ABSTRACT

In 2002, several mooring chains of a deepwater offloading buoy failed prematurely within a very small time frame. These chains were designed according to conventional offshore fatigue assessment using API recommendations. With this first deepwater buoy application, a new mooring chain fatigue mechanism was discovered. High pretension levels combined with significant mooring chain motions caused interlink rotations that generated significant Out of Plane Bending (OPB) fatigue loading. Traditionally, interlink rotations are relatively harmless and generate low bending stresses in the chain links. The intimate mating contact that occurs due to the plastic deformation during the proof loading and the high pretension of the more contemporary mooring designs have been identified as aggravating factors for this phenomenon.

A Joint Industry Project (JIP), gathering 26 different companies, was started in 2007 to better understand the OPB mooring chain fatigue mechanism and to propose mooring chain fatigue design recommendations.

This paper summarizes the full scale fatigue tests on chains and also the tests on small samples addressing the environmental influence on fatigue initiation and crack propagation stages. This paper also addresses the major step that was achieved: the implementation of a multiaxial fatigue criterion to address OPB hotspots as a standard practice in offshore industry. Moreover, the paper presents the first Industry OPB based S-N curves and its comparison to the existing industry fatigue S-N curve. Lastly, this paper provides a summary of the main steps in a framework for OPB fatigue calculation guidelines.

INTRODUCTION

OPB of a chain link refers hereafter to the bending of a chain link out of its “main plane” (the plane containing the oval shape, see Figures 1 and 4). It is caused by the application of transverse forces and OPB moments which are resisted by frictional forces at the contact between links.

In Plane Bending (IPB) of a chain link is related to the bending of a chain link inside its “main plane”. This type of loading has also been considered within the frame of the project. This loading is however less severe for fatigue because the nominal stress related to IPB is approximately seven times smaller than the nominal stress related to OPB loading (in line with the bending inertia ratio). Both OPB and IPB fatigue loadings are experienced in addition to the conventional chain tension fatigue mechanism.

Under high pretension, the interlink friction is high and the moment to be resisted at the contact between links can be significant. This rather unusual loading condition for a chain link arises from the combination of high pretension load, as a percentage of Minimum Breaking Load (MBL), and poor articulation of the fairlead or chainhawse (chain connecting system with the floating body as shown in Figure 2). The alternating OPB stresses may be large enough to cause the fatigue crack propagation in the first moving link adjacent to the chain connection at the fairlead, and failure can occur rapidly. In the particular case of the first deepwater buoy (see Figure 2),