Composite Structures 170 (2017) 146–157

Contents lists available at ScienceDirect

Composite Structures

journal homepage: www.elsevier.com/locate/compstruct

Damage prediction of horizontal axis marine current turbines under hydrodynamic, hydrostatic and impacts loads

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ARTICLE INFO

Article history:
Received 27 February 2017
Accepted 6 March 2017
Available online 8 March 2017

Keywords:
Renewable marine energy
Composite materials
Current turbine
FEA
Dynamic behavior
Damage criteria

ABSTRACT

Marine energy is one of the most exciting emerging forms of renewable energy. Tidal turbines are used to extract this energy and installed on the seabed at locations with catastrophic loading. The present paper employs the finite element method to simulate the behavior of GRP composite nozzle of a tidal turbine under low-velocity impact with implementation of a failure criterion. To investigate this situation, a parametric analysis is conducted which deals with the effect of velocity, energy and geometry of the impactor. The mechanical behavior has been analyzed as both kinematic effect due to deflection of the composite structure and dynamic effect caused by the interaction between the impactor and the hydrodynamic and hydrostatic pressures over the loading. The stress and the deformation distribution are presented. On the other hand, damage modeling was formulated based on Hashin criteria for intra-laminar damage. The effects of the impact velocity and the panel's flexibility on the initiation and propagation of damage have been investigated.

1. Introduction

The kinetic energy available within tidal currents is an untapped source or renewable energy [1]. If an effective method of capturing this energy can be developed, tidal currents could be harnessed to help satisfy the world's growing energy needs. Several studies have shown that marine currents have a large potential as a predictable sustainable resource for generation of electrical power [2,3]. Horizontal axis marine current turbines are one favorable technology that is being developed for this purpose.

Generally, the marine industry interests in the use of marine current turbine for electrical power production. The ability to predict the dynamic behavior of these turbines is essential for the design and analysis of such systems.

In use, the nozzle of a tidal turbine can be prone to accidental impact. This phenomenon may be large enough to cause damage in the composite materials. Damage modeling [4] of light weight structure is an active challenge in many applications such as marine, aerospace and naval fields. However, these structures are very susceptible to degradation of their properties and consequently a catastrophic failure can occur with more than one damage modes [5].

This investigation registers as part of research works which aims at the numerical modeling of the composite behavior under dynamic loads for naval applications. This research axle is of a big importance in various domains following the example of renewable marine energy. In this respect composite materials play a central role in the development of renewable marine energy conversion systems such as turbines.

Today, large tidal turbine blades are almost all made of glass fiber reinforced polymer (GFRP) because it currently represents the best way to strike a balance between performance, weight and structural integrity [6], because the marine environment is particularly require and aggressive (corrosion due to salt, forces of the currents and storms. In this context we used this composite material to analyze the structural integrity of the nozzle. The advantage of GFRP composites is that they relatively inexpensive and provide sufficient strength and stiffness. However, as the turbines size increases, carbon fiber reinforced polymer (CFRP) becomes more popular for developing some parts of the blades and/or the nozzle, such as spar caps and some critical areas such as the trialling edge according to the FEA simulation. On the other hand, carbon fibers normally cost 10–20 times more than glass fibers. In fact carbon fibers provide a much higher modulus and significant weight reduction. Finally GFRP material was selected as a compromise between cost and performance.

In order to meet the needs of the manufacturers of tidal current turbines, which is generally linked to a problem of mass

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http://dx.doi.org/10.1016/j.compstruct.2017.03.015

gain, composite materials present a considerable asset on account of their excellent «mass/resistance» and «mass/rigidity» relations. A structural design of ducted tidal current turbines using composite materials has therefore been examined. The duct of the tidal current turbine is especially confronted by the impacts due to its particular position. The impact damage aspect has also been examined in detail in the present research study.

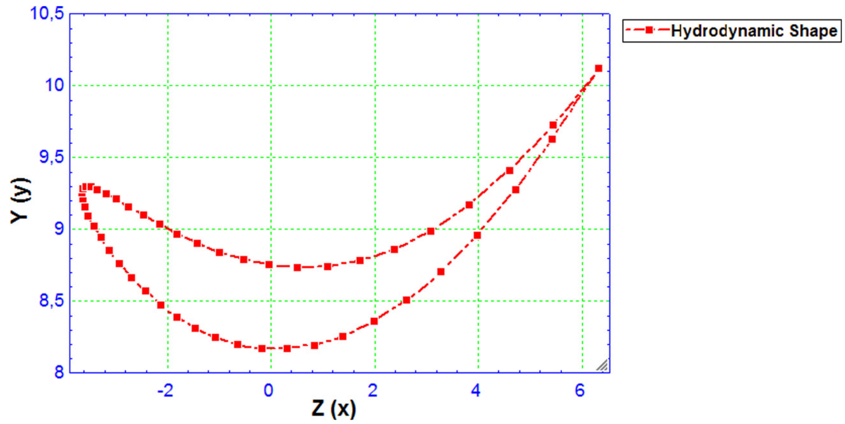

Fig. 1. Hydrodynamic profile.

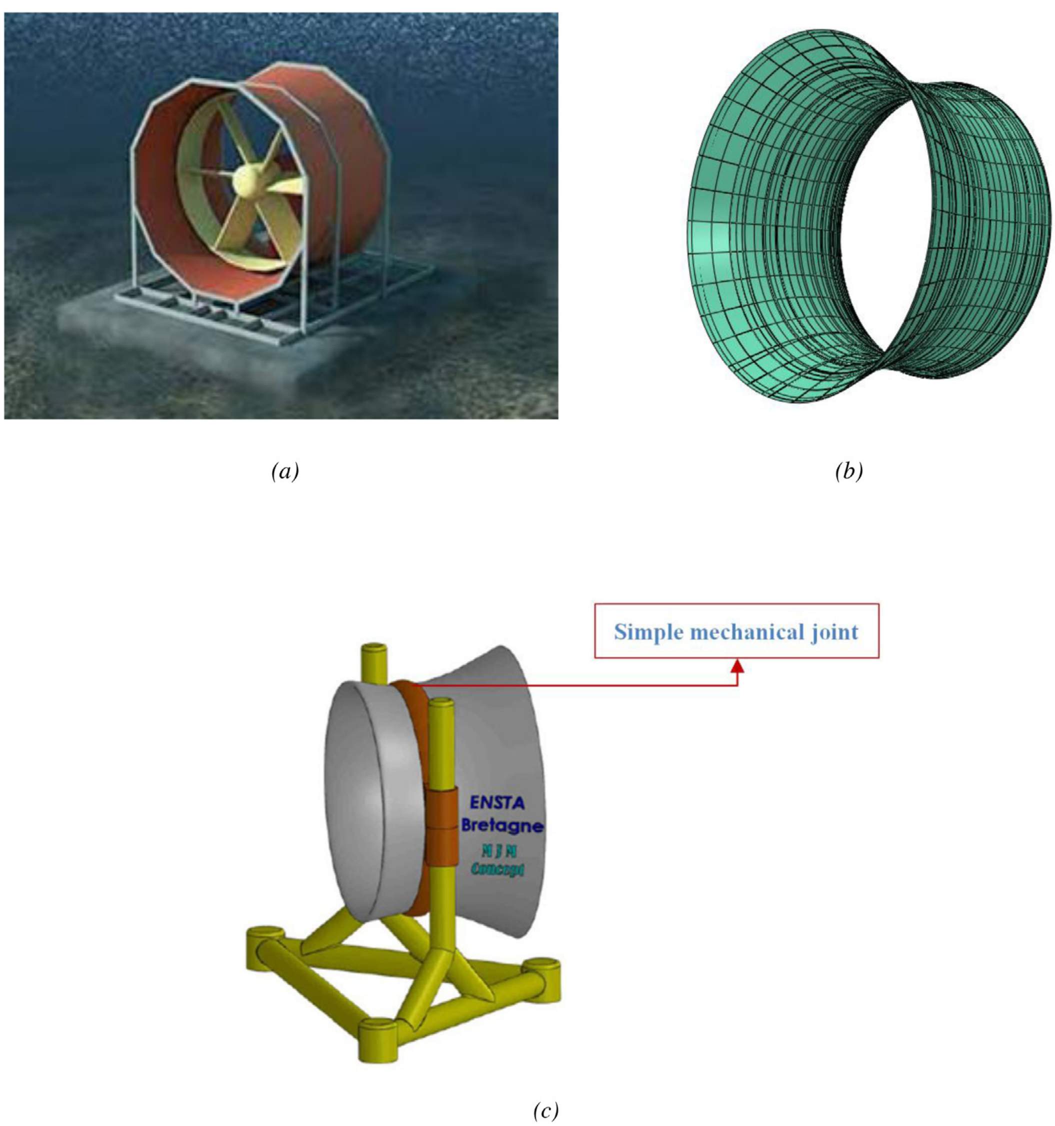

Fig. 2. Marine turbine: (a) real turbine, (b) simulated case and (c) final design.