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Designation of Variable Exhaust Nozzle for Micro Gas Turbine

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Abstract: UAVs are a fast increasing commercial aviation activity that will have a substantial economic influence in the near future. The usage of tiny UAVs in civic and commercial activities such as photography, wildlife research and survey, agriculture surveying and mapping, and others has increased business demand for UAVs. This market's rapid expansion will be accompanied by improvements in functionality such as increased durability, decreased noise and emissions, and expanded mission range, among other things.

Keywords: Variable Exhaust Nozzle, Mechanical Actuation Mechanism, Propulsion System

1. Introduction

The phrase UAV is an abbreviation for unmanned aerial vehicle, which is an aircraft without a pilot's body. The UAV market is predicted to be of tremendous economic and technological relevance for a wide range of applications and their related value in the near future. UAV makers have progressed beyond that during the previous decade. In the military sector, there is a lot of interest in possible UAV uses in the private and commercial industries. The army was the first employer to demonstrate the utility of UAV systems, as well as provide suggestions for their usage in a variety of non-military applications. (Anna Marcellan) (2015).

Propulsion and aircraft integration systems that must be taken into consideration by design, or systems that are already installed, will be taken care of by variable exhaust nozzle. Functions such as thrust vectorization and inversion pose additional design challenges (Eric Gamble, Dwain Terrell 2004). Secondary air can be evacuated from the compressor's high-pressure stage and considered infused mainstream via a circumferential tube near the nozzle throat. We can regulate the mainstream thrust and flow by adjusting the mass flow (A. I. Martin) (1957).

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The nozzle must be capable of operating at all speeds up to Mach 3. This comprises not just the nozzle's internal performance, but also how successfully the energy of the exhaust gas flow is employed to create thrust, as well as the resistance of the nozzle's outer surface. Not only must nozzles be efficient while cruising at Mach 3, but they must also be efficient during take-off, climb, subsonic flight, and wandering (Jack F. Runckel 1963). The nozzle efficiency is also essential, as a 1% difference in nozzle gross thrust coefficient over the speed range resulted in a 5% change in aero plane gross weight, according to the research. (Schmeer, James W.) (1963).

Mechanical actuation techniques for accomplishing the needed geometric changes of the nozzle components should be maintained to a minimum to reduce complexity. Aerodynamically adjustable nozzles meet this criterion (Migdal, David 1963). It would be desirable to design the nozzle to offer some noise reduction during take-off and landing if this could be done without affecting performance. However, the most efficient noise-suppressor nozzle designs have exceedingly intricate geometric geometries or need large weight increases (Schmeer, James W. 1960). The position of the nozzle on the aero plane should be considered in terms of the influence of the local flow field on the thrust and drag of the exhaust system (Swihart, John M.) (1962).

A variety of nozzles are available, including two-dimensional (2D), axisymmetric, plug, ejector, and single expansion ramp (SERN) nozzles. The final nozzle idea should be selected based on the program or the functional requirements of the vehicle. Each term should be judged on its own merit in relation to the key program criteria. Weight, performance, camouflage, reliability / maintenance, and cost must be considered when conducting a trade survey. In addition, important flight points must be met. The best option should be the simplest nozzle to meet your requirements (Eric Gamble, Dwain Terrell 2004).

In terms of manufacturing difficulty, it falls in between easy and medium. The key reason is that most of the parts just required going through the cutting, welding, and assembly processes. Following that, the equipment that will be used includes a metal cutting machine and a welding machine. In terms of labour, only one person with minimal expertise would be required to make these things. Finally, the total number of pieces required is 74.

Because of its potential and future demand, several academics and companies are presently working on micro gas turbines as the ideal propulsion technology for tiny UAVs utilized in civil applications. The key issues to be addressed are the optimum variable exhaust nozzle design, which will enable a micro gas turbine propulsion system to demonstrate its benefits when used in a power propulsion system for a small civil UAV for specialized usage.

One of the constraints is the compatible mechanical actuation mechanisms which will be applied in specific use of UAV. As a result, it is necessary to agree on a design that is effective but not unduly complicated. Secondly, the material to create a prototype for variable exhaust nozzle design must be low in cost yet good to perform its task under any relevance conditions. The material also must be able to purchase easily.

The design of the flaps function is the first step in the design process for a variable exhaust nozzle. Flaps function regulates the exit area of the exhaust nozzle by changing the angle of its flaps. The next step is to design the actuator ring, which will coordinate the motions of the entire exhaust nozzle opening duct.

We will continue to designate the inlet ring as the procedure progresses. This component will actually link the variable exhaust nozzle to the main body of the micro gas turbine. The next step is to design the actuator ring arm, which connects the inlet ring with the actuator ring. These components are critical to the simultaneous movement of all flaps at the same time.

The process will then be repeated with the flap connection. This component will join the flaps and the inlet ring arm. The final step is to use the match function to join all of the elements into the final model, which is a variable exhaust nozzle.

3.0 Results and Discussion

The final model of the variable exhaust nozzle will be flow-simulated using SOLIDWORKS. This model's analysis type is external, and the sole physical characteristic that will be used in this simulation is gravity, which is -9.81 m/s^2 on the y-axis. Carbon monoxide, a genuine gas, was used in the simulation for the flow components. Finally, in this flow simulation, two parameters will be defined for the initial and ambient conditions. The first is a thermodynamic parameter in which the pressure value is set as a constant variable with a value of 101325 Pa and the temperature value is set as an independent variable with values of 300, 400, and 500℃. The second parameter is velocity parameter which the value is set to -25 m/s in the z-axis direction.

3.1 Flow Simulation Result of Pressure

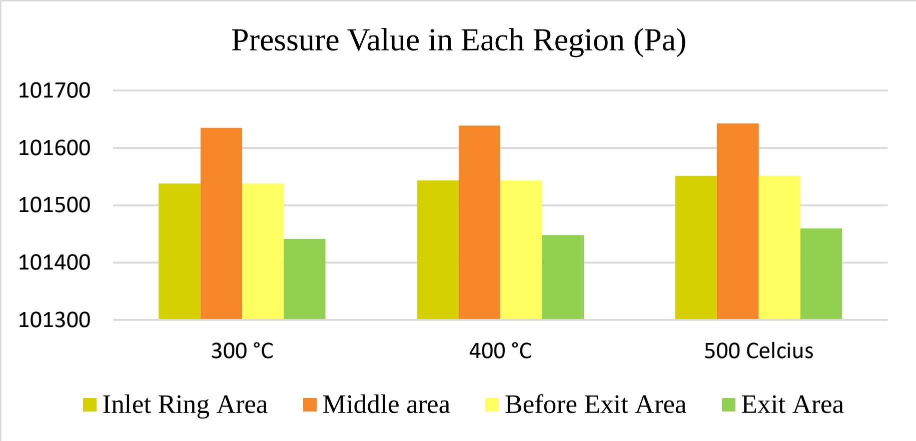

Figure 1: Clustered Bar Chart on Every Region of Pressure

Table 1: Pressure Value in Each Region (Pa)

	Inlet Ring Area (Pa)	Middle area (Pa)	Before Exit Area (Pa)	Exit Area (Pa)
300 °C	101538.1	101635	101538.1	101441.2
400 °C	101543.5	101639	101543.5	101448.1
500 °C	101551.1	101642.7	101551.1	101459.5

According to temperature value at 300 °C at Figure 1, the average pressure within the variable exhaust nozzle at the input ring area value is 101538.09Pa. The pressure is then increased to 101635.01Pa in the variable exhaust nozzle's middle part. Following that, the pressure value began to fall, as seen in the image above, where the orange region gradually changed colour to yellow, with the same value in the entrance ring area. Finally, there is a slightly green region area at the departure area of the variable exhaust nozzle, indicating that the pressure has fallen from 101538.09Pa to 101441.18Pa.

Temperature value at 400℃ and 500 °C also show the similar trend, with the pressure increasing from the entrance ring region to the middle portion of the variable exhaust nozzle and then decreasing to the nozzle's exit area. Because the thermodynamic parameter is modified, the temperature of carbon monoxide rises from 300 °C to 400 °C and then to 500°C. As a result, each value in the coloured zone represents a different pressure value. The data in Figure 1 demonstrate that when the temperature value from the thermodynamic parameter increases generally, the value of each coloured zone increases.

3.2 Flow Simulation Result of Temperature

Despite the thermodynamics parameter of the analysis increasing from 300°C to 400°C to 500°C, the pattern of temperature value at the variable exhaust nozzle remains unchanged. The sole difference between those three figures is the temperature value at the variable exhaust nozzle, which is reduced from the inlet ring to the nozzle's departure region. The temperature at the entrance ring area is typically 2270 °C and remains constant until the variable exhaust nozzle's middle section. The temperature is then reduced from the middle section to 226.830 °C and remains constant until the nozzle's departure area.

3.3 Flow Simulation Result of Velocity

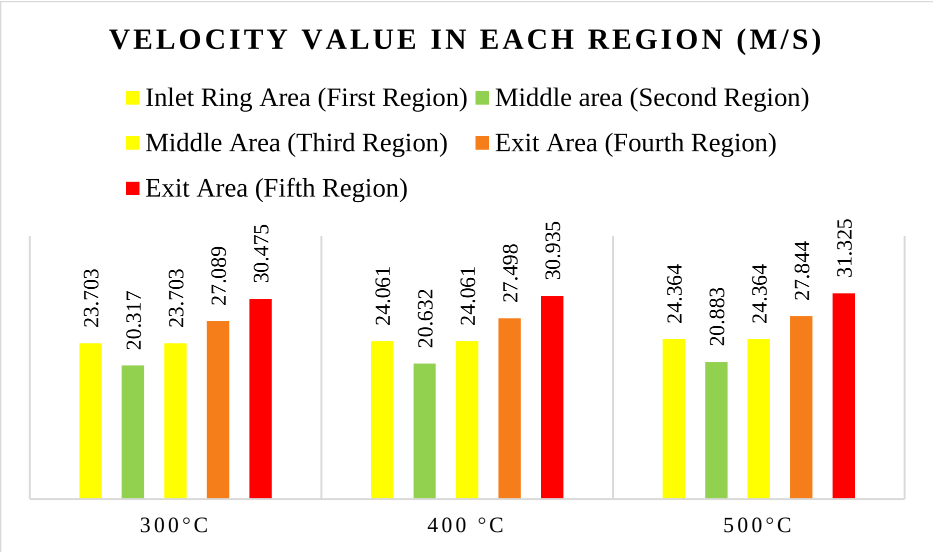

Figure 2: Clustered Bar Chart on Every Region of Velocity

Table 2: Velocity Value in Each Region (m/s)

	Inlet Ring Area (First Region) (m/s)	Middle area (Second Region) (m/s)	Middle Area (Third Region) (m/s)	Exit Area (Fourth Region) (m/s)	Exit Area (Fifth Region) (m/s)
300 °C	23.703	20.317	23.703	27.089	30.475
400 °C	24.061	20.632	24.061	27.498	30.935
500 °C	24.364	20.883	24.364	27.844	31.325

According to Table 2, at 300°C, the velocity within the variable exhaust nozzle at the input ring area value is 23.703 m/s on average. The velocity is then reduced somewhat in the middle region of the variable exhaust nozzle to 20.317 m/s. Following then, the pressure value began to rise, as shown in the figure above, where the yellow zone gradually changed colour to the yellow and orange regions, with values of 23.703 m/s and 27.089 m/s, respectively. Finally, in the variable exhaust nozzle's departure location, there is a little red zone indicating that the pressure averagely rose from 27.089 m/s to 30.475 m/s.

At temperatures of 400°C and 500°C, the velocity value decreases from the entrance ring region to the middle portion of the variable exhaust nozzle and subsequently increases all the way to the nozzle's exit area. Since changing the thermodynamic parameter, the temperature of carbon monoxide has grown from 300 C to 400 C and finally to 500 C. As a result, each colour represents a different velocity value. The data in Figure 2 demonstrate that when the temperature value from the thermodynamic parameter increases generally, the value of velocity at each coloured zone increases.

4. Conclusion

Firstly, based on this result study it can be conclude that overall pressure value for the different value of temperature in thermodynamics parameter is increased from the Inlet ring area (first region) to middle area (second region) and then decreased till the exit area (fourth region). All values in the region increase when the thermodynamic parameter is increased from 300℃ to 400℃. From the flow simulation result on pressure, it can be concluded that when the temperature of the thermodynamics parameter increase, the pressure inside variable nozzle also increases.

The temperature of the inlet ring area is 227 ℃ and gradually decreases till the value of 226.83℃ at the exit are of variable exhaust nozzle. The same pattern of the temperature change which is decreasing from the inlet ring area till the exit area can be observed. As the temperature of the thermodynamic parameter increases, the velocity inside variable nozzles also increases. Finally, velocity decreases from the inlet ring area (first region) to the middle area (second region) and then increased till the exit area (fifth region) even though the value of temperature in thermodynamics parameter changed. From the flow simulation result on velocity, it can be concluded that overall value of velocity is increased.

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