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STRENGTH ANALYSIS OF SEAWEED CULTIVATION MODULE

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Introduction

Seaweed is widely cultivated and eaten in Asia, sugar kelp (*Saccharina latissima*) is nutritious food that is rich in fibre, vitamins and minerals. It is used in dishes like *sushi, soups, salads* and many other products. Sugar kelp is a marine algae, also known as sea belt and Devil's apron due to its shape. It can grow up to 12 feet long. When dried, a white sweet-tasting powder forms on the frond. Long known as a sweetener and as a thickening and gelling agent that can be added to food and cosmetics, sugar kelp is being grown and harvested by various commercial firms for a variety of uses, from food to potential biofuels [1]. The spores grow into small plants less than one-tenth of an inch in size along string wound around a piece of a PVC pipe.

The article presents an attempt to a new approach in seaweed cultivation that is carried out by a company UAB *Metal Production* in Lithuania. In the article we investigate how the module made of PE80 will work under given conditions. The aim is to study the design of seaweed cultivation module, determine its stresses and displacements with finite element analysis system *Solidworks Simulation*.

Fig. 1. Seaweed Kelp [1]

Seaweed cultivation module

Seaweed cultivation module dimensions are 5980×4082×5418 mm (L × W × H) excluding the bottom ropes (see Fig. 2). polyethylene pressure pipe PE80-SDR11 is used for the seaweed cultivation module. Polyethylene has the simplest molecular structure of all polymers. It consists of two carbon and four hydrogen atoms in the basic repeating unit [2]. Main mechanical properties of PE80 are presented in Table 1.

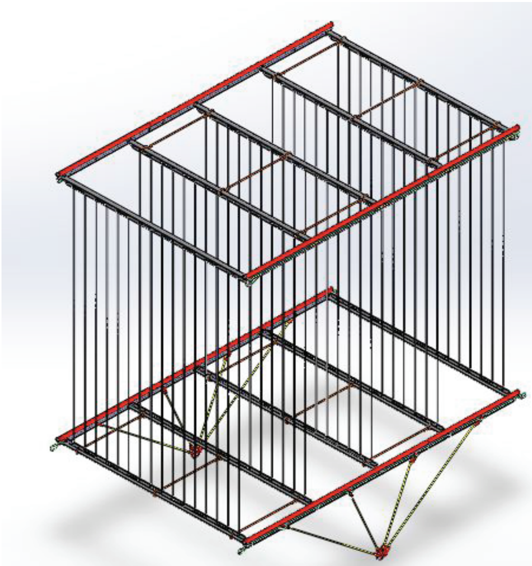

Fig. 2. Isometric view

Table 1. ***Main mechanical properties of PE80***

Property	Standard	Unit	Value
Density at 23 °C	ISO 1183	g/cm^3	0.94
Modulus of elasticity	ISO 527	MPa	750
Tensile strength at yield	ISO 527	MPa	20
Elongation at yield	ISO 527	%	10
Elongation at brake	ISO 527	%	>600

High density polyethylene (HDPE) is a type of linear polyethylene with a density range from 0.94 to 0.97 g/cm^2 as per ASTM D883. HDPE exhibits high strength and modulus. Thus, it is preferred for use in the manufacture of plastic pipes [3]. It is known that PE80 strength reduces over a period of 50 years at different temperatures. For current application sea water temperature considered is 20° C and the stress is reduced from 10-11 MPa to 8 MPa over a period of 50 years as recommended in [4]. Analysis is produced with the lower frame of the module because it sustains bigger hydrostatic pressure (the 3D model created with *Solidworks* is presented in Fig. 3).

Fig. 3. Isometric view of the structure under analysis

Numerical modelling and results

Numerical modelling of reinforced thermoplastic pipes under buckling, bending, external pressure and combined loading is presented in the papers [5-7]. The pipe is modelled as a cylindrical shell and material nonlinearity is evaluated. Seaweed cultivation module plastic pipe frame structure is modelled as solid. Finite element analysis is made taking into account maximum immersing depth of 30 m. Reference geometry fixture is considered and applied on the holes with reference to top plane and displacement is allowed in Y direction which is normal to plane. Roller slider fixture is considered and applied on the holes where structure is allowed to slide. Reference geometry fixture is also considered and applied on the two faces with reference to top plane and displacement is allowed in X and Y-direction which is normal to plane. Very fine mesh is applied to the structure and mesh control is applied to some parts taking into consideration the holes and extrude cut in the module. Load due to gravitational force is considered and applied on the selected faces, as well as hydrostatic pressure load (see Fig. 4):

$$p = \rho g h, \tag{1}$$

where
p – hydrostatic pressure, Pa;
ρ – density of water, kg/m^3;
g – acceleration of gravity, m/s^2;
h – height of water column, m.

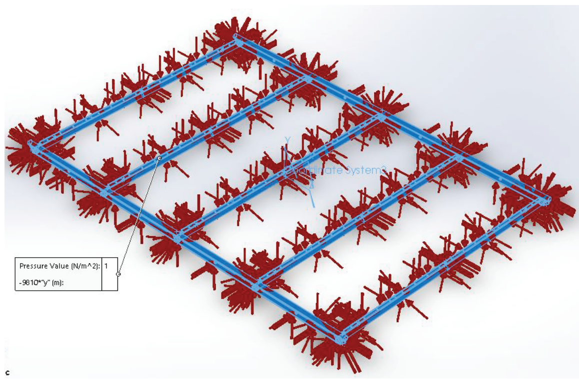

Fig. 4. Loads applied to the Structure

Stresses and displacements of the module at 30 m depth are presented in Figures 5 and 6. Maximum Von Mises stress induced is 4.97 MPa and maximum displacement is 46.4 mm. We use the yield strength as allowable stress, so the factor of safety is 4.

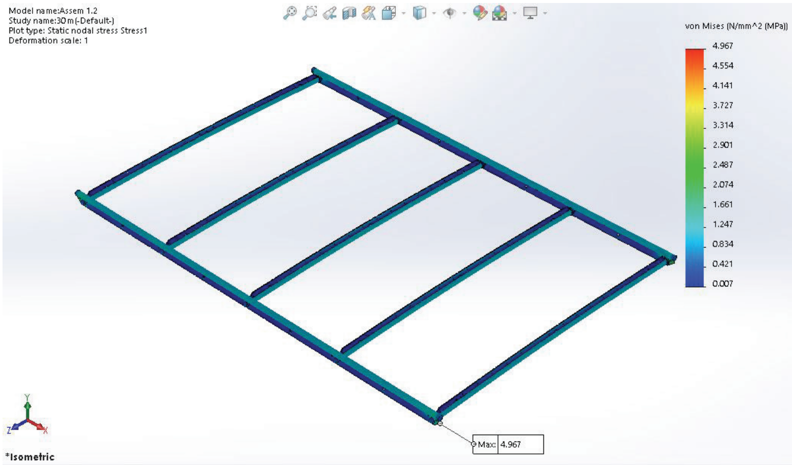

Fig. 5. Stress of the module in still water

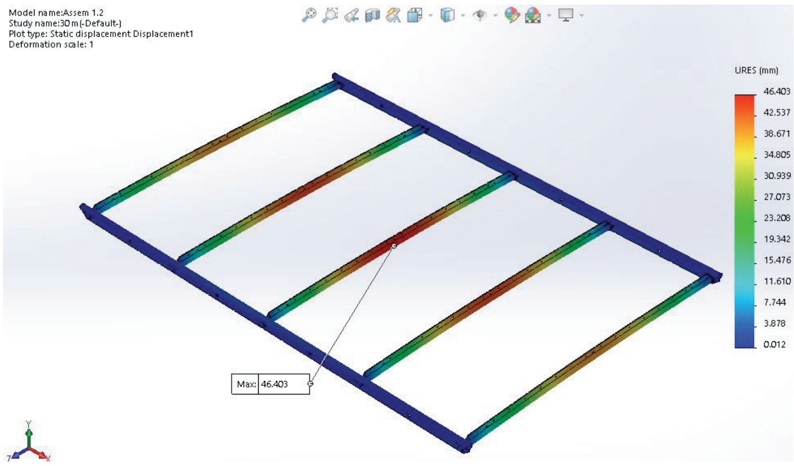

Fig. 6. Displacement of the module in still water

Additionally, the influence of water flow (1.3 m/s) is taken into consideration. *Solidworks Flow Simulation* is used for analyzing the effect of flow and calculating forces acting on module elements. The distributed values of the forces are applied to the surfaces of flat faces and tubes and numerical analysis was repeated with them. The results are shown in Figures 7 and 8. Maximum Von Mises stress and displacement rise up to 7.9 MPa and 107 mm respectively. In this case the factor of safety is about 2.5.

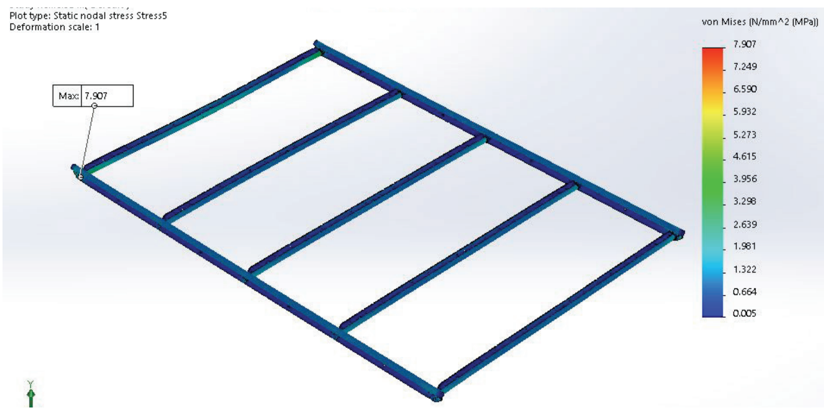

Fig. 7. Stress of the module in flowing water

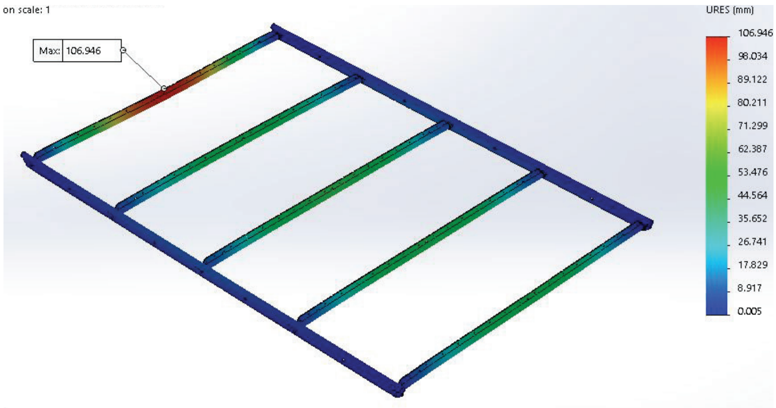

Fig. 8. Displacements of the module in flowing water

Conclusions

1. PE80, the selected material for module can sustain stress and displacement without any failure. Safety factor of the structure at 30 m depth without water flow is about 4 and with flow is about 2.5.
2. High stresses occurred places are not at critical points. They are at corner edges and holes which can be reduced by applying fillets. The stresses for the whole structure are low and within the limits.
3. After obtaining and comparing the results of influence of flow with velocity to results without influence of flow, it is observed that there is a 59 % rise in stress and 130 % rise in displacement.

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Summary

STRENGTH ANALYSIS OF SEAWEED CULTIVATION MODULE

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This paper is an attempt to a new approach in seaweed cultivation module that is carried out by a company UAB Metal Production in Lithuania. The article is concerned with how the module made of PE80 works under given conditions. The aim was to study the design of seaweed cultivation module, determine its stresses and displacements with *Solidworks Simulation*. The maximum depth of immersion up to 30 m is considered, as well as influence of seawater flow. It was determined that the module is designed within the factor of safety limits.

Keywords: *Seaweed cultivation module, FEM, PE80 strength.*

Santrauka

JŪROS DUMBLIŲ AUGINIMO MODULIO STIPRUMO TYRIMAS

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Straipsnyje nagrinėjamas jūros dumblių auginimo modulis, kuris buvo suprojektuotas Lietuvos įmonės UAB „Metal Production“ konstruktorių. Buvo išstudijuota modulio konstrukcija, išsiaiškinta medžiagos (PE80) elgsena, esant pasirinktoms eksploatavimo sąlygoms. Naudojant baigtinių elementų analizės sistemą *Solidworks Simulation*, buvo nustatyti konstrukcijos įtempiai ir poslinkiai. Pasirinktas maksimalus modulio panardinimo gylis – 30 m, taip pat įvertintas ir jūros srovės poveikis. Buvo nustatyta, kad modulis yra suprojektuotas su tinkama atsarga.

Prasminiai žodžiai: *dumblių auginimo modulis, BEM, PE80 stiprumas*.

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