Analysis of Submarine with the Study of Mechanical Investigations using Borei - Class Submarine Model

Amit Kumar Mehar
Associate Professor, Mechanical Engineering
Raghu Engineering College (Autonomous)
Andhra Pradesh, India

Potoju Muralidhar
Mechanical Engineering
Raghu Engineering College (Autonomous)
Andhra Pradesh, India

Abstract— In this current era of globalization every prosperous country in the world are wishes to develop a high technological machine-like nuclear-powered submarine, long ranging missile equipped submarines etc. To increase their naval strength and force for their countries pride. Even a highly equipped and technologically advanced submarine got damaged due to the collisions with mountain rocks, or ice bergs in ocean / sea. Sometimes these collisions lead to critical damage of parts of submarine, or injuries to soldiers. In this research work, modelling of a Borei – class submarine models are done by using a modelling software, CATIA V5. Various investigations and their analysis done by using ANSYS CFD & ANSYS Explicit Dynamics By using ANSYS the analyzed parameters are drag force, drag coefficient, lift Force, lift coefficient, deformation, total velocity, total acceleration, equivalent stress, maximum principal stress, minimum principal stress, maximum shear, stress, stress intensity, equivalent strain, maximum principal elastic strain, minimum principal elastic strain, maximum shear elastic strain, elastic strain intensity.

Keywords— Borei-class submarine, CATIA, ANSYS, CFD, Explicit Dynamics, Drag, Lift, Deformation, Stress, Strain, Streamlines, Velocity, Acceleration.

INTRODUCTION:
A ship powered by atomic energy is called nuclear submarine that travels primarily under-water, but also on the surface of the ocean. previously conventional submarines used diesel engines that required air for moving on the surface of the water, and battery – powered electric motors for moving beneath it. The limited lifetime of electric batteries meant that even the most advanced conventional submarine could only remain submerged for a few days at slow speed, and only a few hours at top speed. On the other hand, nuclear submarines can remain under-water for several months. This ability, combined with advanced weapons technology, makes nuclear submarines one of the most useful warships ever built. [1-3]

I. SHIP STRUCTURE AND PARTS
A Submarine has Outer hull and inner hull which is made of different material alloys Like Hy80 or Titanium Harden steel, etc. inner hull protects the crew from the water pressure bearing down on the submarine in the outer hull provides a streamlined shape to the submarine.

C. Trim tanks: These are in the front part and aft (rearward) sections of the submarine, which are also able to take on or release water in order to keep the submarine's weight equally distributed.

D. Rudder: These are vertically aligned, to submarine and by moving it, the ship can be directed side-to-side.

E. Stern planes: are horizontally aligned, so that moving them will guide the submarine's movement upward or downward.

F. Propeller: These powered by the steam-driven turbine and generators. The steam is created by the nuclear reactor.

G. Nuclear Reactor: These are essentially a glorified steam engine. It's usually located in the rear portion of the submarine. The reactor is protected by a thick metal casing that weighs around 100 tons. A specially designed alloy inside this shielding further protects the radioactive fuel rods.

H. Sonar sphere: is located in the Front part of the submarine. Sonar helps a submarine detect other objects in the water. It works by sending out a sound wave. If this sound wave strikes an object, a portion of the sound will be echoed back to the sub.

J. Mess deck: Forward compartment: submarine's crew is housed and fed in very tight, efficient quarters called the berthing and mess deck. Usually, this area is in the middle level of the ship's forward compartment.

II. NUCLEAR SUBMARINE ATMOSPHERE
Nuclear Powered Submarines is particularly suitable for vessels which need to be at sea for long periods without refueling. In Nuclear Powered Submarines are submariners live and work in an atmosphere composed of approximately 80% naturally occurring nitrogen, 19% oxygen (manufactured aboard ship), and a complex mixture of inorganic and organic contaminants. The concentrations of contaminants exist as a balance between the rates of production from human and operational activities and the rate of removal by engineering systems. The biological effects of inorganic gases, particularly carbon dioxide, have been extensively studied. Investigators are now attempting to define the composition and concentration of volatile organic compounds that accumulate during 90-day submergences. Medical studies have not conclusively shown that crewmembers incur adverse health effects from continuous exposures to the sealed atmospheres of nuclear submarines. In future, constraints on fossil fuel use in transport may bring marine nuclear propulsion into more widespread use. So far, exaggerated fears about safety have caused political restriction on port access [4-9]
III. BOREI-CLASS SUBMARINE MODEL DESIGN AND ANALYSIS.

Using the CATIA Design software and prepare the Borei – class submarine model.
This Borei – class submarine model was design in Catia and after modelling the submarine it is imported to ANSYS.
In ANSYS There is two types tests are conducted on submarine

A. ANSYS CFD Analysis

B. ANSYS Explicit Dynamics

A. ANSYS CFD Analysis

In this research work CFD analysis done at Borei – class submarine model and find the Pressure Effect, Velocity Effect, Drag force, Drag Coefficient, Lift force, Lift coefficient, Streamlines, Volume Rendering, at Different velocities and compare the different at different velocities 500m/s, 1000m/s, 1500m/s. and find the results of all these parameters effect on the submarine. [10-14]

B. ANSYS Explicit Dynamics

In this research work Explicit Dynamics analysis done at Borei – class submarine model and find the deformation, total velocity, total acceleration, equivalent stress, maximum principal stress, minimum principal stress, maximum shear. [15-17]

IV. ABOUT BOREI-CLASS SUBMARINE:

The new design for this Borei class submarine carries Bulava submarine-launched ballistic missiles. Borei-class submarine was planned to launch in 2009 but due to delay of Bulava development and fitted in 2013. There is lot of failures during test launches by 2017 out of 27 tests 12 were failure Development of missiles continues.

| Country of origin | Russia |
|-------------------|--------|
| Entered service   | 2012   |
| Crew              | 130 men|
| Diving depth (operative) | 380 m |
| Diving depth (maximum) | 400 - 450 m |
| Sea endurance     | 90 – 100 days |

Dimensions and displacement

| Length          | 160 m |
|-----------------|-------|
| Beam            | 13.5 m|
| Draught         | 10 m  |
| Surfaced displacement | 14 720 tons |
| Submerged displacement | 24 000 tons |

Propulsion and speed

| Surfaced speed  | 15 knots |
|-----------------|----------|
| Submerged speed | 26 - 29 knots |
| Propulsion      | nuclear reactor and pump jet propulsion |

Armament

| Missiles       | 16 x Bulava SLBMs |
|----------------|--------------------|
| Torpedoes      | 6 x 533 mm torpedo tubes |

Analysis of Borei-class submarine:

Pressure:
The pressure at 500 m/s, 1000m/s, 1500m/s velocity:

fig: 1 pressure at 500 m/s

fig: 2 pressure at 1000 m/s

Fig: 3 pressure at 1500m/s

Velocity:

velocity effect at 500 m/s,1000m/s,1500m/s.

fig: 4 velocity at 500m/s

fig: 5 velocity at 1000m/s

Fig: 6 velocity at 1500m/s

Velocity streamlines

An important concept in the study of hydrodynamics concerns the idea of streamlines. The below figure shows that velocity streamlines at 500m/s striking on the Borei-class submarine model.

Velocity streamlines at 500 m/s,1000m/s, 1500m/s.

fig: 7 streamlines 500m/s

fig: 8 streamlines 1000m/s

Fig: 9 streamlines 1500m/s

Volume rendering

Volume rendering shows that the body Borei-class submarine. The enclosure applied on the body is suitable or not can be visualize in this volume rendering.

fig: 10 volume rendering
**I. Explicit Dynamics**

Compression with same velocity at 8.09935 knots and same collision time 10000 s with changing fixed supports.

### Deformation

- **Fig 16.** Deformation of top fixed support
- **Fig 17.** Deformation of both side fixed support

| Time [s] | Minimum [mm] | Maximum [mm] |
|----------|--------------|--------------|
| 1.1755e-038 | 0 | 0 |
| 3.2399e-002 | 0 | 0 |

| Time [s] | Minimum [mm] | Maximum [mm] |
|----------|--------------|--------------|
| 1.1755e-038 | 0 | 0 |
| 3.2399e-002 | 0 | 0 |

**Table 1**

**Table 2**

The deformation of the submarine analyzed at velocity of 8.09935 knots, found that deformation is independent of fixed supports.

### Total velocity

- **Fig 18.** Total velocity of top fixed support
- **Fig 19.** Total velocity of both side fixed support

| Time [s] | Minimum [mm] | Maximum [mm] |
|----------|--------------|--------------|
| 1.1755e-038 | 4196.7 | 613.07 |
| 3.2399e-002 | 0 | 0 |

| Time [s] | Minimum [mm] | Maximum [mm] |
|----------|--------------|--------------|
| 1.1755e-038 | 4196.7 | 613.07 |
| 3.2399e-002 | 0 | 0 |

**Table 3**

**Table 4**

The total velocity of the submarine analyzed at velocity of 8.09935 knots, found that total velocity is independent of fixed supports.

### Total acceleration

- **Fig 20.** Total acceleration of top fixed support
- **Fig 21.** Total acceleration of both side fixed support

| Time [s] | Minimum [mm] | Maximum [mm] |
|----------|--------------|--------------|
| 1.1755e-038 | 15184 | 0 |
| 3.2399e-002 | 0 | 0 |

| Time [s] | Minimum [mm] | Maximum [mm] |
|----------|--------------|--------------|
| 1.1755e-038 | 15184 | 0 |
| 3.2399e-002 | 0 | 0 |

**Table 5**

**Table 6**

The total acceleration of the submarine analyzed at velocity of 8.09935 knots, found that total acceleration is independent of fixed supports.

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**Equivalent elastic stress**

- **i.** Equivalent stress of top fixed support
- **ii.** Equivalent stress of both side fixed support

| Time [s] | Minimum [MPa] | Maximum [MPa] |
|----------|---------------|---------------|
| 1.1755e-038 | 17.920 | 0 |
| 3.2399e-002 | 0 | 0 |

| Time [s] | Minimum [MPa] | Maximum [MPa] |
|----------|---------------|---------------|
| 1.1755e-038 | 17.920 | 0 |
| 3.2399e-002 | 0 | 0 |

**Table 7**

**Table 8**

The equivalent stress of the submarine analyzed at velocity of 8.09935 knots, found that equivalent stress is independent of fixed supports.

**Maximum principal stress**

- **i.** Maximum principal stress of top fixed support
- **ii.** Maximum principal stress of both side fixed support

| Time [s] | Minimum [MPa] | Maximum [MPa] |
|----------|---------------|---------------|
| 1.1755e-038 | 0 | 4.5418 |
| 3.2399e-002 | 0 | 0 |

| Time [s] | Minimum [MPa] | Maximum [MPa] |
|----------|---------------|---------------|
| 1.1755e-038 | 0 | 4.5418 |
| 3.2399e-002 | 0 | 0 |

**Table 9**

**Table 10**

The maximum principal stress of the submarine analyzed at velocity of 8.09935 knots, maximum principal stress found that is independent of fixed supports.

**Minimum principal stress**

- **i.** Minimum principal stress of top fixed support
- **ii.** Minimum principal stress of both side fixed support

| Time [s] | Minimum [MPa] | Maximum [MPa] |
|----------|---------------|---------------|
| 1.1755e-038 | 15.047 | 15.047 |
| 3.2399e-002 | 0 | 0 |

| Time [s] | Minimum [MPa] | Maximum [MPa] |
|----------|---------------|---------------|
| 1.1755e-038 | 15.047 | 15.047 |
| 3.2399e-002 | 0 | 0 |

**Table 11**

**Table 12**

The minimum principal stress of the submarine analyzed at velocity of 8.09935 knots, minimum principal stress found that is independent of fixed supports.

**Maximum shear stress**

- **i.** Maximum shear stress of top fixed support
- **ii.** Maximum shear stress of both side fixed support

| Time [s] | Minimum [MPa] | Maximum [MPa] |
|----------|---------------|---------------|
| 1.1755e-038 | 15.047 | 15.047 |
| 3.2399e-002 | 0 | 0 |

| Time [s] | Minimum [MPa] | Maximum [MPa] |
|----------|---------------|---------------|
| 1.1755e-038 | 15.047 | 15.047 |
| 3.2399e-002 | 0 | 0 |

**Table 13**

**Table 14**

The maximum shear stress of the submarine analyzed at velocity of 8.09935 knots, maximum shear stress found that is independent of fixed supports.

**Stress intensity**

- **i.** Stress intensity of top fixed support
- **ii.** Stress intensity of both side fixed support

| Time [s] | Minimum [MPa] | Maximum [MPa] |
|----------|---------------|---------------|
| 1.1755e-038 | 0 | 16.318 |
| 3.2399e-002 | 0 | 0 |

| Time [s] | Minimum [MPa] | Maximum [MPa] |
|----------|---------------|---------------|
| 1.1755e-038 | 0 | 16.318 |
| 3.2399e-002 | 0 | 0 |

**Table 15**

**Table 16**

The stress intensity of the submarine analyzed at a velocity of 8.09935 knots, stress intensity found that is independent of fixed supports.

**Equivalent elastic strain**

- **i.** Equivalent strain of top fixed support
- **ii.** Equivalent strain of both side fixed support

| Time [s] | Minimum [mm] | Maximum [mm] |
|----------|--------------|--------------|
| 1.1755e-038 | 0 | 6 |
| 3.2399e-002 | 0 | 0 |

| Time [s] | Minimum [mm] | Maximum [mm] |
|----------|--------------|--------------|
| 1.1755e-038 | 0 | 6 |
| 3.2399e-002 | 0 | 0 |

**Table 17**

**Table 18**

The equivalent strain of the submarine analyzed at velocity of 8.09935 knots, found that equivalent strain is independent of fixed supports.

**Maximum principal elastic strain**

- **i.** Maximum principal elastic strain of top fixed support
- **ii.** Maximum principal elastic strain of both side fixed support

| Time [s] | Minimum [mm] | Maximum [mm] |
|----------|--------------|--------------|
| 1.1755e-038 | 0 | 0 |
| 3.2399e-002 | 0 | 0 |

| Time [s] | Minimum [mm] | Maximum [mm] |
|----------|--------------|--------------|
| 1.1755e-038 | 0 | 0 |
| 3.2399e-002 | 0 | 0 |

**Table 19**

**Table 20**

The maximum principal elastic strain of the submarine analyzed at velocity of 8.09935 knots, maximum principal elastic strain found that is independent of fixed supports.
The maximum principal elastic strain of the submarine analyzed at velocity of 8.09935 knots, found that maximum principal elastic strain is independent of fixed supports.

**Minimum principal elastic strain**

| i. Minimum principal elastic strain | ii. Minimum principal elastic strain of both side fixed support |
|-------------------------------------|----------------------------------------------------------|
| Top fixed support                   | 1.7156e-03/28, 0/0.0/0.0 | 1.7156e-03/0, 0/0.0/0.0 |
| Bottom fixed support                | 3.2390e-02, 0.8516e-06/0.0/0.0484 | 3.2390e-02/0, 0.8516e-06/0.0484 |

Table 21 Table 22

The minimum principal elastic strain of the submarine analyzed at a velocity of 8.09935 knots, found that minimum principal elastic strain is independent of fixed supports.

**Maximum shear elastic strain**

| i. Maximum shear elastic strain of top fixed support | ii. Maximum shear elastic strain of both side fixed support |
|-----------------------------------------------------|----------------------------------------------------------|
| Top fixed support                                   | 1.7156e-03/28, 0/0.0/0.0 | 1.7156e-03/0, 0/0.0/0.0 |
| Bottom fixed support                                | 3.2390e-02, 0.8516e-06/0.0/0.0484 | 3.2390e-02/0, 0.8516e-06/0.0484 |

Table 23 Table 24

The maximum shear elastic strain of the submarine analyzed at velocity of 8.09935 knots, found that maximum shear elastic strain is independent of fixed supports.

**Elastic strain intensity**

| i. Elastic strain intensity of Top fixed support | ii. Elastic strain intensity of both side fixed support |
|------------------------------------------------|----------------------------------------------------------|
| Top fixed support                               | 1.7156e-03/28, 0/0.0/0.0 | 1.7156e-03/0, 0/0.0/0.0 |
| Bottom fixed support                            | 3.2390e-02, 0.8516e-06/0.0/0.0484 | 3.2390e-02/0, 0.8516e-06/0.0484 |

Table 25 Table 26

The elastic strain intensity of the submarine analyzed at velocity of 8.09935 knots, found that elastic strain intensity is independent of fixed supports.

Comparing the top fixed support at velocity 8.09935 knots with same velocity changing the fixed supports and increases the collision time from 10000 s to 1000000 s.

**Deformation**

| i. Equivalent stress of Top fixed support | ii. Equivalent stress of both bottom support |
|------------------------------------------|------------------------------------------------|
| Top fixed support                        | 1.7156e-03/28, 0/0.0/0.0 | 1.7156e-03/0, 0/0.0/0.0 |
| Bottom fixed support                     | 3.2390e-02, 0.8516e-06/0.0/0.0484 | 3.2390e-02/0, 0.8516e-06/0.0484 |

Table 27 Table 28

The deformation of the submarine analyzed at velocity of 8.09935 knots and comparing with changing the fixed support and increasing collision time from 10000 s to 1000000 s, found that deformation is high compare less collision time.

**Total velocity**

| Total velocity of Top fixed support | Total velocity of bottom fixed support |
|-------------------------------------|----------------------------------------|
| Time [s]. Maximum [m]               | Time [s]. Maximum [m]                  |
| 1.7156e-03/28, 0/0.0/0.0 | 3.2390e-02/0, 0.8516e-06/0.0/0.0484 |
| 3.2390e-02, 0.8516e-06 | 3.2390e-02/0, 0.8516e-06/0.0484 |

Table 29 Table 30

The total velocity of the submarine analyzed at velocity of 8.09935 knots and comparing with changing the fixed support and increasing collision time from 10000 s to 1000000 s, found that total velocity is high compare to less collision time.

**Total acceleration**

| i. Maximum principal stress of Top fixed support | ii. Maximum principal stress of both bottom support |
|------------------------------------------------|----------------------------------------------------------|
| Top fixed support                               | 1.7156e-03/28, 0/0.0/0.0 | 1.7156e-03/0, 0/0.0/0.0 |
| Bottom fixed support                            | 3.2390e-02, 0.8516e-06/0.0/0.0484 | 3.2390e-02/0, 0.8516e-06/0.0484 |

Table 31 Table 32

The total acceleration of the submarine analyzed at velocity of 8.09935 knots and comparing changing the fixed support and with increasing collision time from 10000 s to 1000000 s, found that total acceleration is less compare to less collision time.

**Equivalent elastic stress**

| i. Equivalent stress of Top fixed support | ii. Equivalent stress of both bottom support |
|------------------------------------------|------------------------------------------------|
| Top fixed support                        | 1.7156e-03/28, 0/0.0/0.0 | 1.7156e-03/0, 0/0.0/0.0 |
| Bottom fixed support                     | 3.2390e-02, 0.8516e-06/0.0/0.0484 | 3.2390e-02/0, 0.8516e-06/0.0484 |

Table 33 Table 34

The equivalent elastic stress of the submarine analyzed at a velocity of 8.09935 knots and comparing with changing the fixed support and increasing collision time from 10000 s to 1000000 s, found that equivalent elastic stress is less compare with less collision time.

**Maximum principal stress**

| i. Minimum principal stress of Top fixed support | ii. Minimum principal stress of both bottom support |
|------------------------------------------------|----------------------------------------------------------|
| Top fixed support                               | 1.7156e-03/28, 0/0.0/0.0 | 1.7156e-03/0, 0/0.0/0.0 |
| Bottom fixed support                            | 3.2390e-02, 0.8516e-06/0.0/0.0484 | 3.2390e-02/0, 0.8516e-06/0.0484 |

Table 35 Table 36

The maximum principal stress of the submarine analyzed at a velocity of 8.09935 knots and comparing with changing the fixed support and increasing collision time from 10000 s to 1000000 s, found that maximum principal stress is high compare with less collision time.

**Minimum principal stress**

| i. Minimum principal stress of Top fixed support | ii. Minimum principal stress of both bottom support |
|------------------------------------------------|----------------------------------------------------------|
| Top fixed support                               | 1.7156e-03/28, 0/0.0/0.0 | 1.7156e-03/0, 0/0.0/0.0 |
| Bottom fixed support                            | 3.2390e-02, 0.8516e-06/0.0/0.0484 | 3.2390e-02/0, 0.8516e-06/0.0484 |

Table 37 Table 38

The minimum principal stress of the submarine analyzed at a velocity of 8.09935 knots and comparing with changing the fixed support and increasing collision time from 10000 s to 1000000 s, found that minimum principal stress is low compare with less collision time.

**Maximum shear stress**

| i. Maximum shear stress of Top fixed support | ii. Maximum shear stress of both bottom support |
|--------------------------------------------|------------------------------------------------|
| Top fixed support                          | 1.7156e-03/28, 0/0.0/0.0 | 1.7156e-03/0, 0/0.0/0.0 |
| Bottom fixed support                       | 3.2390e-02, 0.8516e-06/0.0/0.0484 | 3.2390e-02/0, 0.8516e-06/0.0484 |

Table 39 Table 40

The maximum shear stress of the submarine analyzed at a velocity of 8.09935 knots and comparing with changing the fixed support and increasing collision time from 10000 s to 1000000 s, found that maximum shear stress is low compare with less collision time.
The stress intensity of the submarine analyzed at a velocity of 8.09935 knots and comparing with changing the fixed support and increasing collision time from 10000 s to 1000000 s, found that stress intensity is low compare with less collision time

**Maximum principal elastic strain**

1. Maximum principal elastic strain of top fixed support
2. Maximum principal elastic strain of bottom fixed support

| Time [s] | Maximum [MPa] | Minimum [MPa] | Mean [MPa] |
|----------|---------------|---------------|------------|
| 3.3293x10^-02 | 1.7156x10^-02 | 3.3293x10^-02 | 4.1320x10^-02 |
| 1.7156x10^-02 | 3.3293x10^-02 | 1.7156x10^-02 | 5.7172 |

Comparing the top fixed support at velocity 8.09935 knots with chaining the velocity at 16.1987 knots with bottom fixed support with same collision time 10000 sec.

**Total velocity**

The total velocity of the submarine analyzed at a velocity of 8.09935 knots and comparing with changing the fixed support and increasing the velocity to 16.1987, found that total velocity is high in 16.1987 in compare to 8.09935.

**Total acceleration**

The total acceleration of the submarine analyzed at velocity of 8.09935 knots and comparing with changing the fixed support and increasing the velocity to 16.1987, found that total acceleration is low in 16.1987 in compare to 8.09935.

**Equivalent elastic strain**

1. Equivalent strain of top fixed support
2. Equivalent strain of bottom fixed support

| Time [s] | Maximum [MPa] | Minimum [MPa] | Mean [MPa] |
|----------|---------------|---------------|------------|
| 3.3293x10^-02 | 1.7156x10^-02 | 3.3293x10^-02 | 4.1320x10^-02 |
| 1.7156x10^-02 | 3.3293x10^-02 | 1.7156x10^-02 | 5.7172 |

The equivalent strain of the submarine analyzed at velocity of 8.09935 knots and comparing with changing the fixed support and increasing collision time from 10000 s to 1000000 s, found that equivalent strain is high compare with less collision time.

**Maximum shear elastic strain**

1. Maximum shear elastic strain of top fixed support
2. Maximum shear elastic strain of bottom fixed support

| Time [s] | Maximum [MPa] | Minimum [MPa] | Mean [MPa] |
|----------|---------------|---------------|------------|
| 3.3293x10^-02 | 1.7156x10^-02 | 3.3293x10^-02 | 4.1320x10^-02 |
| 1.7156x10^-02 | 3.3293x10^-02 | 1.7156x10^-02 | 5.7172 |

The maximum shear elastic strain of the submarine analyzed at velocity of 8.09935 knots and comparing with changing the fixed support and increasing collision time from 10000 s to 1000000 s, found that maximum shear elastic strain is high compare with less collision time.

**Minimum principal elastic strain**

1. Minimum principal elastic strain of top fixed support
2. Minimum principal elastic strain of bottom fixed support

| Time [s] | Maximum [MPa] | Minimum [MPa] | Mean [MPa] |
|----------|---------------|---------------|------------|
| 3.3293x10^-02 | 1.7156x10^-02 | 3.3293x10^-02 | 4.1320x10^-02 |
| 1.7156x10^-02 | 3.3293x10^-02 | 1.7156x10^-02 | 5.7172 |

The minimum principal elastic strain of the submarine analyzed at velocity of 8.09935 knots and comparing with changing the fixed support and increasing collision time from 10000 s to 1000000 s, found that minimum principal elastic strain is high compare with less collision time.

**Elastic strain intensity**

1. Elastic strain intensity of top fixed support
2. Elastic strain intensity of bottom fixed support

| Time [s] | Maximum [MPa] | Minimum [MPa] | Mean [MPa] |
|----------|---------------|---------------|------------|
| 3.3293x10^-02 | 1.7156x10^-02 | 3.3293x10^-02 | 4.1320x10^-02 |
| 1.7156x10^-02 | 3.3293x10^-02 | 1.7156x10^-02 | 5.7172 |

The elastic strain intensity of the submarine analyzed at a velocity of 8.09935 knots and comparing with changing the fixed support and increasing collision time from 10000 s to 1000000 s, found that elastic strain intensity is high compare with less collision time.

The deformation of the submarine analyzed at velocity of 8.09935 knots and comparing with changing the fixed support and increasing the velocity to 16.1987, found that deformation is high in 16.1987 in compare to 8.09935.
maximum principal stress

\[ \text{Maximum principal stress of top fixed support} \quad \text{Maximum principal stress of bottom fixed support} \]

The maximum principal stress of the submarine analyzed at velocity of 8.09935 knots and comparing with changing the fixed support and increasing the velocity to 16.1987, found that maximum principal stress is low in 16.1987 in compare to 8.09935.

Minimum principal stress

\[ \text{i. Minimum principal stress of top fixed support} \quad \text{ii. Minimum principal stress of bottom fixed support} \]

The minimum principal stress of the submarine analyzed at velocity of 8.09935 knots and comparing with changing the fixed support and increasing the velocity to 16.1987, found that minimum principal stress is low in 16.1987 in compare to 8.09935.

Maximum shear stress

\[ \text{i. Maximum shear stress of top fixed support} \quad \text{ii. Maximum shear stress of bottom fixed support} \]

The maximum shear stress of the submarine analyzed at velocity of 8.09935 knots and comparing with changing the fixed support and increasing the velocity to 16.1987, found that maximum shear stress is low in 16.1987 in compare to 8.09935.

Stress intensity

\[ \text{i. Stress intensity of top fixed support} \quad \text{ii. Stress intensity of bottom fixed support} \]

The stress intensity of the submarine analyzed at velocity of 8.09935 knots and comparing with changing the fixed support and increasing the velocity to 16.1987, found that stress intensity is low in 16.1987 in compare to 8.09935.

Equivalent elastic strain

\[ \text{i. Equivalent strain of top fixed support} \quad \text{ii. Equivalent strain of bottom fixed support} \]

The equivalent elastic strain of the submarine analyzed at velocity of 8.09935 knots and comparing with changing the fixed support and increasing the velocity to 16.1987, found that equivalent elastic strain is high in 16.1987 in compare to 8.09935.

Maximum principal elastic strain

\[ \text{i. Maximum principal elastic strain of top fixed support} \quad \text{ii. Maximum principal elastic strain of bottom fixed support} \]

The maximum principal elastic strain of the submarine analyzed at velocity of 8.09935 knots and comparing with changing the fixed support and increasing the velocity to 16.1987, found that maximum principal elastic strain is high in 16.1987 in compare to 8.09935.

Minimum principal elastic strain

\[ \text{i. Minimum principal elastic strain of top fixed support} \quad \text{ii. Minimum principal elastic strain of bottom fixed support} \]

The minimum principal elastic strain of the submarine analyzed at velocity of 8.09935 knots and comparing with changing the fixed support and increasing the velocity to 16.1987, found that minimum principal elastic strain is high in 16.1987 in compare to 8.09935.

Maximum shear elastic strain

\[ \text{i. Maximum shear elastic strain of top fixed support} \quad \text{ii. Maximum shear elastic strain of bottom fixed support} \]

The maximum shear elastic strain of the submarine analyzed at velocity of 8.09935 knots and comparing with changing the fixed support and increasing the velocity to 16.1987, found that maximum shear elastic strain is high in 16.1987 in compare to 8.09935.

Elastic strain intensity

\[ \text{i. Elastic strain intensity of top fixed support} \quad \text{ii. Elastic strain intensity of bottom fixed support} \]

The elastic strain intensity of the submarine analyzed at velocity of 8.09935 knots and comparing with changing the fixed support and increasing the velocity to 16.1987, found that elastic strain intensity is high in 16.1987 in compare to 8.09935.

The Below tables show the Drag force along the velocities 500, 1000, 1500 at different velocities for Titanium alloy. From the table it is observed that the increasing in the velocity will leads to increase in the Drag Force of the Submarine. And drag coefficient is also increases.

Drag force along the velocities of 500, 1000, 1500.

\[
\begin{array}{ccc}
\text{velocity} & 500 & 1000 & 1500 \\
\text{Drag force} & 681705.1 & 2724829 & 4795526 \\
\end{array}
\]

Graph 1 Drag force

Drag Coefficient along the velocities of 500, 1000, 1500.

\[
\begin{array}{ccc}
\text{velocity} & 500 & 1000 & 1500 \\
\text{DRAG COEFF} & 1112988 & 4448701 & 7829431 \\
\end{array}
\]
Lift Force along the velocities of 500, 1000, 1500.

| Velocity | Lift Force |
|----------|------------|
| 500      | -307278    |
| 1000     | -1227523   |
| 1500     | -2337382   |

Table 81

Lift Coefficient along the velocities of 500, 1000, 1500.

| Velocity | Lift COEFF |
|----------|------------|
| 500      | -501516    |
| 1000     | -2004120   |
| 1500     | -3816134   |

Table 82

In this research the blow tables show the deformations and velocities and accelerations and stress, strains and shows the changes of the occurs on the submarine. In this research we did this compression between changed the Fixed supports with same velocities and increasing the collision time.

Total Deformation

| TOP SUPPORT (max time) | BOTTOM SUPPORT (max time) |
|------------------------|---------------------------|
| 3.2390E-02             | 3.3291E-02                |
| 613.07                 | 6274.6                    |

Table 83

Total Velocity

(Top vs bottom supports) Total velocity

| TOP SUPPORT (max time) | BOTTOM SUPPORT (max time) |
|------------------------|---------------------------|
| 3.2390E-02             | 3.3291E-02                |
| 15184                  | 1.41E+05                  |

Table 84

Total Acceleration

(Top vs bottom supports) Total acceleration

| TOP SUPPORT (max time) | BOTTOM SUPPORT (max time) |
|------------------------|---------------------------|
| 3.2390E-02             | 3.3291E-02                |
| 17.802                 | 9.2819                    |

Table 85

Equivalent Elastic Stress

(Top vs bottom supports) Equivalent elastic stress

| TOP SUPPORT (max time) | BOTTOM SUPPORT (max time) |
|------------------------|---------------------------|
| 3.2390E-02             | 3.3291E-02                |
| 17.802                 | 9.2819                    |

Table 86
Maximum principle stress

| TOP SUPPORT (max time) | BOTTOM SUPPORT (max time) |
|------------------------|---------------------------|
| 3.2390E-02             | 3.3291E-02                |
| 4.5418                 | 4.0823                    |

Table 87

Maximum Principle Stress

Graph 9 Time vs velocity (Top vs bottom supports) Maximum principle Stress

Minimum Principle Stress

| TOP SUPPORT (max time) | BOTTOM SUPPORT (max time) |
|------------------------|---------------------------|
| 3.2390E-02             | 3.3291E-02                |
| 1.035                  | 0.75162                   |

Table 88

Minimum principle stress

Graph 10 Time vs velocity (Top vs bottom supports) Minimum principle stress

Maximum Shear Stress

| TOP SUPPORT (max time) | BOTTOM SUPPORT (max time) |
|------------------------|---------------------------|
| 3.2390E-02             | 3.3291E-02                |
| 9.1588                 | 4.8786                    |

Table 89

Maximum Shear Stress

Graph 11 Time vs velocity (Top vs bottom supports) Maximum shear stress

Stress Intensity

| TOP SUPPORT (max time) | BOTTOM SUPPORT (max time) |
|------------------------|---------------------------|
| 3.2390E-02             | 3.3291E-02                |
| 18.318                 | 9.7572                    |

Table 90

Stress Intensity

Graph 12 Time vs velocity (Top vs bottom supports) Stress intensity

Equivalent Elastic Strain

| TOP SUPPORT (max time) | BOTTOM SUPPORT (max time) |
|------------------------|---------------------------|
| 3.2390E-02             | 3.3291E-02                |
| 0.13397                | 0.58765                   |

Table 91

Equivalent Elastic Strain

Graph 13(Time vs velocity (Top vs bottom supports) Equivalent elastic strain

Maximum Principle Elastic Strain

| TOP SUPPORT (max time) | BOTTOM SUPPORT (max time) |
|------------------------|---------------------------|
| 3.2390E-02             | 3.3291E-02                |
| 9.60E-02               | 0.67854                   |

Table 92

Maximum Principle elastic strain

Graph 14 Time vs velocity (Top vs bottom supports) Maximum principle elastic strain

Minimum Principle Elastic Strain

| TOP SUPPORT (max time) | BOTTOM SUPPORT (max time) |
|------------------------|---------------------------|
| 3.2390E-02             | 3.3291E-02                |
| 9.52E-02               | 2.00E-03                  |

Table 93

Minimum Principle elastic strain
Graph 15 Time vs velocity (Top vs bottom supports)
Minimum principle elastic

Maximum Shear Elastic Strain

|                     | TOP SUPPORT (max time) | BOTTOM SUPPORT (max time) |
|---------------------|------------------------|---------------------------|
| Total Deformation   | 3.2390E-02             | 3.3291E-02                |
| Elastic Strain      | 0.1648                 | 0.70747                   |

Table 94

Graph 16 Time vs velocity (Top vs bottom supports)
Maximum shear elastic strain

Elastic Strain Intensity

|                     | TOP SUPPORT (max time) | BOTTOM SUPPORT (max time) |
|---------------------|------------------------|---------------------------|
| Total Deformation   | 3.2390E-02             | 3.3291E-02                |
| Elastic Strain      | 0.1648                 | 0.70747                   |

Table 95

Graph 17 Time vs velocity (Top vs bottom supports)
Elastic strain intensity

In this research the blow tables show the deformations and velocities and accelerations and stress, strains and shows the changes of the occurs on the submarine. In this research we did this compression between changed the Fixed supports with changed the velocities and increasing the collision time.

Total Deformation

|                      | TOP SUPPORT | BOTTOM SUPPORT |
|----------------------|-------------|----------------|
| Equivalent Elastic Stress | 8.09935 knots | 16.1987 knots |
|                      | 37.391      | 128.64         |

Table 96

Graph 18 Time vs velocity (Top vs bottom supports) Total deformation

Total Velocity

|                      | TOP SUPPORT | BOTTOM SUPPORT |
|----------------------|-------------|----------------|
| Total Velocity       | 8.09935 knots | 16.1987 knots |
|                      | 613.07      | 7693.1         |

Table 97

Graph 19 Time vs velocity (Top vs bottom supports) Total velocity

6.20 Total Acceleration

|                      | TOP SUPPORT | BOTTOM SUPPORT |
|----------------------|-------------|----------------|
| Total Acceleration   | 8.09935 knots | 16.1987 knots |
|                      | 15184       | 1.44E+09       |

Table 98

Graph 20 Time vs velocity (Top vs bottom supports) Total acceleration

Equivalent Elastic Stress

|                      | TOP SUPPORT | BOTTOM SUPPORT |
|----------------------|-------------|----------------|
| Equivalent Elastic Stress | 8.09935 knots | 16.1987 knots |
|                      | 17.802      | 3.6118         |

Table 99
### Maximum Elastic Stress

|             | TOP SUPPORT | BOTTOM SUPPORT |
|-------------|-------------|----------------|
| 8.09935 knots | 16.1987 knots |
| 4.5418      | 2.9065      |

#### Graph 21
Time vs velocity (Top vs bottom supports)
Equivalent elastic stress

### Maximum Shear Stress

|             | TOP SUPPORT | BOTTOM SUPPORT |
|-------------|-------------|----------------|
| 9.1588      | 2.0816      |

#### Graph 24
Time vs velocity (Top vs bottom supports)
Maximum shear stress

### Stress Intensity

|             | TOP SUPPORT | BOTTOM SUPPORT |
|-------------|-------------|----------------|
| 8.09935 knots | 16.1987 knots |
| 18.318      | 4.1632      |

#### Graph 25
Time vs velocity (Top vs bottom supports)
Stress intensity

### Minimum Principle Stress

|             | TOP SUPPORT | BOTTOM SUPPORT |
|-------------|-------------|----------------|
| 8.09935 knots | 16.1987 knots |
| 1.035       | 0.44647     |

#### Graph 22
Time vs velocity (Top vs bottom supports)
maximum Principle stress

### Minimum Shear Stress

|             | TOP SUPPORT | BOTTOM SUPPORT |
|-------------|-------------|----------------|
| 1.035       | 0.44647     |

#### Graph 23
Time vs velocity (Top vs bottom supports)
Minimum principle stress

### Maximum Principle Elastic Strain

|             | TOP SUPPORT | BOTTOM SUPPORT |
|-------------|-------------|----------------|
| 8.09935 knots | 16.1987 knots |
| 9.60E-02    | 1.3162      |

#### Graph 26
Time vs velocity (Top vs bottom supports)
Equivalent elastic strain

### Maximum Principle Elastic Strain

|             | TOP SUPPORT | BOTTOM SUPPORT |
|-------------|-------------|----------------|
| 8.09935 knots | 16.1987 knots |
| 9.60E-02    | 1.3162      |

#### Graph 26
Time vs velocity (Top vs bottom supports)
Equivalent elastic strain
CONCLUSION

It is observed that when submarine collision test with some object in under water with a velocity the deformations and stress and strain which are occurred on submarine and find the drag and lift on the submarine.

In this research work of Computational Fluid Dynamics, the Drag force and drag coefficient, is gradually increases when the velocities are increases from 500 to 1500. Lift coefficient and lift force is decreasing when the velocity increases from 500 to 1500.

Using explicit dynamics the collision test did on the submarine with the velocity of 8.09935(15kmph) knots with variable fixed supports of both top and bottom supports and only top fixed support and collision time is same(10000 s), and found that there is no change in deformations, velocities, accelerations, Equivalent stress, maximum principal stress, minimum principal stress, stress intensity, Equivalent elastic strain, maximum principal elastic strain, minimum principal elastic strain, maximum shear elastic strain, strain intensity There is No effect on submarine with changing the fixed support.

Due to that we compare that submarine collision test with velocity (8.09935 Knots) and compare with top fixed support and bottom fixed support and increasing collision time (time from 10000 s to 1000000 s) the Total Deformation and Total velocity also increases but acceleration decreases. In stress we found Equivalent stress, minimum principal stress, stress intensity is same, but the maximum principal stress is increased. In strains we found Equivalent elastic strain, maximum principal elastic strain, minimum principal elastic strain, maximum shear elastic strain, strain intensity all strains are high compared to previous collision time.

When we compare this collision test with changing the velocity from 8.09935 knots to 16.1987 knots with bottom fixed support with collision time(10000 s) the deformations, velocities and accelerations are high compared to the 15kmph and in the stress we found equivalent stress, maximum principal stress, minimum principal stress, stress intensity all are low compared to the 8.09935 knots speed collision. In strains we found Equivalent elastic strain, maximum principal elastic strain, minimum principal elastic strain, maximum shear elastic strain, strain intensity all strains are high compare to 8.09935 knots.
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