significant strain drop from the intensity exchanger to the air. The properties of the line are all influenced by the stream's length, cross section, and level between the two heads. Because of extra imperatives like space area and mass stream rate, among others, these characteristics are obliged. To get the imperative exact characteristics, top to bottom review is performed. The post-hex outlet cylinder's holy messenger is significant to the general drag made. How much drag made diminishes with diminishing symmetrical point. The pull of the stream from the free stream at this line's exit has an effect on the tension differential across the intensity exchanger.

4. IMPLEMENTATION

Accordingly, the first model should go through a workable framework or arrangement technique to direct reproductions to get the last model. The steps that need to be taken are to set the model's limit conditions, provide the recreation material, network the model, use numerical methods to solve the problem, and finally set up the post to get the right results.

Boundary Conditions

Inlet: Since the entering stream is in opposition to the plane's flight path but traveling in the opposite direction, the Delta limit condition is consistently regarded as the Area's normal speed. According to the flying circumstances specified at various altitudes, the usual speed is chosen.

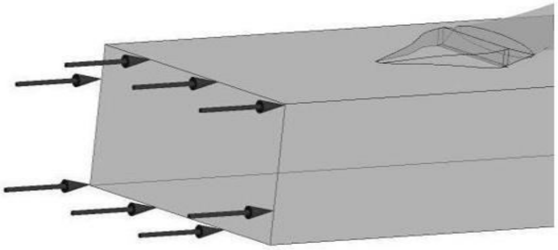


Fig 5 Boundary for inlet

Outlet: The conditions at the outlet limit are used as the reference pressure, not the typical speed to space. The speed may not be equivalent to the channel stream condition because the wind current faces the erosion stream on one of the airplane's surfaces. However, the reference pressure, which is the environmental strain at that particular height, almost remains unchanged.

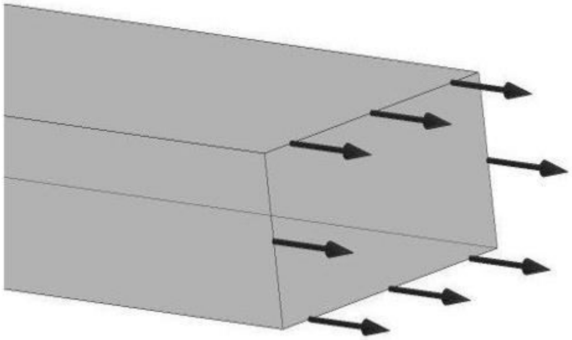


Fig 6 Boundary of outlet

Moving walls: Because it is a free-air stream, the entire air is moving at the same speed with little wall erosion, so the nature of the stream has no effect on the properties of the air that enters the NACA channel. The case arrangement's base mass and side walls are considered to be moving at the same speed as the delta limit state's normal speed.

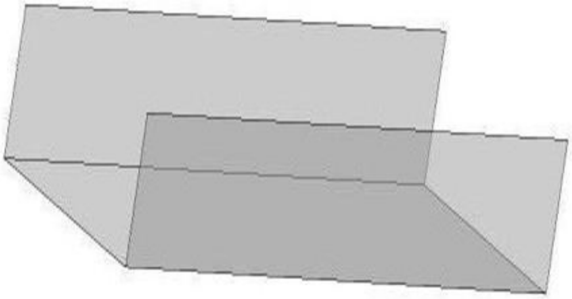


Fig 7 Boundary for moving walls

Friction walls: The top mass of the crate space is regarded as a wall with rubbing impacts because of the materials used, similar to the walls of the NACA Inlet, heat exchanger, and pipelines, which all have stream with contact impacts. The airplane's top mass is made of metal and affects the flow.

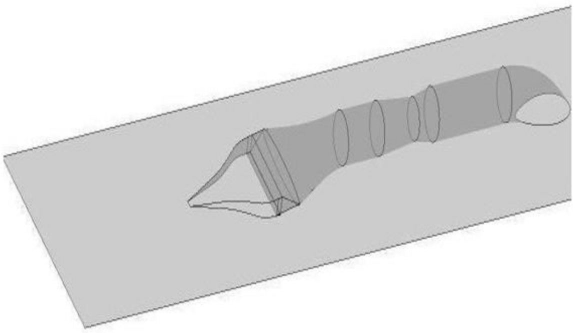


Fig 8 Boundary for friction walls

Material Description: The gas used is called "Ideal Air." The reference temperature, strain, consistency, and thickness of the substance fluctuate because of the examination being performed at different heights or elevations. Rather than straightforwardly contributing mathematical qualities into the material, all the previously mentioned attributes of air are determined as expressions that are used as info boundaries.

Mesh: Mesh is crucial for obtaining the required results, which are dependable for additional exploration. The method that is utilized is referred to as the "Patch Conforming method," and it employs various face sizes at various locations. For the locations where stream examination is carried out, the first layer has a thickness of 1E-3 m (meter) and an expansion of 7 layers in order to produce the appropriate results.

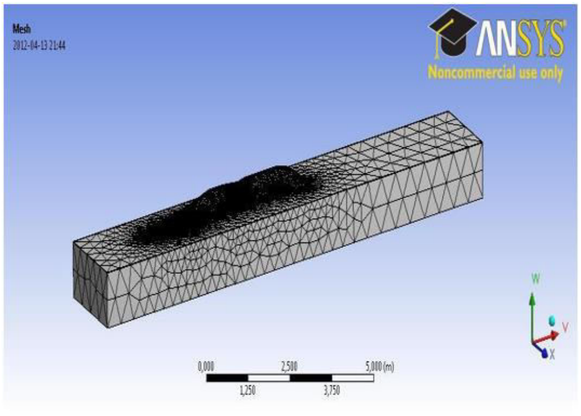


Fig 9 Mesh

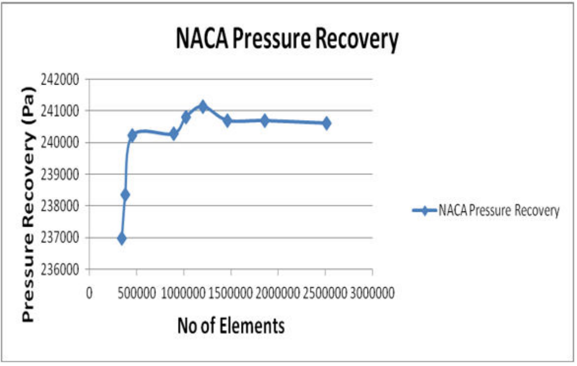


Fig 10 NACA pressure graph

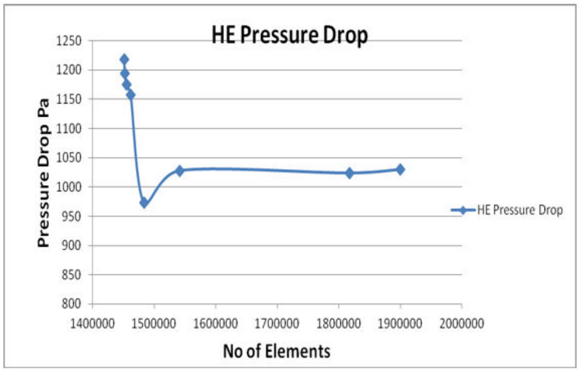
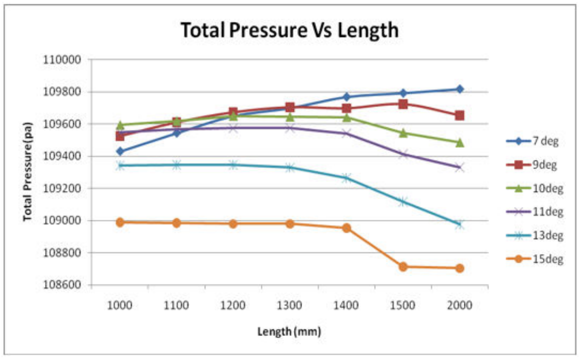
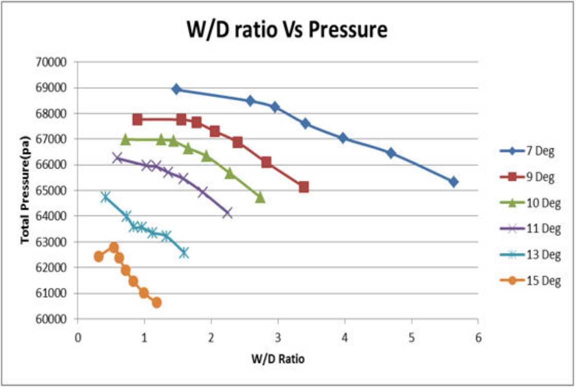


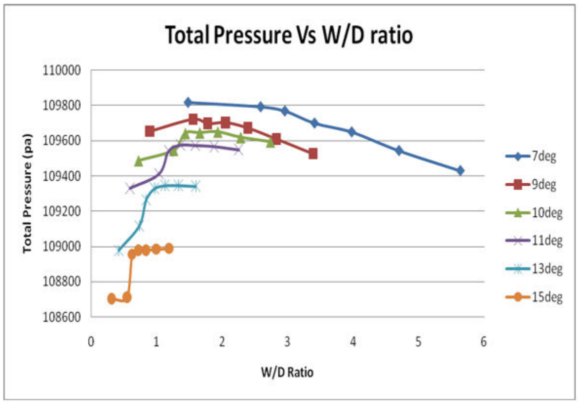
Fig 11 Heat exchanger (HE) pressure graph

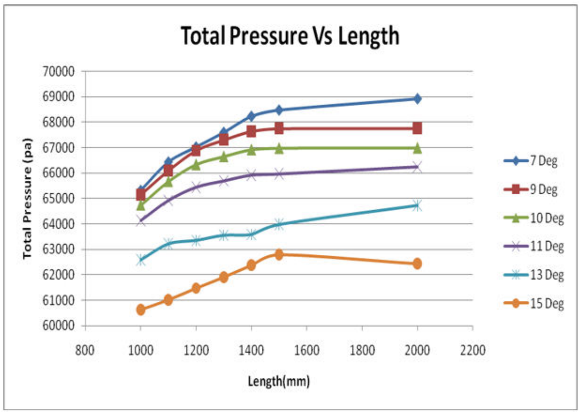
5. RESULTS AND DISCUSSION

Now is the best time to verify that the investigation has been completed and that the findings to discuss have been established so that the games can be played on the stream model, as shown in the previous section. This section will walk the peruser through the entire model's last decisions, including how the intensity exchanger's still up in the air, the iterative strategy used to make the last stream model, and an assessment of the NACA channel's highlights.









6. CONCLUSION

This project aims to provide a method for coordinating several devices in order to design and construct the NACA smash air channel, which will be evaluated for various viewpoints and exhibitions. After developing the framework for calculating the heat exchanger's volume to meet every requirement of a flying mission, the NACA inlet is developed for various configurations based on design factors. At long last, a spout is utilized to portray the strain drop in an intensity exchanger. This tension drop is assessed utilizing an iterative cycle that may either be mechanized or done physically. This structure might be utilized to concentrate on different parts of the plan, such drag and tension recuperation, to further develop execution. The NACA channel has been analyzed, as mentioned in part 6 recently. The charts obviously show that the tension recuperation performs best for ground level activity when the W/D proportion is somewhere in the range of 1 and 2, and that it performs best at journey level when the W/D proportion is between roughly 0.5 and 2, for generally given mixes. According to the sources used in the NACA study, the W/D ratio between 3 and 5 has better performance, while this project's examination reveals that it is better between 0.5 and 2 for voyage level and 1 and 2 for ground level. From the previously mentioned figures, clearly the 7 degree slope point performs better compared to the next slope points with regards to pressure recuperation and drag commitment. According to Emmet A. Mossman and Lauros M. Randall's "An Experimental Investigation of the Design Variables for NACA Submerged Duct Entrances," the NACA channel performs best between 5-7 degrees of slope. According to the apparatus chain that was laid out for this project, the NACA divert performs better at both the strain recuperation angle and the lowest drag at 7 degrees. Compared to other arrangements, ramp angle. Therefore, we may draw the conclusion that the tool chain developed here works flawlessly, allowing for future activities or more analysis to be performed to improve the flow utilising this tool chain produced.

Future Tasks

1) Only the drag produced by the NACA channel has been included in the analysis of drag calculations to far; however, this analysis might be improved upon by accounting for the drag produced by the air channel system's exit pipe installation.

2) Because temperature essentially affects the attributes of air and is straightforwardly connected with the drag created by the air channel framework's leave segment, it is feasible to carry out temperature-subordinate stream examination and study its belongings in present hex cylinders on decide the exact measure of drag produced by the whole framework.

3) Using boundaries to implement heat transfer analysis in flow.

4) Examination of the post hex pipe and angle of the outlet portion.

5) A thorough examination of the boundary layers around pipes and surfaces that might enhance flow performance.

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