Study of tension in mooring cables under parametric excitation for submerged floating tunnels

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Abstract

The coastal highway E39 project in Norway is considering the construction a Submerged Floating Tunnel (SFT). Some of the preliminary designs use a mooring system to maintain the structure in the prescribed position. The main environmental load in such a system will be long period swell waves. This low frequency excitation produces a parametrically excited system. Certain situations might lead to parametric resonance or dynamic instability that causes excessive vibrations of the cable and the SFT. However, it is unclear how parametric excitation affects the cable tension of a mooring system. Correct design should avoid excessive forces that might break the line or very small forces that lead to momentarily slack cables. The aim of this paper is to assess the validity of using the stability charts for the design of mooring lines with respect to safe levels of cable forces. This is achieved through the numerical analysis of a cable model using Abaqus. Cable vibrations and cable forces are analysed and compared for a range of amplitudes and frequencies of the support motions. Also the dry and submerged cases are compared, clearly exposing the repercussion of the hydrodynamic effects.

Keywords: dynamic, cable, mooring, parametric resonance, submerged floating tunnel

1 Introduction

The coastal highway E39 project in Norway plans to replace several ferry connections crossing the fjords with fixed links. 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 a Submerged Floating Tunnel (SFT), which essentially consists of at watertight tube that is floating at a certain depth in the water. This type of structure has also been called submerged floating tube bridge or Archimedes bridge. Depending on the floatability of the tunnel, the position of the tube in the water has to be fixed either using pontoons or by mooring it to the seabed. In this paper, the vertically moored tunnel variety is studied. This typology has no visual impact and reduces the risks of ship collisions by placing the tube at a sufficient depth below the sea level. See an example of an SFT fixed by vertical mooring lines in Figure 1.

The idea of an SFT was first theoretically proposed already over one century ago. Since then, there have been a few attempts to materialize it. However, to this day, no such structure has been built. Thus, when finally built in Norway, it will be the first of its kind. Even if the engineering knowledge and the technology are available, there is an evident lack of experience designing, building and operating such a structure. For this reason, it

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