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# Studies on gasketed flange joints under bending with anisotropic Hill plasticity model for gasket

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ABSTRACT

The behavior of a gasketed flange joint under bending loads has been studied by three dimensional finite element analysis (FEA) and experiments. The in-plane and bending stiffness of spiral wound gaskets are considered using anisotropic Hill plasticity material model. The variation in bolt axial force of joints under bending load predicted by the finite element analysis compares well with the experimental results. The contact stress distribution obtained have significant variation in the pattern from the previous material models and consistent with the results of Bouzid [1] regarding flange rotation.



## 1. Introduction

Gasketed flange joints are common in pipe joints and long pressure vessels. These joints are subjected to bending moments due to dead weight, wind loads. The joint must maintain the seal and prevent leakage. The ASME [2] procedure for the design of flange joint with bending is based on the calculation of equivalent internal pressure that replaces the bending moment. It is important to note that the gasket characteristics are not taken into consideration in the equivalent pressure method. Koves [3] evaluated the effect of external bending moment on the flange joint and developed a correction factor using energy method. Abid and Nash [4] made an experimental study on ANSI and compact VCF bolted flange joints under pressure, external force and moment and both the results were compared. They established a superposition approach for estimating the load capacities of these joints. Their study show sufficient amount of bending loads can be allowed on a flange joint. Sawa et al. [5] analyzed the gasketed joint under bending. The stress and sealing performance of flange joint under bending is analyzed in our earlier work [6] by using average pressure closure relationship for gaskets. Bouzid [1] replaced the bending moment by an equivalent axial force distributed as a sine wave in the circumferential direction.

Considerable work on the performance of gasketed flange joint for normal operating conditions (bolt load, internal pressure) has been done by many authors using analytical and numerical methods. Sawa et al. [7] presented a mathematical model for determining the contact stress distribution in a pipe flange connection based on the theory of elasticity by treating it as an axisymmetric problem. Sawa et al. [8] extended the earlier investigation by a numerical method considering the stress–strain curve of the gasket as piecewise linear. Bouzid and Derenne [9] developed an analytical method considering the rotational flexibility of the flange for determining the contact stresses in order to predict the joint tightness. A finite element simulation for bolt-up process with spiral wound gasket was carried out by Fukuoka and Takaki [10].

Presently, the through thickness deformation behavior from uniaxial compression test is used for the study of gaskets with specially designed material models. These material models consider only the deformation behavior in the thickness direction. The in-plane and transverse directions are decoupled from the through the thickness deformation. Since the analysis of the gasketed joints under bending is a three dimensional problem due to flange rotation, simplified assumption of considering the one dimensional behavior yields less accurate results.

Structural analysis such as gasketed joints under bending requires the complete set of three dimensional elastic and plastic constants. Characterizing the mechanical properties of SWGs is just one of the many important tasks that simulations can accomplish. A method of obtaining the relation between the microscopic

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