Asyraf Syazwan Ahmad Tajuddinet al. 2021, 9:3
ISSN (Online): 2348-4098
ISSN (Print): 2395-4752

International Journal of Science, Engineering and Technology

An Open Access Journal

Seaglider Strength Stability Due to Sea Head Wave Using SeaFEM

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Abstract- A Seaglider can be described as an autonomous underwater glider (AUV) vehicle that has a pressure hull that is enclosed by a fairing made from fiberglass in which the wings, rudders and trailing antenna are combined to. Seagliders are commissioned to independently gather information on the encompassing water segment, which includes salinity levels, oxygen content and temperature. Then, the data gathered are delivered back to the satellite via antenna mast while it resurfaces at sea level which renders the Seaglider exposed to the head sea wave. The strength stability of Seaglider due to sea head wave is yet to be determined which is vital to ensure that the Seaglider is able to deliver its data safely without any malfunctions. The objectives of this thesis are to conduct the strength stability of Seaglider to head sea wave and to compare strength results with previous researcher. The method approach that is used for this thesis is by utilizing SeaFEM Compasis software in order to determine structural strength of Seaglider and also simulate sea waves acting upon the hull of Seaglider. Stress and displacement experienced by the Seaglider during structural analysis are to be compared with the dynamic pressure from the seakeeping analysis. This is to ensure that the Seaglider is able to withstand the pressures generated by sea head waves acting upon its hull. Based on the findings from structural and seakeeping analyses that has been carried out, the Seaglider has the required structural stability in order to withstand the pressure generated by the sea head waves while it is operating at sea. This is determined by comparing results from the structural analysis with the seakeeping analysis. The von misses stress and displacement experienced by the Seaglider at sea level was calculated and compared with the calculated dynamic pressure produced by sea head waves. The value of von mises stress was lower than the dynamic pressure generated by sea head waves which rendered the Seaglider an adequate strength stability due to sea head waves. Besides that, the values of von mises stress, displacement and dynamic pressure of sea head waves were compared with other researches and the values were in line with each other and still within the acceptable margin.

Keywords- Seaglider, Sea Head Waves, Structural, Seakeeping

I.INTRODUCTION

A Seaglider can be described as a vehicle that has a pressure hull that is enclosed by a fairing made from fiberglass in which the wings, rudders and trailing antenna are combined to. The design of this operations involved. A low-drag vehicle shape which includes a pressure hull is chosen due to fact that it is almost neutrally compressible in seawater, the low-drag shape combined with a pressure hull inspired the fairing-hull configuration. Seaglider's wings has a wingspan of 1m had to be positioned aft of the total body diameter where the two-part fairing is joined [1]. It is essential to determine its structural strength stability as this AUV operates from a far in sea water depths up to 1000m. It is critical to evaluate the structural integrity of the AUV, since it works in water that is deep under the surface at a depth of 1,000 metres. Seagliderutilises a GPS antenna-mounted mass for sending and receiving signals, which are routed via the antenna's mass through Iridium Satellite Communications. Its transmission and reception speeds are 180 byte/s net and the power consumption is 35 J/Kbyte [2].

The Seaglider operates like other AUVs using the saw tooth profile seagliders fly permits them to cover a monumental distance, staying in the field for quite a long time to months all at once. This low-energy, low-commotion, high endurance strategy for propulsion makes autonomous underwater gliders and stages like them, undeniably appropriate for long periods of ecological examinations. During these long periods of deployements, Seagliders independently gather information on the encompassing water segment, which includes salinity levels, oxygen content and temperature. The delivery of this information renders the operator a clearer picture on the health of the biome [3].

II.OBJECTIVES

There are two main objectives of this study which is to conduct strength stability of sea glider due to head sea wave using SeaFEM along with comparing the structural and seakeeping results with previous researchers.

III.SCOPE OF STUDY

In this final year year topic, the scope of study will only be focused on the structural strength stability of the Seaglider which is one type of AUV like the Slocum and Spray. The study regarding the structural strength stability of Seaglider proposed is only limited to the strength of the Seaglider’s body/hull towards sea wave only and not including other types of waves that are not at sea. For this study, two types of simulations will be conducted in which the first simulation tests the Seaglider’s hull in seakeeping analysis. In seakeeping analysis, the Seaglider will be tested against the sea waves while it is floating at sea. The second simulation would be a structural analysis whereby the Seaglider’s hull is tested against forces and pressure assigned to it to measure the stress and displacement of the material used by Seaglider.

IV.PROBLEM STATEMENT

The Seaglider is an automated underwater vehicle (AUV) which operates at depths as deep as 1000m which needs a hull that is strong enough to withstand the pressure at great depths. When the Seaglider has completed its cycle in a saw tooth pattern, it will resurface and pitch forward which tilts its antenna mast to send information gathered in sea depths to a satellite. In this condition, this AUV is floating on sea water and experiencing force exerted by sea head waves onto the body/hull of Seaglider. This has led to the proposal this final year project in which the stress and displacement of Seaglider’s due to sea head wave is to be determined because very little to no study has been made regarding Seaglider strength stability due to sea head wave. Previous studies regarding Seaglider only considered the structural and hydrodynamics analysis of the AUV without including any pressure, stress and displacement caused by sea waves.

V.PROJECT METHODOLOGY

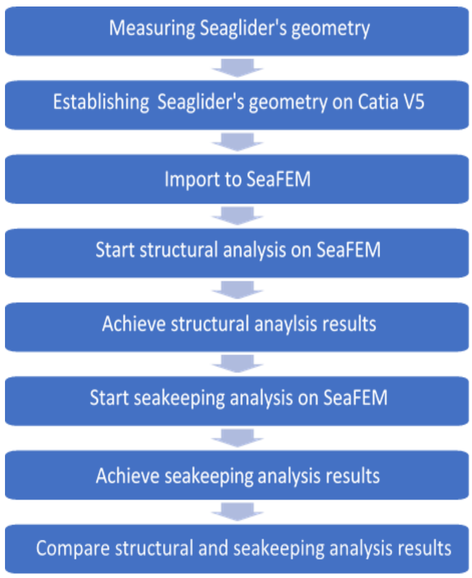

Figure 1 Project methodology process flowchart.

Catia V5

Catia V5 is used to create the Seaglider’s geometry based on design and measurement reference from

[1],[6] and KornsbergSeaglider website but not every part of the Seaglider has specific measurements due to fact that some parts like the tail and wings are not specified in all of the design references stated earlier. An educated guess and proper scaling ratio had to be made in order to compensate the lack of detailed measurements on the tail and wings of the Seaglider. There a few steps involved in the creation of Seaglider's geometry After opening Catia V5, choose part design and name the part as 'Seaglider' and save it. Next, from the start tab choose mechanical design then part design. Next, choose yz plane to sketch on in which the first circle is created which is the largest diameter of Seaglider at 30cm. Then from there, several other offset planes with a specified distance from each other will be created along the y axis according to the length of 1.8m-2m and shape of Seaglider.

Circles will be created on the offset planes along the y axis based on the diameter at different sections of Seaglider. Afterwards, procced to exit workbench then select multi-section solids then select the circles created on the offset planes one by one from the tail until the tip of the AUV. At this point, the geometry of Seaglider is padded and presented in 3-Dimentional form. From here, the tail section will be created by choosing the plane situated at the tail of Seaglider and create a centered rectangle at the center with a width of 1cm and 40cm length. Next, exit workbench then pad the centered rectangle with a 16cm definition.

Then, the select the surface of padded centered rectangle in the x axis to create a profile that matches of the Seaglider's tail design based on the design references in [1],[6] and KornsbergSeaglider website. When that is done, proceed with selecting the profile created earlier then pocket the centered rectangle at 1cm dimension and the desired tail shape can be obtained. Next, select a plane on either side which is around 1/3 or 67cm from the tail of Seaglider then create a new angle plane with a z axis rotation at 90deg. Afterwards, create a centered rectangle at the center of the chosen side with 20cm in length and 1cm in width.

Then pad the centered rectangle 35cm in reverse direction from the hull of Seaglider which now has a surface in the z-axis. Select the surface in the z-axis then create a profile that matches the shape of the wing on the design references mentioned earlier. Then, exit the workbench then select the profile created and pocket the it at 1cm dimension. The steps are repeated for the other wing of the Seaglider as it is identical with the one created.

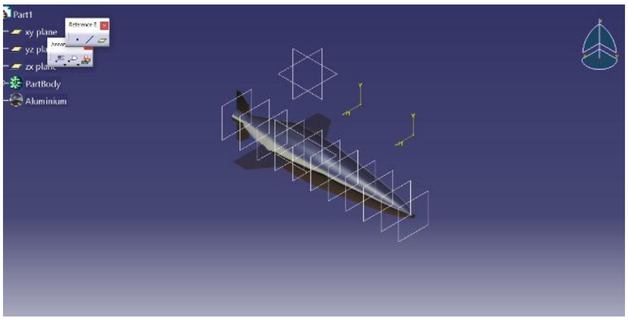

Figure 2 Completed Seaglider geometry on Catia V5

Sea FEM

Structural Analysis - The Seaglider geometry in CATpart.file format created in Catia V5 earlier is then converted imported into SeaFEMCompasis into an IGES.file. Then, the imported geometry is selected to be tested in the Structural analysis. A few parameters are set first under the seakeeping analysis before proceeding with the creation of boundary conditions. The first parameter to set is under the pre data tree tab then then choose Tdyn Data tab which then will reveal Contraints option in which the Fixed constraints is selected to whole Seaglider geometry. Afterwards, under the Materials and Properties, then Shells and select Isotropic shell and choose Aluminum as its material with the thickness of 0.01m. Next, choose Orthopic shell and choose E_Glass_Epoxy_Ortho with thickness of 0.01m.

Next, under the Loadcases option choose Loadcase 1 then Shells and then pick Pressure load with factor of 1. For the current purpose of this study, only Pressure load is selected and considered to act upon the Seaglider. After completing the Tdyn Data, the Seaglider geometry is then meshed using the mesh tab under Generate mesh. Next, proceed with the calculation process under the calculate tab which then will be proceeded with the postprocess. In postprocess, the results of the Pressure load acting upon Seaglider is then represented in contour.

Seakeeping Analysis - Afterwards, the Seaglider geometry in CATpart.file format created in Catia V5 earlier is then converted imported into SeaFEMCompasis into an IGES.file. Then, the imported geometry is selected to be tested in the seakeeping analysis. A few parameters are set first under the seakeeping analysis before proceeding with the creation of boundary conditions and analysis area. The first parameter to set is under the pre data tree tab then then choose Tdyn Data tab which then will reveal General the endata in which the environment is set to only waves and type of analysis is set to seakeeping.

Next, under the results options, select all options available on under general, loads and kinematics. Then, the problem description option is set to infinite depth and the environment data option is set to waves. The time data is maintained while the mooring data is not included because mooring is not included in this study. Next, the body data, numerical data and boundary conditions options are not set yet and will be set later after the geometry and boundary conditions has been created. After that, under the file tab select the import the Seaglider geometry file in the form of IGES.file into SeaFEM Compasis.

Then, open the pre data tree, under the layers tab create a new layer then create a circle geometry under the geometry tab. The circle would be situated at the center of the Seaglider with a radius of 10m. Then create another layer and this time create another cylinder geometry at the center of the Seaglider with a radius of 100m and the height of -100m. Afterwards, under the tdyn Data tab select the body data option then select only the Seaglider and from there, select the body data 1 and right click to draw groups. On the body data 1 tab, insert the mass as 52kg and unselect all six degrees of freedom for the purpose of this study.

At the current stage, selecting all of the degrres of freedom will not allow the geometries to be calculated and analyze. The next step is to proceed with the boundary conditions in which for this case only Free surface and Outlet parameters are selected. The Free surface is chosen by clicking on the lines that is at the surface of the Seaglider/geometries created at position 0,0,0. Outlet parameter is chosen by selecting the lines that act as the perimeter of the geometries. After completing the parameters on the Tdyn Data, continue with generating mesh using the smallest option of meshing possible of the geometries under the mesh tab. After mesh is successfully generated, continue with calculating the meshed geometries under the calculate tab. After waiting for a while, proceed with the postprocess to visualize the results like the the dynamics pressure and total pressure on the Seaglider in contour form.

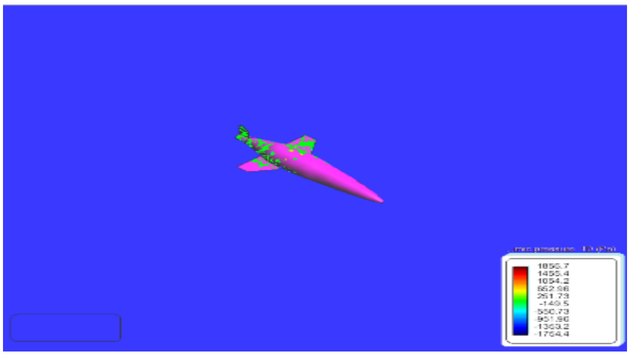

Figure 3Seagliderseakeeping analysis on SeaFEM

VI.RESULTS AND DISCUSSIONS

Structural analysis

In this chapter, the results for both analyses that has been carried out are presented and discussed. The analyses carried out are:

I. Structural analysis
II. Seakeeping analysis

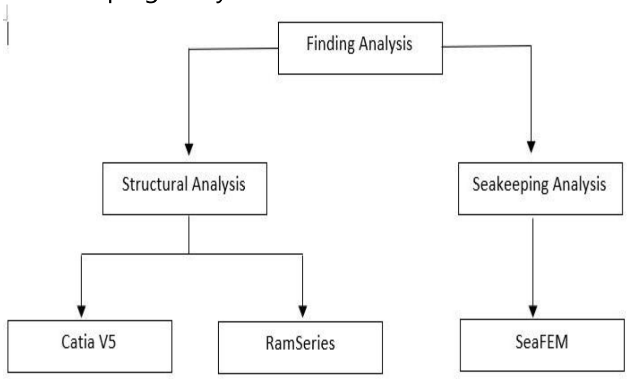

Figure 4 Flowchart of analysis process

Table -1 Structural Analysis of Seaglider

Seaglider's Depth, (m)	Pressure Applied, (Mpa)	Von mises stress, (Mpa)	Fatigue Strength, (Mpa)
0	0.101325	0.10349	1.79e-5
500	5.06	12.3	8.95e-3
1000	10.53	25.6	1.86e-2

Table -2Aluminium T-6061 Properties

Young's Modulus, (Gpa)	Tensile Yield Strength, (Mpa)	Ultimate Tensile Strength, Mpa	Fatigue Strength, (Mpa)	Shear Modulus, (Gpa)
68.9	276	310	96.5	26

According to [4], the properties of aluminium T-6061 that had been tabulated in Table 2 were to be compared with the von misses stress and displacement of Seaglider. The pressures applied on the Seaglider were in accordance with its depth at sea. In this study, only the Seaglider's strength stability due to sea head wave was to be determined. Thus, the von misses stress and displacement at the levels were the main values to be calculated.

Due to the fact that, no study has been made regarding Seaglider's strength stability due to sea head wave, the values of von mises stress and displacement at 1000m were compared with results gathered by other researcher. According to [5], the values of von misses stress and displacement for a Seaglider with an aluminium T-6061 hull were 109 Mpa and 0.0279 mm in which the von misses stress exceeded the fatigue strength of aluminium. Based on my calculations, the values for von mises stress and displacement were at 25.6 Mpa and 0.0186 mm.

There was not much difference in the values of displacement but the difference was noticeable in the von mises stress. The von misses stress calculated by [5] may had some errors because it had exceeded the fatigue strength of aluminium. Fatigue is a type of cracking that occurs when loads are applied repeatedly. These stresses must be tensile or stress reversal (a cycling back and forth between tension and compression) [6].

A seaglider has been proven capable to operate and carry out its operations at depths of 1000 m in a saw tooth pattern and is able to withstand pressures more than 10 Mpa according to [1],[2]. This proved that the von misses stress should be at a value that is lower than the fatigue strength of aluminium as it was not possible for the Seaglider to operate for months at a time if its fatigue strength had been exceeded.

Sea keeping analysis

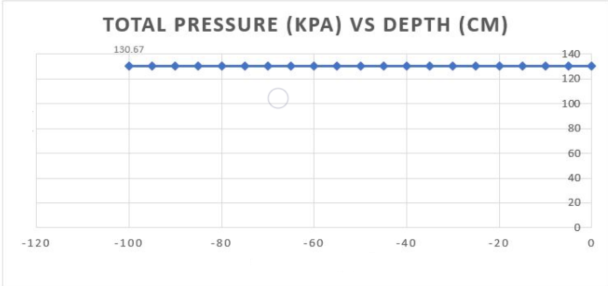

Chart -1: Total pressure vs Depth.

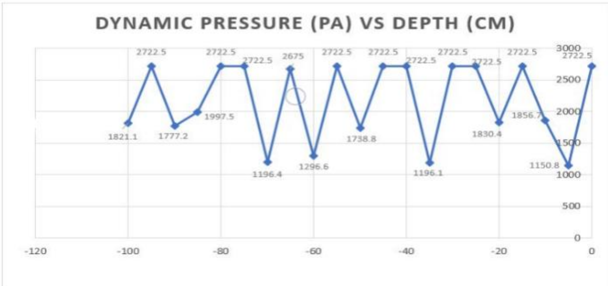

Chart -2: Dynamic pressure vs Depth.

Based on [7], the results gathered from three sensors that were installed at different locations on the ship hull, the wave impact can be translated into readings in pressure, Pa. The minimum and maximum pressure caused by sea waves readings for the three sensors were at 1.51kPa and 4.94kPa respectively. The pressures of wave impact on the ship hull were mostly around 2.16kPa to 3.65kPa. Based on Table 4, the minimum and maximum dynamic pressure of sea waves were 1.20kPa and 2.72Kpa respectively.

This indicated that the dynamic pressures obtained on Table 4 were within the acceptable pressure range gathered by the three sensors in the study conducted by [7]. On Table 4, the dynamic pressure started at 2.72Kpa and finally dropped to 1.82Kpa as the depth decreased. A decrement of 10cm depth was chosen to measure the dynamic pressure of sea waves onto the Seaglider. The dynamic pressure fluctuated in a wave form at 0cm until -100cm but finally decreased from 2.72kpa to 1.82kpa. The dynamic pressure decreases over time as the depth decreases. This may be caused by the decrease in the orbital motion as the depth decreases.

Circular orbital motion is the motion in which water passes the energy in a circle that is carried by the wave as it travels like in Figure 5. When the depth of sea water reaches a point below the sea level, the circular orbit movement will diminish to a point until it is negligible. This depth is known as wave base which can be represented as one-half the wavelength (*l/2)* that is measured from still water level. Wave base's depth is solely determined by the wavelength, so if the wave is longer the water base becomes deeper.

The decline of orbital motion with depth contributes to various deep-water applications that includes ships, submarines and etc. For instance, large ocean waves are able to be avoided by submarines when they fill up their ballast tanks and submerge under the wave base. Massive storm waves can even be evaded when a submarine dives down at only 150m under sea level [8]. Water waves have two types of energy which are kinetic energy which originated from moving particles and potential energy from the water's vertical position relative to the mean level. The entire amount of energy is proportional to the square of the wave height and is proportional to the square of the wave height kinetic and potential energy are split.

The potential and kinetic energy of a wave that is higher than still water level will be greater as compared to a wave lower than still water level [9]. When a wave travels below the still water level, the energy passed through the sea water in an orbital motion will be less resulting in the decrease of force generated by sea waves. As the force produced by sea waves decreases, the dynamic pressure caused by head sea waves would also decrease. Since Seaglider glides in a saw tooth pattern at depths up to 1000m, it can be interpreted that it shares the similar operational mechanism as a submarine does which makes a Seaglider less susceptible to sea waves as it moves down the still water level. Based on the results on Table 4, it can be interpreted that the dynamic pressure produced by sea waves decrease with depth due to the decrease in potential and kinetic energy generated by orbital motions of sea waves.

Conclusion

Based on the simulation results for both structural and seakeeping analysis that has been gathered, the results obtained via utilizing SeaFEM software were comparable with previous researchers. The structural analysis results which were von misses stress and displacement obtained were within the range of values obtained by [5]. Besides that, the results for seakeeping analysis which was dynamic pressure caused by head sea waves was comparable with results gathered by [7]. The strength stability of the Seaglider due to sea head waves was determined by means of obtaining the structural and seakeeping analysis and comparing them.

From the structural analysis, the von misses stress obtained at sea level was 0.10349 MPa and 25.6 Mpa at 1000m deep which translates that the Seaglider possesses the adequate structural stability the operational depths between 0m (sea level) to 1000m. From the seakeeping analysis, the dynamic pressure caused by sea head waves were ranged at 1.82 Kpa and 2.72 Kpa which were far from reaching the tensile yield strength. It can be said that the Seagldier has the required structural stability to withstand the head sea waves when it is delivering data at sea level and also performing its dives up at 1000m below sea level.

Based on the findings in regards with the structural and seakeeping analyses results, the Seaglider is indeed able to operate smoothly without facing any breakdowns that is caused by fatigue due to the stresses acting upon it repeatedly. It is able to glide in a saw-tooth pattern at depth between 1m to 1000m below sea level while it gathers data like water salinity, chlorophyll levels and temperature at sea. Besides that, the Seaglider is able to withstand the sea head waves acting on it while it is floating at sea level when it is transmitting data from its internal hard drive to the satellite via its antenna mast.

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