Characterization of Self Exciting and Self Limiting VIV of Freely Oscillating Riser Pipes in Time Domain

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ABSTRACT

The ability to predict Vortex Induced Vibration (VIV), at least within engineering accuracy, is very important for deep water risers, flowlines, and wellheads. Uncertainty driven designs and operations cost the industry tremendously. Best practice synchronized perfect lock-in response calculations of VIV and VIM (Vortex Induced Motions) has brought new challenges to all subsea, umbilicals, risers, and flowlines (SURF) designs. A new simplified “Wake-Oscillator” model has been developed to characterize self-exciting and self-limiting nature of vortex induced vibration of transversely oscillating cylinders, in time domain. The model is then extended to capture fluid structure interaction due to inline motions and predict associated vortex shedding induced combined in-line and transverse vibration of a freely oscillating cylinder. This is a novel simple engineering type fluid structure coupling model which will provide time dependent force coefficients along the length of risers and flowlines, based on the characterization of self-exciting and self-limiting nature of VIV. A full direct time integration, using the time and space dependent lift forces, results in a more realistic vibration response amplitudes and frequencies including effects from all participating modes.

KEY WORDS: Vortex induced vibration; Self-Exciting; Self-Limiting; Reduced velocity; Mass-damping.

INTRODUCTION

The ability to accurately describe fatigue critical Vortex Induced Vibrations (VIV) of a freely oscillating cylinder with associated lift, added mass, and damping is very important for deep water risers and flow lines subject to current. Uncertainty driven unrealistically conservative designs and operations cost the industry tremendously. Therefore, the topic of understanding VIV physics and developing engineering prediction model for realistic vibration amplitudes due to vortex shedding has received continuous interest from experimental, analytical, and numerical researchers.

Flow of fluid around a cylinder and resulting vibration has been the subject of intense research efforts for several decades, and results are gradually evolving. Early works were mostly experimental focusing on understanding physics of formation of vortices, various associated parameters, and their influence on VIV. With the availability of increased computer power, recent efforts are concentrated in numerical simulations employing computational fluid dynamics (CFD) procedures along with experimental verifications. However, search for simple and efficient semi-empirical model continues. Primary reason for this is the fact that such a model can be used for flows with higher Reynolds’ number than it is practical in a CFD model.

Early VIV works were based on simple single degree of freedom (SDOF) model. These models attempted to represent VIV phenomena observed in laboratory experiments, commonly known as phenomenological (Wake-Oscillator) models. They were based on the idea that a self-exciting and self-limiting wake oscillates with the vibrating cylinder. Natural frequency of the oscillator is proportional to free stream velocity satisfying Strouhal relationship. Coupling of wake oscillation with the structure was through common terms in equations for both. A lot of effort has gone into transverse VIV alone with inline boundary fixed. Comparatively limited work has been performed to investigate the effect of inline motion on transverse VIV. Present work demonstrates that for practical riser designs VIV analysis should include coupling effects of inline motions.

VIV PROCESS

Extensive amount of information on the phenomena of VIV can be found in open literature. A brief summary of VIV process is depicted here to set the necessary background for a proposed new VIV model. The focus is on areas of VIV understanding which forms the basis of proposed model.

When fluid flows past a bluff cylinder, flow around the cylinder slows down. This is due to viscosity of fluid forming a boundary layer at the cylinder surface and abrupt changes in flow path. Boundary layers separate from the cylinder body at different angular positions depending on turbulences of the flow (characterized by Reynolds number). From the two shear layers on both sides of the cylinder vortices are shed alternately, with associated changes in pressure distributions around the cylinder surface. Thus, shedding of vortices (a Von Karman Street) exerts fluctuating forces on the cylinder in transverse direction to fluid flow, thereby oscillating the