Parametric Excitation of Mooring Cables for Submerged Floating Tunnels

Daniel CANTERO
Postdoctoral researcher
Norwegian University of Science and Technology
Trondheim, Norway
daniel.cantero @ntnu.no

Daniel Cantero, born 1981, received his civil engineering degree from the Univ. of Granada (Spain) and his PhD at University College Dublin (Ireland)

Anders RØNNQUIST
Professor
Norwegian University of Science and Technology
Trondheim Norway
anders.ronnquist @ntnu.no

Ander Rønnquist received his PhD in bridge dynamics and since 2009 is member of the structural dynamics group at the Norwegian Univ. of Sci. and Techn.

Arvid NAESS
Professor
Norwegian University of Science and Technology
Trondheim, Norway
arvid.naess@ntnu.no

Arvid Naess received his MSc in technical physics, his PhD in mathematics and Dr.techn. in civil eng. from the Norwegian Univ. of Sci. and Techn.

Summary

The ferry links crossing the fjords along the west coast of Norway are going to be replaced by fixed links. Among the proposed solutions is the construction of Submerged Floating Tunnels (SFT). A mooring system should be used to restrain the movements of these floating structures. Long period waves, such as swell waves, parametrically excite the system and might result in excessive vibrations in the cable. This paper presents the equations of motion of the mooring line and derives an analytical expression, which allows for a quick identification of the system's stability. This expression is obtained through the Harmonic Balance Method (HBM) with two harmonic terms. The contribution of multiple modes of vibration is investigated for the case of small sag to span ratios. The expression is compared with the results from a numerical model, revealing the applicability of the proposed formulation.

Keywords:dynamic; cable; mooring; parametric resonance; submerged floating tunnel.

1. Introduction

The Norwegian government has decided to eliminate all ferries along the coastal highway E39 in order to reduce travel time and boost local economy. This route crosses several fjords and there are currently eight ferry connections in operation to cross them. These crossings are characterized by great widths (up to 5 km) and depths (up to 1 km) where non-conventional engineering solutions will be necessary. One of the proposed solutions is the construction of Submerged Floating Tunnels (SFTs), that, when built, will be the first of its kind worldwide.

An SFT is also called an Archimedes Bridge (AB) and was first proposed in 1886 [1]. Since then, studies have investigated the feasibility of this new concept and concluded that the necessary technology is available [2]. SFTs are essentially buoyant tunnels that float at certain depth in the water (Fig. 1). To avoid excessive movements, the structure must be moored or tethered. However, the dynamic behaviour needs special attention due to changes in water level [2].

Tethering systems have been extensively investigated and developed for tension leg platforms in the oil industry and are based on sea bed moorings designed to remain in tension throughout their operational life [2]. The main environmental loads in such a system will be those produced by waves. The waves with longest wave periods have the potential to affect structures at greater depths [1]. This is the case of swell waves that will affect the SFT and its mooring system even at considerable depths. This low frequency excitation produces a parametrically excited system. Small parametric excitations might lead to parametric resonance or dynamic instability that causes excessive vibrations of the mooring cable and the SFT even at frequencies away from the natural frequencies of the system.

Parametric Excitation (PE) has been extensively studied in the field of differential equations and dynamic systems, [3] being one representative example. In bridge engineering this phenomenon has often been reported in cable stayed bridges [4] when girder or mast oscillations parametrically excite the cables. Similarly, in offshore platforms, parametric instability is an important aspect in

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