IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

CASE STUDIES IN MISSILE DESIGN FAILURES BY CFD SIMULATION

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Abstract— In this proposed paper the aerodynamic characteristics of an anti-aircraft missile were computed using Computational fluid dynamics by ANYS2020R1 software which is analysis software. Generally predicting the aerodynamic characteristics is mandatory in case of performance analysis. Aerodynamic characteristics are important role in missile aerodynamic because on the basis of results we conclude that missile design is stable or not and how they behave when missile is in cruise stage. Aerodynamic coefficient are Drag, Drag coefficient, moment, moment coefficient characterization is carried out at subsonic & supersonic speed with their Mach number's at standard sea level. The motivation of such work is caused due to lack of data on missile aerodynamic at supersonic level. The object moving at high speed induced the drag which decrease the velocity and affect the efficiencies of object. Now days we are moving towards high speed vehicle. By high speed vehicle, we save our time and more accurate on target like in defense system we use the different ballistic missile for targeting the object. Designing field give the ability to make more efficient body design for Aerospace Industry. By this paper, we develop prototype missile design with accurate aerodynamics.

Keywords- Missile Design, Drag, Drag Coefficient, Moment, Moment coefficient, Yaw, Pitch, Roll, AOA (Angle of Attack), Dynamic pressure.

I). INTRODUCTION

In Today modern military usage missile or a guided missile is a self-propelled guided weapon system. The technologies of a guided missile are propulsion, guidance and control which helps in making a missile specific to a target, i.e., they determine the size, range and state of motion of a missile. Missiles are more accurate on target. Ancient time we use the bow which same like as a missile body design but only the difference is that they don't have any propulsion engine and any control system. One distinction between a missile and an airplane is that, unlike an airplane a missile is usually expandable in the accomplishment of its mission. From the configurational point of view, the distinction is frequently made that a missile is more slender than an airplane and tends to possess smaller wings & fins in proportion to its body. These distinctions are, however, subject to many exceptions. In fact, configurational distinctions between missile and airplane seem to narrow as the operational speed increases. Therefore, much of the missile aerodynamics contained herein will be directly applicable to airplanes. Now days we are moving towards hypersonic missile design which are more stable than subsonic and supersonic design because on the fast moving object the force acting on a body are negligible only the aerodynamic forces are acting on it. Fins are used for the stabilization and wings control the yaw, roll, pitch moment. Military weapon and missile design represents a critical aspect of modern defense systems. These sophisticated technologies play a pivotal role in safeguarding nations, ensuring strategic deterrence, and maintaining global security.

In this introduction, we will explore the fundamental concepts and importance of military weapon and missile design.

1. Purpose and Significance:

Military weapons and missiles are developed to serve various purposes, including deterrence, defense, and offense. They are designed to neutralize threats, protect national interests, and maintain geopolitical stability. The significance of these technologies lies in their ability to project force across great distances, offering nations a means to respond to evolving security challenges.

2. Technological Advancements:

Over the years, military weapon and missile design have witnessed rapid technological advancements. These innovations encompass propulsion systems, guidance and control mechanisms, stealth capabilities, and precision targeting. As technology evolves, so does the potential for enhancing the efficiency and effectiveness of these weapons.

3. Classification:

Military weapons and missiles are categorized based on their intended use, range, payload, guidance systems, and launch platforms. This classification system enables military strategists to select the most suitable weapons for specific scenarios. Categories include anti-aircraft, anti-ship, anti-tank, ballistic missiles, cruise missiles, and more.

4. Aerodynamics and Design Challenges:

Aerodynamics play a critical role in missile design. Engineers must address challenges related to stability, maneuverability, and speed. The design process involves optimizing shapes, control surfaces, and propulsion systems to ensure missiles can perform accurately and reliably.

5. Guidance and Control:

Missiles rely on advanced guidance and control systems to navigate and hit their targets with precision. These systems may include GPS, inertial guidance, radar, and homing sensors. The integration of these technologies enhances the likelihood of mission success.

6. Nuclear and Conventional Payloads:

Missiles can carry various types of payloads, including nuclear warheads, conventional explosives, chemical agents, or biological weapons. The choice of payload depends on the mission and strategic objectives.

7. Global Arms Control and Non-Proliferation:

The proliferation of advanced military weapons and missiles has led to international efforts for arms control and non-proliferation treaties. These agreements aim to curb the spread of these technologies and reduce the risk of conflict escalation.

8. Ethical and Moral Considerations:

The development and use of military weapons raise ethical and moral questions. The potential for collateral damage and civilian casualties necessitates careful consideration and adherence to international humanitarian laws.

9. Future Trends:

As technology continues to evolve, the future of military weapon and missile design holds exciting prospects. Advancements in artificial intelligence, hypersonic technology, and autonomous systems are expected to reshape the landscape of modern warfare.

II). RESEARCH AND DEVELOPMENT DEPARTMENT

An R&D department is a specialized division within an organization dedicated to the investigation, creation, and enhancement of products, services, or processes. Its primary purpose is to foster innovation, generate new knowledge, and advance existing technologies to meet the evolving needs of the organization and its stakeholders.

In this department, there is a special area within a research center where scientists research and develop new technologies and theories. Nowadays, countries invest more money in this field because this department strengthens the country. It is a process aimed at creating or advancing designing technology. A research and development (R&D) department is a crucial component of many organizations, including businesses, government agencies, and academic institutions. It is responsible for driving innovation, improving products and services, and staying competitive in a rapidly evolving world. In this description, we will delve into the functions and significance of an R&D department.

Functions and Activities:

Innovation: The R&D department is at the forefront of innovation, constantly exploring new ideas, concepts, and technologies that can lead to the development of novel products or services.

Product Development: R&D teams work to design, prototype, and refine products or services, ensuring they meet quality standards and market demands.

Process Improvement: R&D plays a critical role in optimizing internal processes, which can lead to increased efficiency, cost savings, and better overall performance.

Market Research: R&D departments conduct market research to identify emerging trends, consumer preferences, and unmet needs, which informs the development process.

Testing and Validation: Rigorous testing and validation procedures are performed to ensure that new products or processes meet safety, regulatory, and quality standards.

Importance:

Competitive Advantage: Organizations with robust R&D capabilities can gain a competitive edge by introducing innovative products or services ahead of competitors.

Long-Term Viability: R&D investments can lead to breakthroughs that sustain an organization's long-term viability and relevance in its industry.

Adaptation to Change: In rapidly evolving markets, R&D helps organizations adapt to new technologies and changing customer expectations.

Types of R&D Departments:

Corporate R&D: Large corporations often have dedicated R&D departments responsible for developing new products or technologies in-house.

Government R&D: Government agencies invest in R&D to address societal challenges, promote scientific progress, and enhance national security.

Academic R&D: Universities and research institutions conduct R&D to advance knowledge and train the next generation of researchers.

Challenges:

Resource Allocation: Balancing the budgetary demands of R&D with other operational needs can be challenging.

Risk Management: R&D projects inherently carry risks, including the potential for failure or uncertain returns on investment.

Intellectual Property: Protecting intellectual property rights for innovations is crucial to maintain a competitive advantage.

6. Future Trends:
Interdisciplinary Collaboration: R&D increasingly involves collaboration across various disciplines, such as technology, biology, and data science.

Digital Transformation: The integration of digital technologies, such as AI, big data, and IoT, is reshaping R&D processes.

Sustainability: R&D efforts are focusing on creating eco-friendly products and processes to address environmental concerns.

III). DFENCE SYSTEM

Every country has its own defense system, and India also has its own defense system. The primary weapon in defense systems is missiles. Missiles have the capability to destroy targets in just seconds. That's why every country is engaged in finding and researching new types of designs that are more efficient.

IV). MISSILE CONFIGURATION

Missiles can be classified in various ways, based on their characteristics, purpose, or technology. Here are some common classifications of missiles:

1. By Propulsion:

- **Ballistic Missiles:** These follow a ballistic trajectory, which means they are launched into the atmosphere and then follow a parabolic path to their target. They can be further divided into short-range, medium-range, intermediate-range, and intercontinental ballistic missiles (SRBM, MRBM, IRBM, ICBM).

- **Cruise Missiles:** Cruise missiles are powered throughout their flight and can travel at varying altitudes and speeds. They are known for their maneuverability and can be land, air, or sea-launched.

- **Guided Rockets:** These are similar to missiles but may not have the advanced guidance systems of traditional guided missiles.

2. By Purpose:

- **Anti-Aircraft Missiles:** Designed to target and destroy aircraft in flight.
- **Anti-Ship Missiles:** Used to attack and sink or damage surface ships.
- **Anti-Tank Missiles:** Designed to penetrate armored tanks and vehicles.
- **Intercontinental Ballistic Missiles (ICBMs):** Meant for long-range delivery of nuclear or conventional warheads.
- **Surface-to-Air Missiles (SAMs):** Used for defense against aircraft, typically from the ground.
- **Surface-to-Surface Missiles (SSMs):** Launched from one surface location to another, often used for ground-based attacks.
- **Submarine-Launched Ballistic Missiles (SLBMs):** Ballistic missiles launched from submarines.

3. By Guidance System:

- **Inertial Guidance Missiles:** Use internal sensors to measure changes in velocity and direction.
- **GPS-Guided Missiles:** Rely on signals from global positioning satellites for navigation.
- **Laser-Guided Missiles:** Homing in on a laser designator aimed at the target.
- **Heat-Seeking Missiles:** Detect and follow the heat emitted by a target, often used against aircraft.

4. By Range:

- Short-Range Missiles (SRMs): Typically have a range of up to 300 kilometers.
- Medium-Range Missiles (MRMs): Have a range of 300 to 1,000 kilometers.
- Intermediate-Range Missiles (IRMs): Have a range of 1,000 to 3,000 kilometers.
- Long-Range Missiles (LRMs): Can have a range exceeding 3,000 kilometers.

5. By Payload:

- **Nuclear Missiles:** Carry nuclear warheads.
- **Conventional Missiles:** Carry conventional explosives or warheads.
- **Chemical and Biological Missiles:** Deliver chemical or biological agents.

6. By Launch Platform:

- **Land-Based Missiles:** Launched from fixed land-based platforms.
- **Sea-Based Missiles:** Launched from ships, submarines, or other naval vessels.
- **Air-Launched Missiles:** Dropped from aircraft.

V). PROBLEM STATEMENT

The objective of this paper is to show the variation in drag force, lift force with the changing the shape ofmissile design with respect to the angle of attack and find out which design is best for defense purpose.

VI). METHODOLOGY

In this paper, a rocket is designed using PTC Creo Parametric 4.0 software. The first step involves creating a 2D slender body shape with a nose, which is then revolved around a central axis to convert it into a 3D model for CFD testing. The commonly used tools for creating a model in Creo 4.0 Parametric include Extrude, Extrude Cut, Revolve, Revolve Cut, Sweep, Swept Cut, Fillet, Chamfer, and Mirror.

The CFD analysis is carried out in three steps:

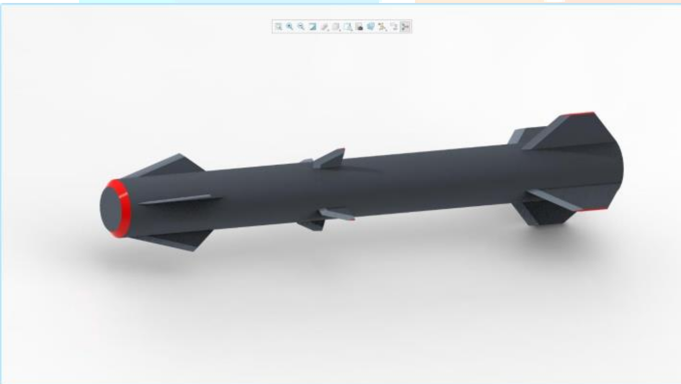
(i) Pre-processing, including geometry design, meshing, boundary conditions, and numerical methods.

(ii) Processing, where fluid flow governing equations are solved using numerical methods until convergence is reached.

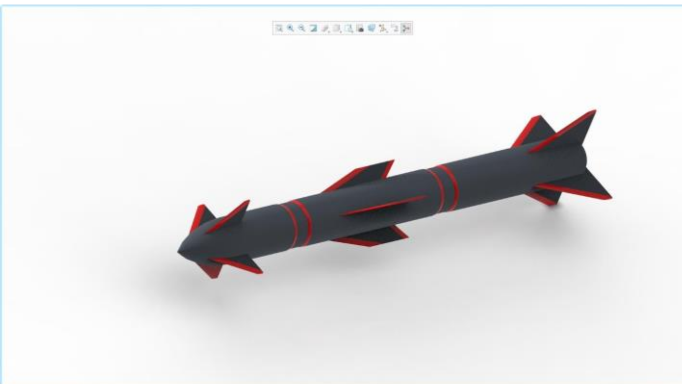
(iii) Post-processing, which involves extracting results in the form of graphs and contours that explain the physics of the flow and provide the required results.

VII). DESIGN

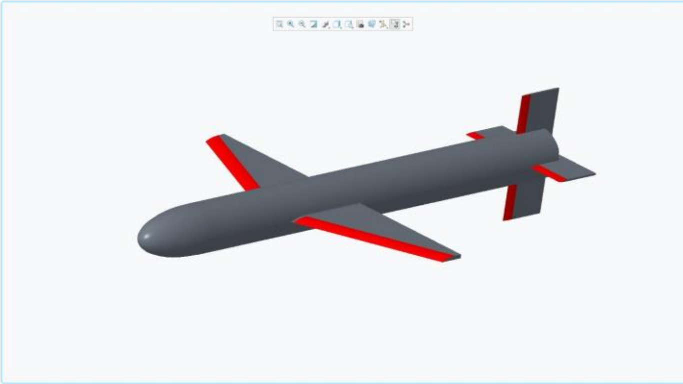
1ST Design



2nd Design



3rd Design



VIII). RESULT AND DISCUSSION

We can observe that by changing the shape of the missile design, the aerodynamic coefficients change at different angles of attack, at a speed of 100 m/s (Mach = 0.29), under standard sea level conditions. we also check the flow simulation over the body

Velocity Variation

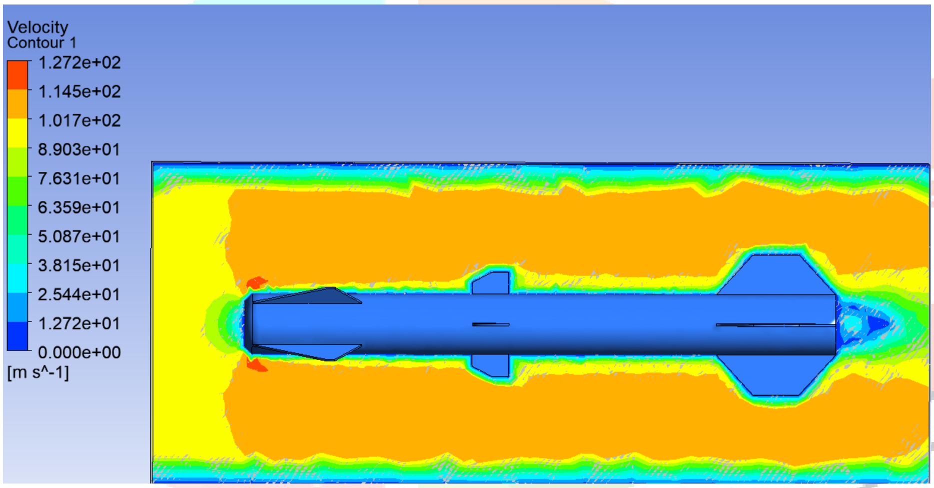


Figure 1: First design At AOA 0

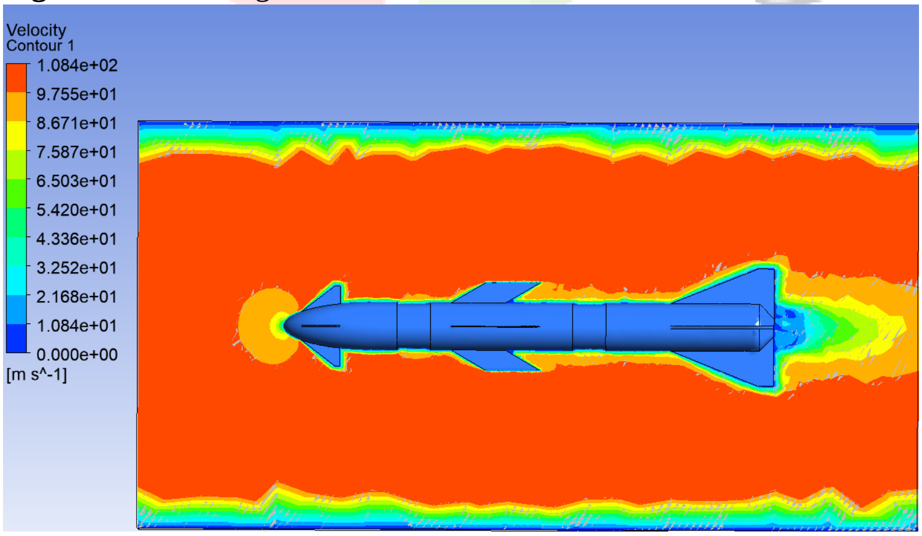


Figure 2: Second design At AOA 0

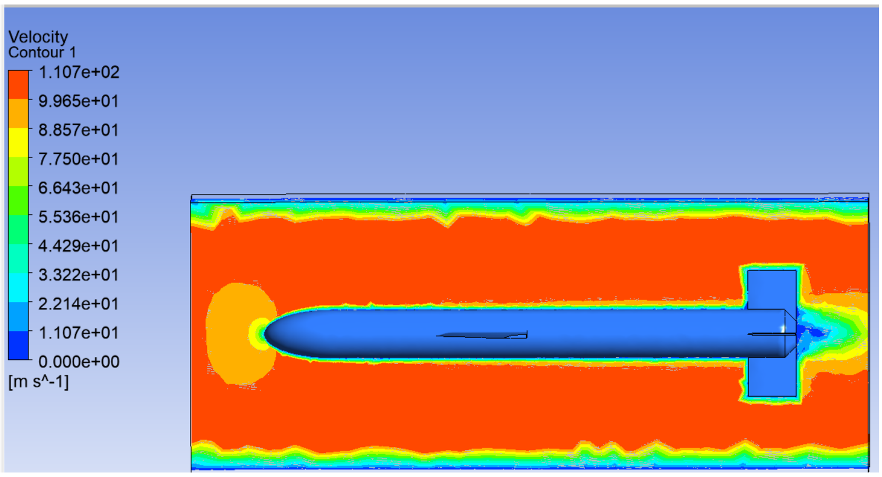


Figure 3: Third design At AOA 0

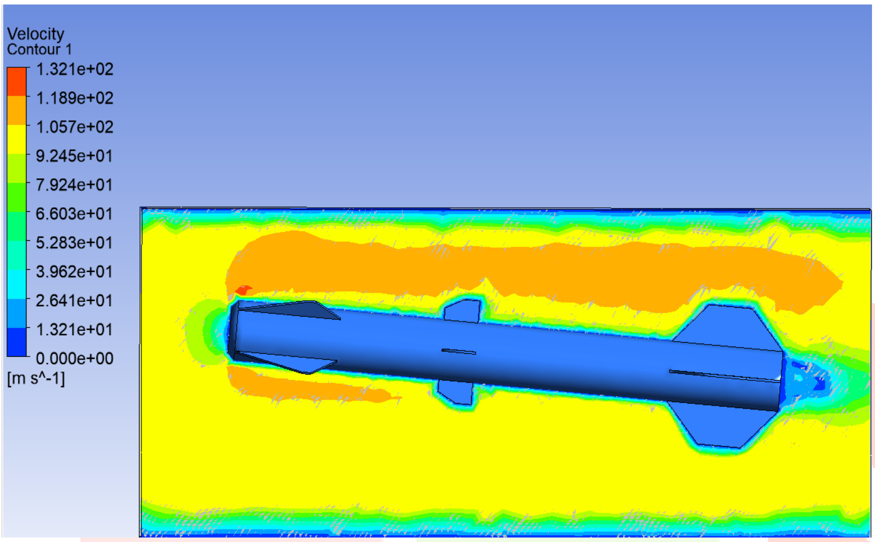


Figure 4: First design At AOA 5

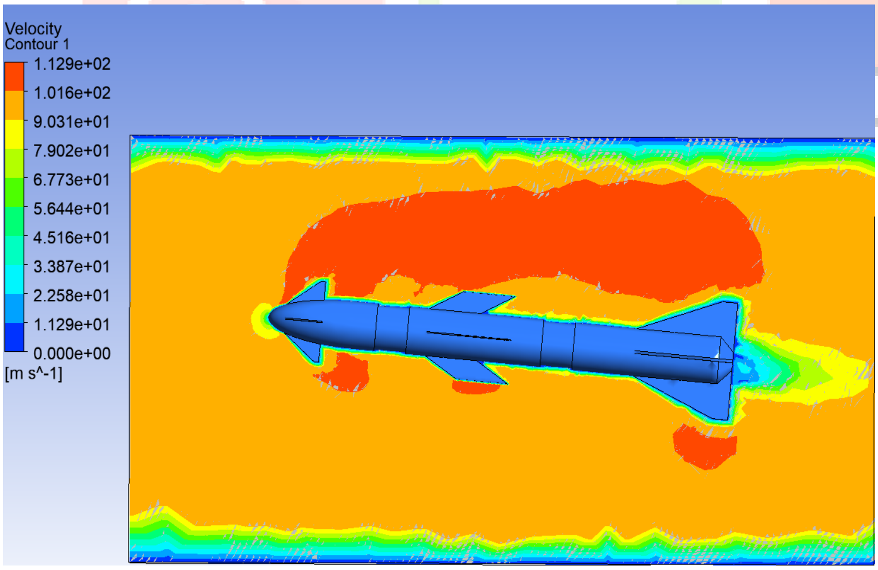


Figure 5: Second design At AOA 5

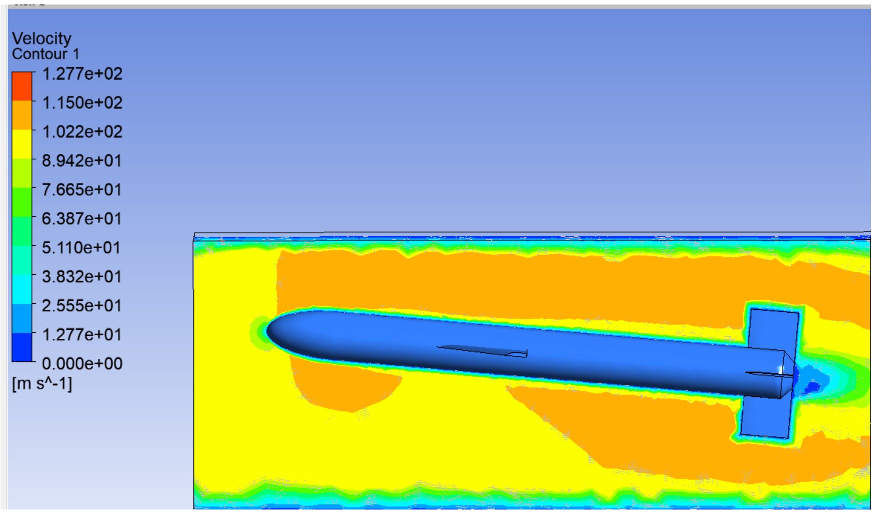


Figure 6: Third design at AOA 5

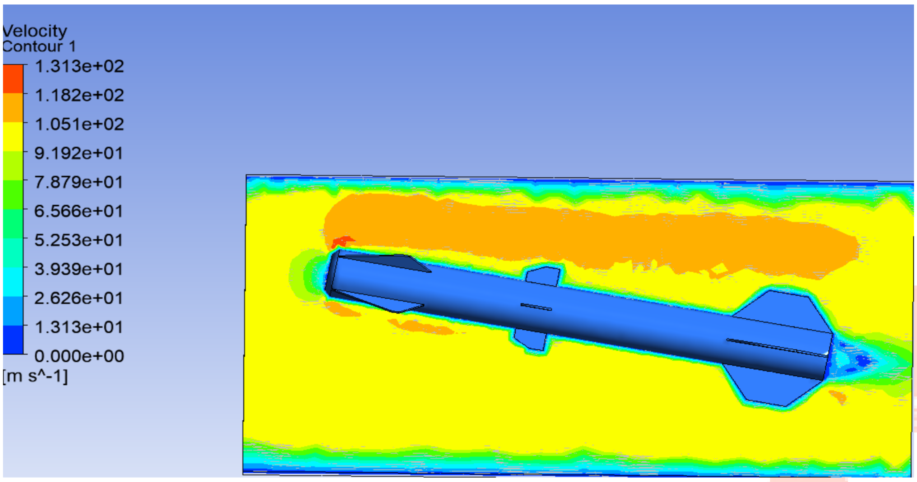


Figure 7: First design at AOA 10

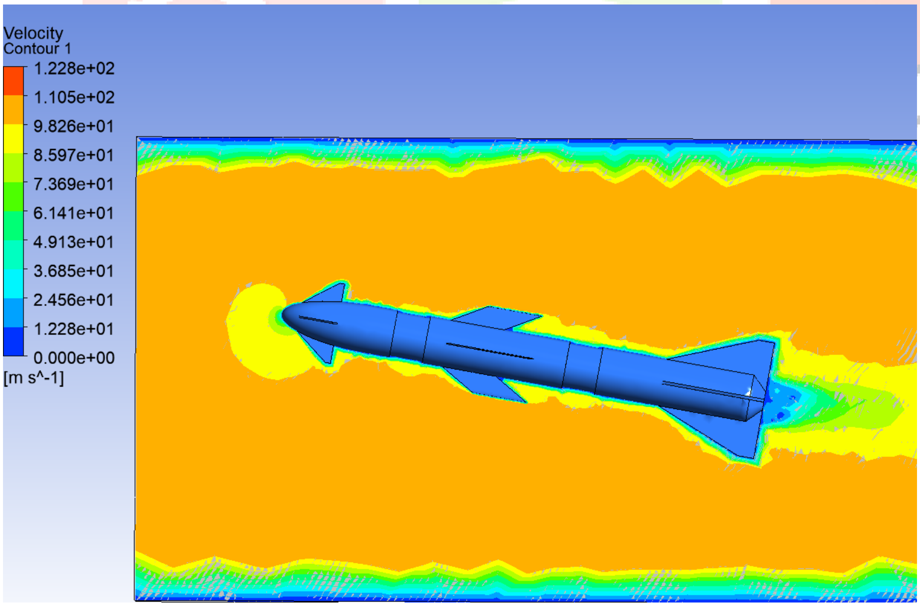


Figure 8: Second design at AOA 10

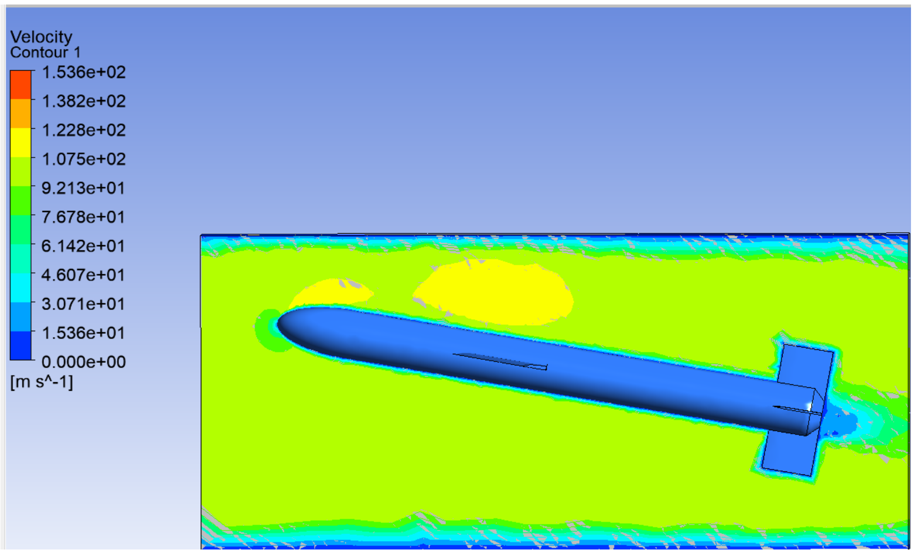


Figure 9: Third design at AOA 10

Pressure Variation

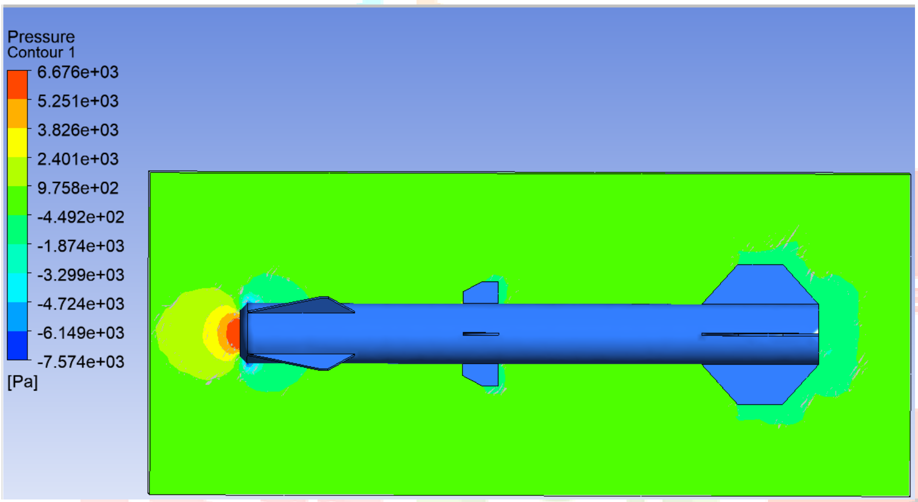


Figure 10: **First design** At AOA 0

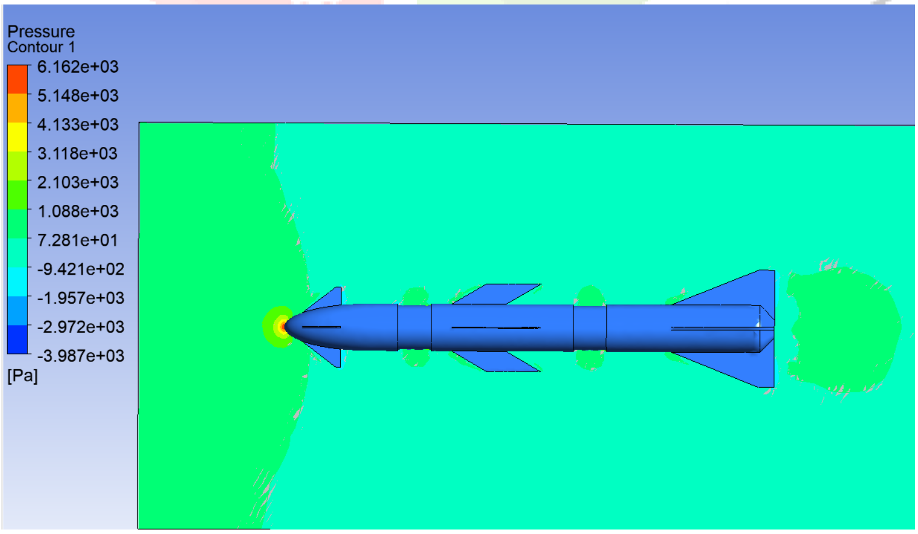


Figure 11: **Second design** At AOA 0

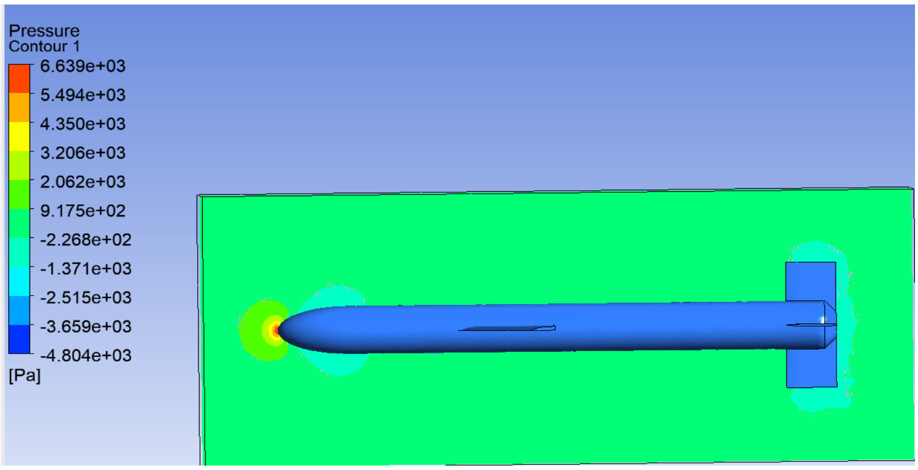


Figure 12: **Third design** At AOA 0

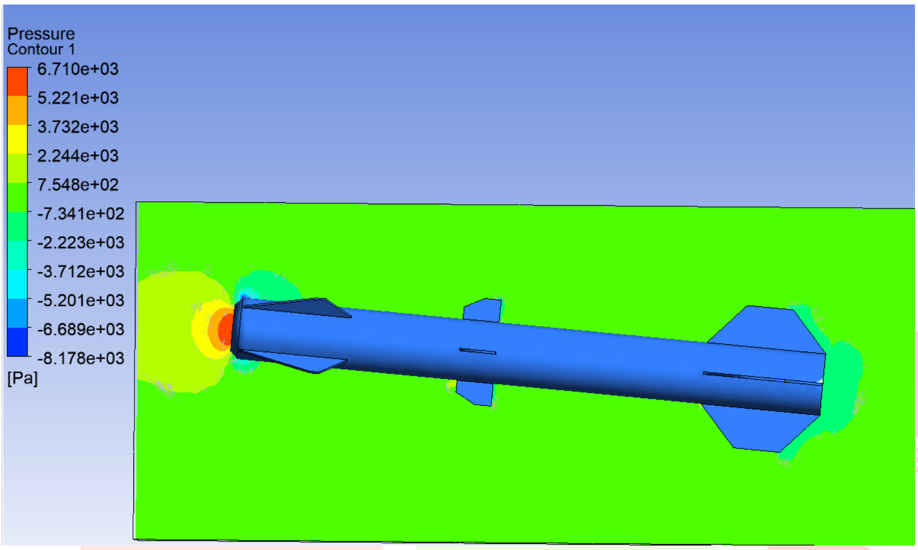


Figure 13: First design At AOA 5

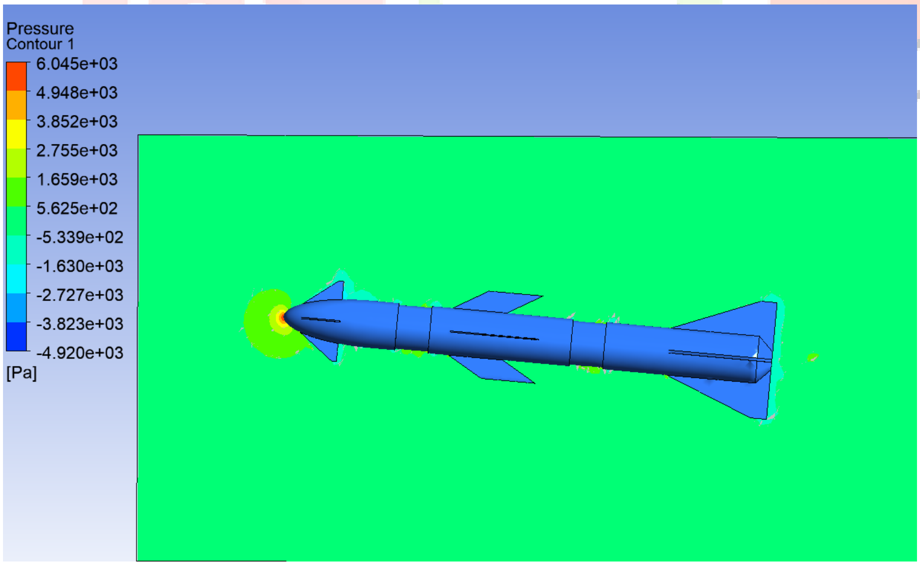


Figure 14**:** Second design At AOA 5

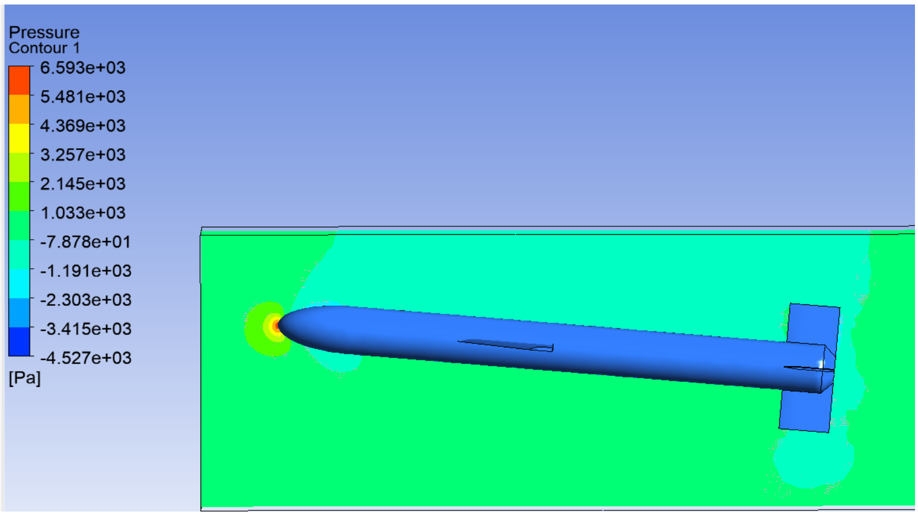


Figure 15: Third design At AOA 5

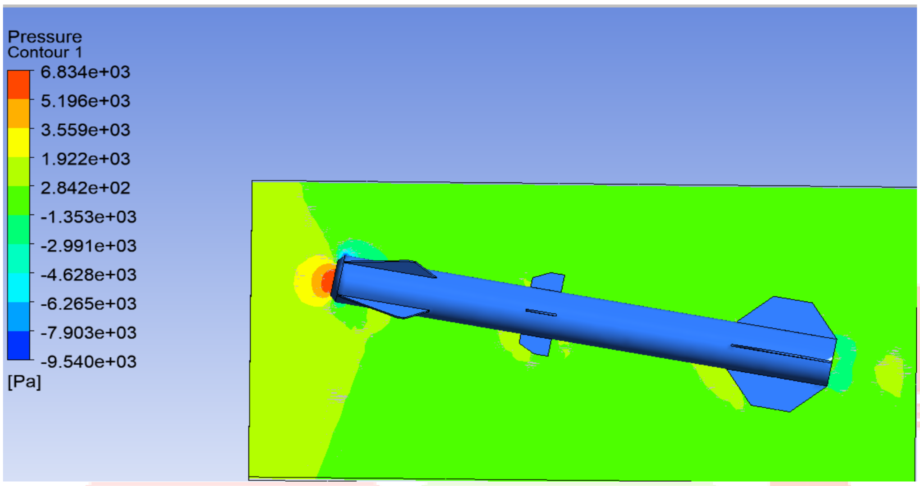


Figure 16: First design At AOA 10

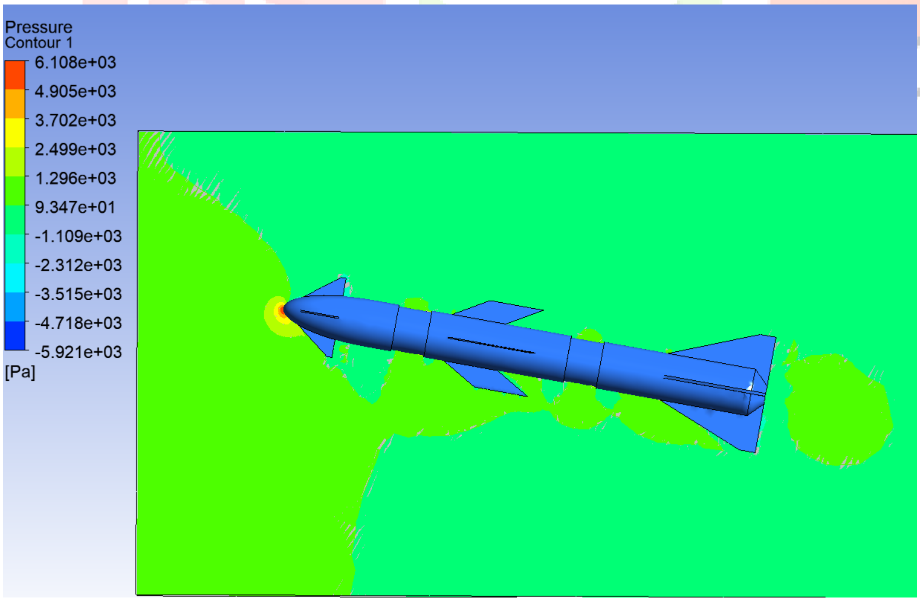


Figure 17: Second design At AOA 10

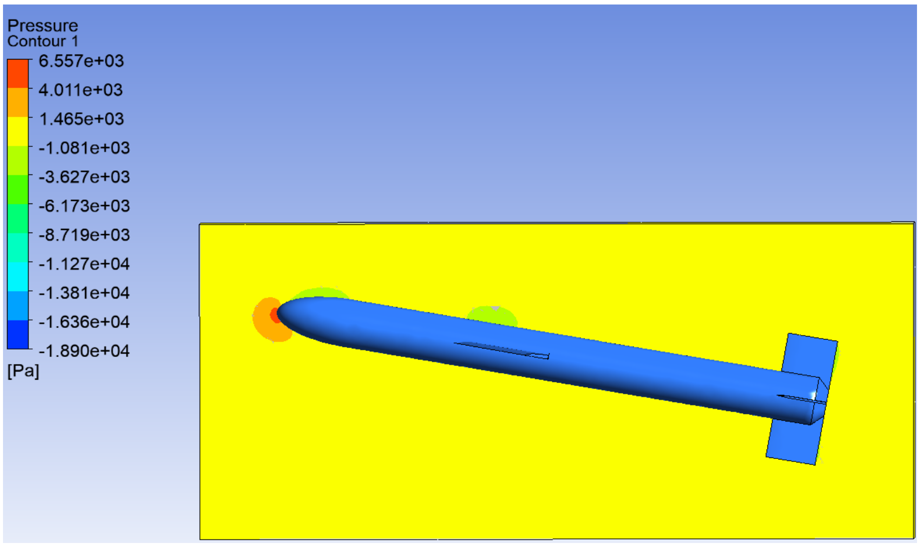


Figure 18: Third design At AOA 10

TABLE: 1ST DESIGN RESULT WITH DIFFERENT ANGLE OF ATTACK WITH SPEED OF 100m/sec

AOA	**LIFT**	**DRAG**	**CL**	**CD**
0	-0.0030125408	0.18808292	-0.0049184337	0.30707416
5	0.26595765	0.21706754	0.43421656	0.35439599
10	0.58203685	0.2978622	0.95026422	0.48630562

AOA	**PITCH**	**PITCH COEFFICIENT**	**YAW**	**YAW COEFFICIENT**	**ROLL**	**ROLL COEFFICIENT**
0	-0.00013024568	-0.000212646	-0.00026321883	-0.00042974501	-8.6706177E-06	-1.415611E-05
5	0.0093634259	0.015287226	0.00057328976	0.00093598326	3.8490372E-05	6.284142E-05
10	0.021521123	0.035136528	-0.00042161203	-0.00068834616	-5.0927461E-05	-8.3146871E-05

TABLE: 2nd DESIGN RESULT WITH DIFFERENT ANGLE OF ATTACK WITH SPEED OF 100m/sec

AOA	**LIFT**	**DRAG**	**CL**	**CD**
0	0.004626574	0.1792337	0.00755359	0.29262644
5	0.022803862	0.20685256	0.037230793	0.33771846
10	0.020925585	0.24282302	0.03416422	0.39644575

AOA	**PITCH**	**PITCH COEFFICIENT**	**YAW**	**YAW COEFFICIENT**	**ROLL**	**ROLL COEFFICIENT**
0	0.00025940608	0.00042352013	0.0019432581	0.0031726663	2.6422167E-05	4.3138232E-05
5	0.001006117	0.00164264	0.0098229395	0.016037451	-8.1860198E-05	-0.0001336493
10	0.0011148228	0.0018201189	0.013064455	0.021329723	0.0011148228	0.00062305917

TABLE: 3rd DESIGN RESULT WITH DIFFERENT ANGLE OF ATTACK WITH SPEED OF 100m/sec

AOA	LIFT	DRAG	CL	CD
0	-0.032687463	0.22221527	-0.053367287	0.36280042
5	1.0837147	0.25350568	1.7693301	0.41388682
10	2.584533	0.72364581	4.2196455	1.1814625

AOA	PITCH	PITCH COEFFICIENT	YAW	YAW COEFFICIENT	ROLL	ROLL COEFFICIENT
0	0.00050531555	0.00082500494	0.0027791429	0.0045373761	0.00050531555	-6.3967251E-05
5	0.026417676	0.043130901	-0.0010409838	-0.0016995654	0.026417676	-0.00014451664
10	0.06659624	0.10872855	0.00059942849	0.00097865879	0.06659624	-6.1920589E-05

IX). CONCLUSION

We conclude that the first design is the most stable, while the third design is the most aerodynamically efficient among the three. Additionally, the second design is inferior in both aerodynamic efficiency and stability.

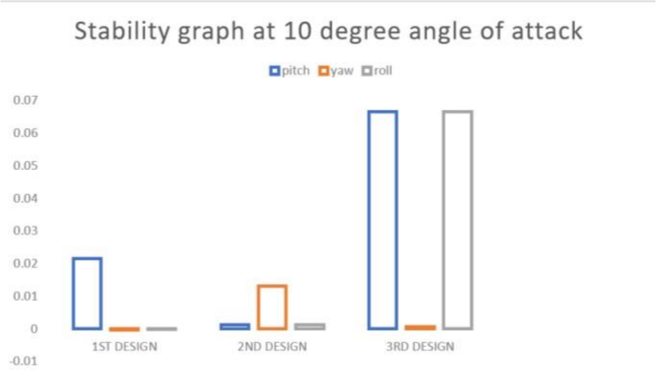


Figure 19

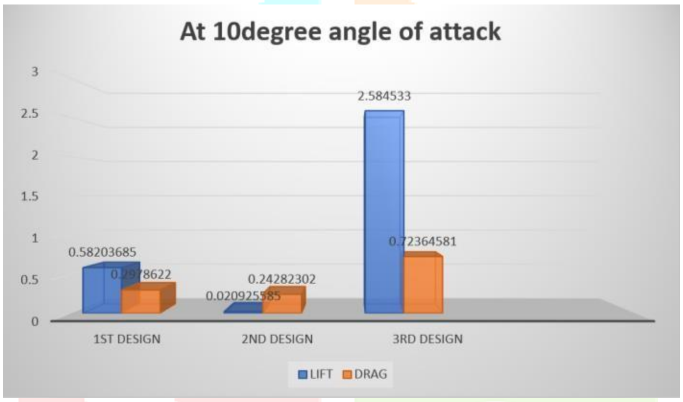


Figure 20

X). REFERENCES

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