Design and Performance Analysis of Single Inlet Multiple Outlet (SIMO) Nozzle with Thrust Vector Control

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Abstract-- Today, thrust vectoring has become a very important research subject which can dramatically change the way aircraft manoeuvring in the future and their performance. This paper a concept defined as SIMO (Single Inlet Multiple Outlet) in detail. This can be explained by having multiple nozzles for exhaust purpose than those conventional one or two nozzles as we know of presently. This idea may yet not be able to apply directly to VTOL (Vertical Take off& Landing), but can be applied very well to change thrust direction of the aircraft effectively including thrust reversal and hence reducing the dependability on the primary control surface to great extent.

Keywords: thrust vector, multiple nozzle, thrust reversal, directional control

I. INTRODUCTION

A nozzle is a device designed to control the direction or characteristics of a fluid flow (especially to increase velocity).

A nozzle is often a pipe or tube of varying cross sectional area, and it can be used to direct or modify the flow of a fluid (liquid or gas). Nozzles are frequently used to control the rate of flow, speed, direction, mass, shape, and/or the pressure of the stream that emerges from them nozzles can be described as

a) Convergent Nozzle
b) Divergent Nozzle
c) ConvergentDivergent Nozzle

A. CONVERGENT NOZZLE

The nozzle in which narrowing down from a wide diameter to a smaller diameter in the direction of the flow. Convergent nozzles accelerate subsonic fluids. If the nozzle pressure ratio is high enough the flow will reach sonic velocity at the narrowest point (i.e. the *nozzle throat*). In this situation, the nozzle is said to be *choked*.

B. DIVERGENT NOZZLE

Expanding from a smaller diameter to a larger one. Divergent nozzles slow fluids, if the flow is subsonic, but accelerate sonic or supersonic fluids.

C. CONVERGENT DIVERGENT NOZZLE

Convergent divergent nozzle can therefore accelerate fluids that have choked in the convergent section to supersonic speeds. This CD process is more efficient than allowing a convergent nozzle to expand supersonically externally. The shape of the divergent section also ensures that the direction of the escaping gases is directly backwards, as any sideways component would not contribute to thrust.

II. SINGLE INLET MULTIPLE OUTLET

Here the project presents a concept about SIMO (Single Inlet Multiple Outlet) Nozzle. Normally in present day aircrafts currently employ one nozzle per engine here the SIMO employs five nozzles instead of one nozzle to single engine. Where the four of these five nozzles are equipped with thrust vectoring, so we can achieve all directional control of the aircraft thus reducing our dependence on the control surfaces.

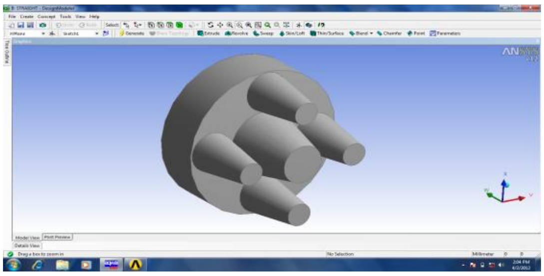

Fig-1: Multiple Nozzle

The arrangement of the secondary nozzles will be in Diamond Formation around the primary nozzle as shown in the figures.

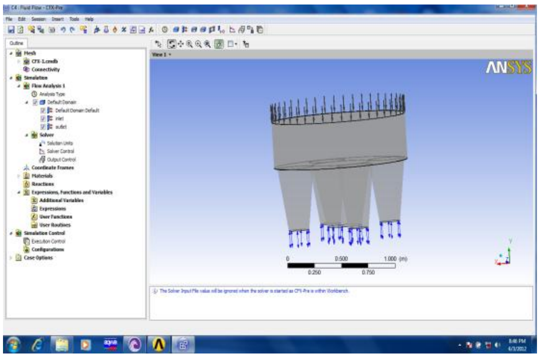

Fig-2: Airflow direction in nozzle

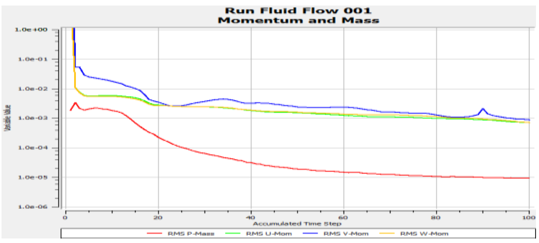

Fig-3: Multiple nozzle momentum and mass

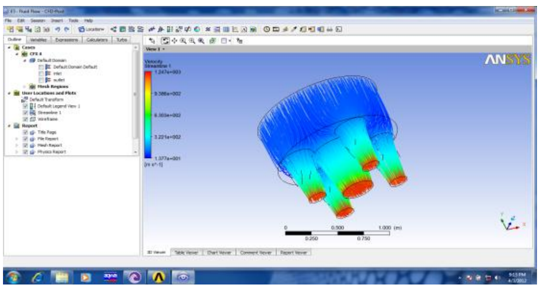

Fig-4: CFD analysis multiple nozzle

Thrust produced level of multiple nozzle section:

	X	Y	Z
Straight	499 N	2.17X10^6 N	415 N

III. MECHANISM

The mechanism based on Nozzle Actuation System for the purpose of tilting the nozzle. Nozzle actuation system is nothing but which provides the force to move the nozzle in such variable geometry devices. There are different type 0f nozzle actuation system namely hydraulic servomechanism etc. The SIMO concept deals with combine servomechanism. A servomechanism, sometimes shortened to **servo**, is an automatic device that uses error-sensing negative feedback to correct the performance of a mechanism. Servo mechanism are used for position control Speed control, remote control airplanes, automatic navigation systems on planes, and antiaircraft -gun control systems. Other examples are fly-by-wire systems in aircraft which use servos to actuate the aircraft's control surfaces. Here in case of multiple nozzle servomechanism is used for the purpose of tilting the secondary nozzles over their hinged joints at the required angle. The nozzle tilting angle has to be kept minimum to avoid thrust losses and nozzle efficiencies due to unparalleled fluid flow in the nozzle with respect to the tilted nozzle axis. The fluid flow in the nozzle as to be parallel to the nozzle axis as possible. The primary nozzle is in the centre location of the nozzle system which is not equipped with Thrust Vectoring System and it is done to provide stability to the aircraft. It will produce steady thrust in one direction only to avoid the aircraft to go into a continuous rolling motion. The secondary nozzles are equipped with thrust vectoring system.

D. BASIC PERFORMANCE OF SECONDARY NOZZLE

- Nozzle left & right act like elevon (elevator/aileron).

Elevator→both the nozzle will go up & down.

Aileron →nozzle one-up & one-down.

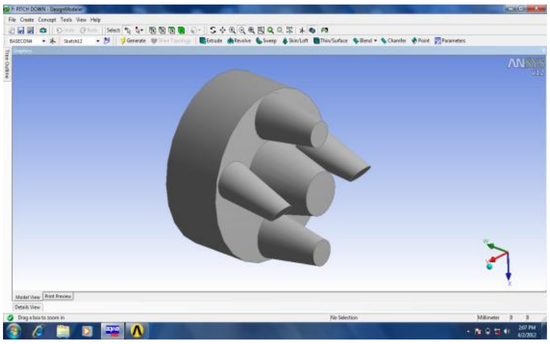

Fig-5: Nozzle move condition

- Nozzle up & down act like rudder

  Rudder → nozzle left & right

IV. BOUNDRY CONDITION INLET:

E. Pitch down Condition

Total pressure: 22atm

Temperature: 2000k

Outlet: subsonic

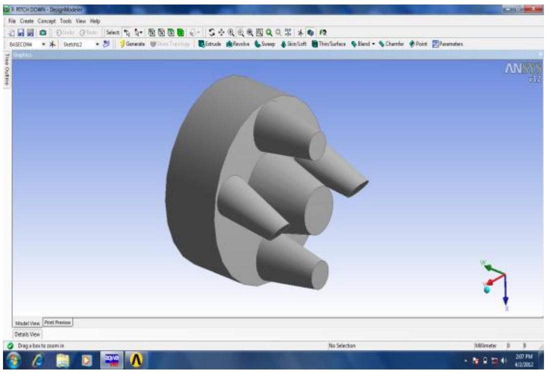

Fig-6: Pitch down condition nozzle

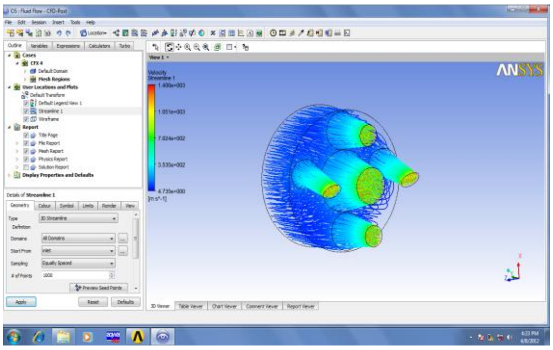

Fig-7: CFD analysis of Pitch down nozzle

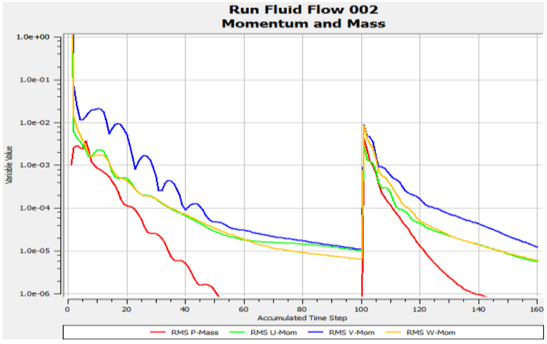

Fig-8: Momentum and mass flow rate of pitch down nozzle

F. Roll left Condition

Total pressure: 22atm

Temperature: 2000k

Outlet: subsonic

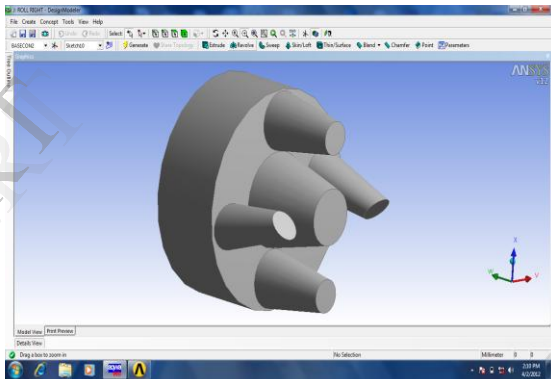

Fig-9: Roll left condition nozzle

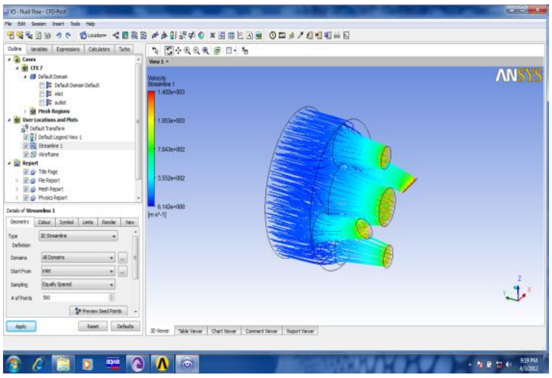

Fig-10: CFD analysis of Roll left nozzle

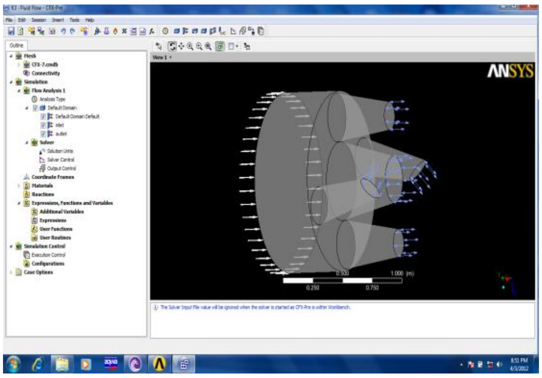

Fig-11: Thrust exhaust view of ansys

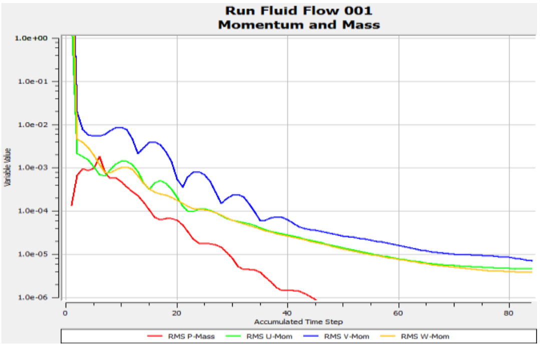

Fig-12: Momentum and mass flow rate of roll leftnozzle

G. Roll right Condition

Total pressure: 22atm

Temperature: 2000k

Outlet: subsonic

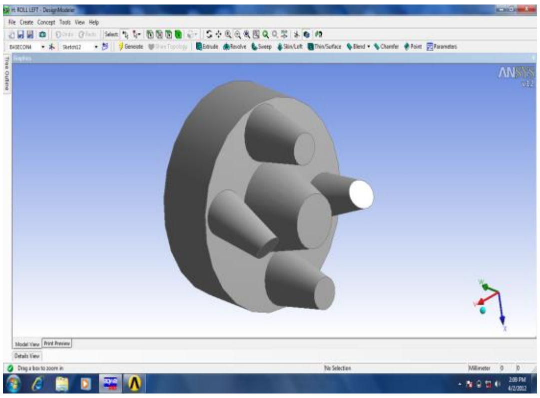

Fig-13: Roll right condition nozzle

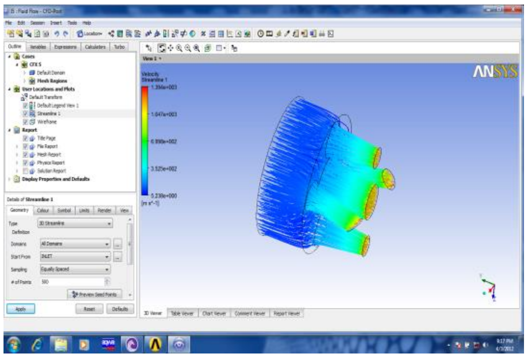

Fig-14: CFD analysis of Roll right nozzle

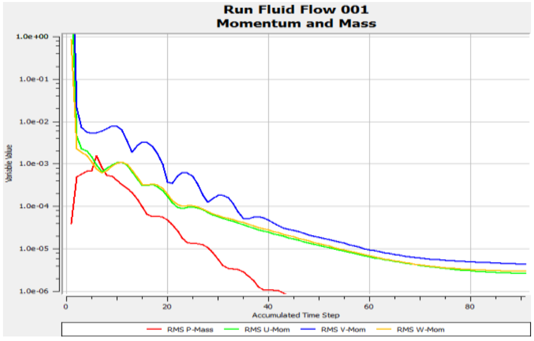

Fig-15: Momentum and mass flow rate of roll right nozzle

H. Yaw left Condition

Total pressure: 22atm

Temperature: 2000k

Outlet: subsonic

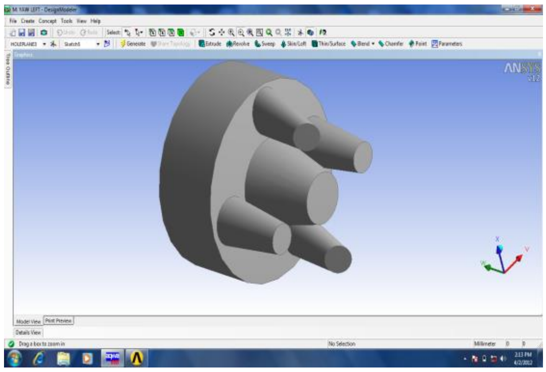

Fig-16: Yaw left condition nozzle

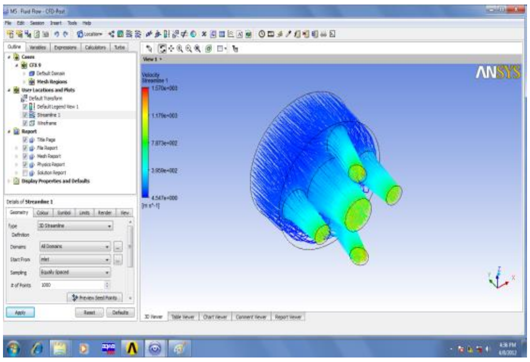

Fig-17: CFD analysis of yaw left nozzle

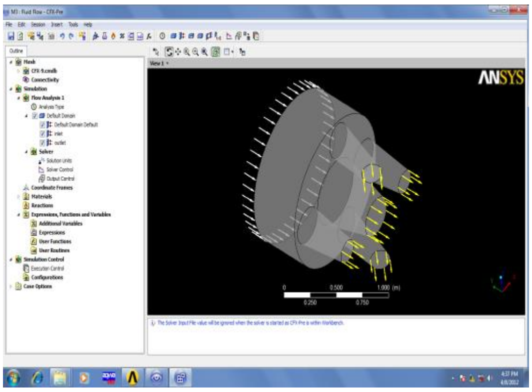

Fig-18: Thrust produced level of yaw left nozzle

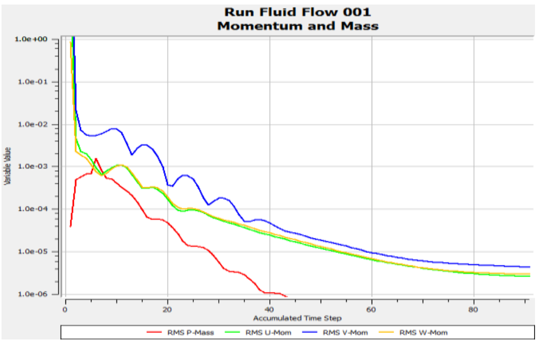

Fig-19: Momentum and mass flow rate of yaw left nozzle

I. Yaw right Condition

Total pressure: 22atm

Temperature: 2000k

Outlet: subsonic

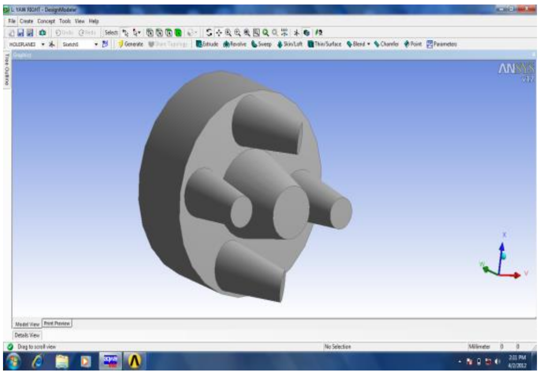

Fig-20: Yaw right condition nozzle

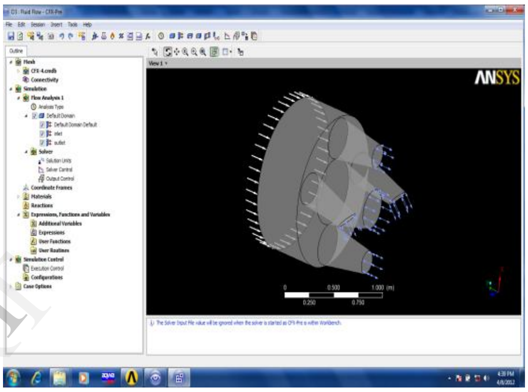

Fig-21: Thrust produced level of yaw right nozzle

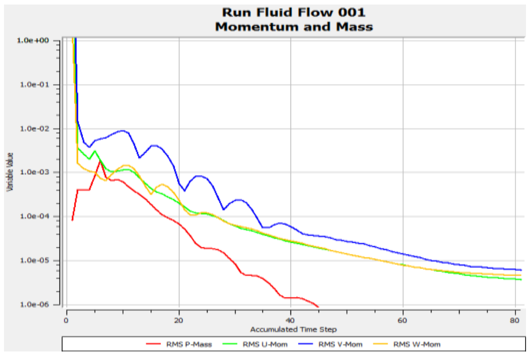

Fig-22: Momentum and mass flow rate of yaw right nozzle

RESULT

Thrust produced level of nozzle section:

	X	Y	Z
STRAIGHT	499 N	-2.17X10^6 N	415 N
PITCH UP	73 N	-2.17X10^6 N	63873 N
PITCH DOWN	73 N	-2.17X10^6 N	-63873 N
ROLL LEFT	-128 N	-2.17X10^6 N	270.96 N
ROLL RIGHT	128 N	-2.17X10^6 N	-270.96 N
YAW RIGHT	63735.7 N	-2.17X10^6 N	352.89 N
YAW LEFT	-63735.7 N	-2.17X10^6 N	-352.8 N

CONCLUSIONS

With thrust reversal system installed on all the nozzles we can achieve thrust reversal too giving the aircraft unprecedented manoeuvrability and ease of slowing down the aircraft during landing. With these kind of nozzles very high degree of manoeuvrability can be achieved. In defence aircraft, these manoeuvres can give very high precision of targeting in air dogfights. These nozzles when installed with conventional thrust reversal systems, they can keep the aircraft in air at a very low speed and may also help in reducing the stall velocity which can hence lead to safer landings. These can also be applied to space propulsion particularly as it can control the direction of spacecraft in space which is normally difficult to control. These nozzles can be made to work in tandem with primary control surfaces so that someday in future in case of failure of primary control surfaces occur, the aircraft can still be maneuverer and saved thereby avoiding loss of millions of dollars' worth of property, aircraft and most important pilot's life.

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