Transient effects of an FPSO with a broken mooring line

Aldo Roberto Cruces Girón1
Alberto Omar Vázquez Hernández1

Byoung Wan Kim2

José Alberto Martínez Farfán1
Hong Gun Sung2

1Mexican Petroleum Institute (IMP)
Mexico D.F., Mexico
2Korea Research Institute of Ships & Ocean Engineering (KRISO)
Daejeon, Korea

ABSTRACT

Breaking of mooring lines is a topic that must be analyzed during the design process of a floating production system. In current design codes this subject is treated as an accidental case. Nevertheless, transient effects after breaking of a line are not considered as relevant.

In this paper an analysis of the relevance of the transient effects, in taut-leg mooring line systems made of chain-polyester-chain in an FPSO with ultra-deep depth under severe storm conditions, is considered. Several coupled analysis in time domain in two ways were performed: 1) When a mooring line is absent since the beginning of simulation (with no transient effects); 2) Breaking a line during simulation (with transient effects).

KEY WORDS: FPSO; coupled analysis; broken mooring line.

ABBREVIATIONS

AMSL Above mean sea level
FPSO Floating, production, storage and offloading vessel
LBP Length between perpendiculars
MBL Minimum breaking load

INTRODUCTION

Oil production in deep waters has been carried out since a few decades ago. With lessons learned and new technology, the processes related with engineering and operation of oil production facilities have been continuously improved. Hull, risers and mooring lines are the main components of floating production systems. These elements are directly related with the global behavior of the floating system.

The mooring system has the function of keeping the platform in areas where it can operate safely. Therefore, the failure of any component may compromise the safety of the platform. However, even with the lessons learned and technological advances, recently there have been fail scenarios in mooring systems. These fails have occurred for various reasons, for example, manufacturing defects, damage during installation, weathering, corrosion, fatigue and out of plane bending (OPB) in chains. A collection of events during the last decade is presented in Majhi and D'Souza (2013) and Ma et al. (2013). Majhi and D'Souza (2013) state that, since 2000, at least 23 incidents of failure related to the mooring system have been documented, 4 of them have been catastrophic. They mention that the trend in the current practice of engineering does not meet operational performance. Even Ma et al. (2013) make a proposal to improve the design code API-RP-2SK and documents related to it.

Furthermore, Fontaine et al. (2014) mentioned that the increase in the number of failures occurred in floating production systems is proportional to the increased use of FPSOs. Many of the failures have been related to different topics, such as design, quality control of materials, installation and inspection/maintenance. Fontaine et al. (2014) reported that between failures occurred, 49% occurred in the operation phase, 22% during installation, 19% due to the design, 6% during construction and 4% for unknown reasons. Regarding the design of offshore structures it is common to analyze situations where any component fails. In the case of mooring systems, breaking of one or more mooring lines during this stage should be analyzed.

The breaking of a line is discussed in the design codes as an accidental situation. However, transient effects that occur after the failure are not considered as relevant. Even in the code API-RP-2SK (2005) this analysis is only recommended to check the motion of the platform (it is not necessary to assess the tension forces) for mooring systems excluding any of the next conditions: i) when one structure is near to other ii) in the case of drilling units where the sudden motion can cause damage to the drilling riser. On the other hand, in DNV-OS-E301 (2013) it is mentioned that the transient response or overshooting appearing immediately after the fail of a line can increment the tension forces of the remaining mooring lines, however, it is mentioned that it is very unlikely to occur in the presence of harsh environmental conditions with considerable excitation oscillatory forces.

When fail situations are analyzed in the mooring system, it is common that a line is not considered in the numerical model, in other words, the simulation is performed without the line. Thus, the platform motion and mooring lines tension are obtained, but without considering the transient effects.

In this paper, the importance of transient effects on an FPSO is investigated for harsh environmental conditions. The objective is to study the relevance of considering the transient effects during analyses of damage condition. The FPSO was studied with two mooring systems taut-leg type. The mooring system MOOR1 is one with 9 lines in a configuration with 3 in 3 groups of lines (3x3). On the other hand, the mooring system MOOR2 has 10 lines evenly distributed. For this purpose coupled analyses were performed.