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Finite Element Analysis of Sucker Rod Couplings with Guidelines for Improving Fatigue Life

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Abstract

The response of a variety of sucker rod couplings to an applied axial load was simulated using axisymmetric finite element models. The calculations investigated three sucker rod sizes and various combinations of the slimhole, Spiralock, and Flexbar modifications to the coupling. In addition, the effect of various make-ups (assembly tightness) on the performance of coupling was investigated. The make-up process, based on measured circumferential displacement of the coupling from a hand-tight position, was simulated by including a section of an axially expanding material in the box section which, when heated, produced the desired mechanical interference which would result from making-up the coupling. An axial load was applied to the sucker rod ranging from -5 ksi to 40 ksi, encompassing three load cycles identified on a modified Goodman diagram as acceptable for indefinite service life of the sucker rods. The simulations of the various coupling geometries and make-ups were evaluated with respect to how well they accomplish the two primary objectives of preloading threaded couplings: (1) to lock the threaded coupling together so that it will not loosen and eventually uncouple, and (2) to improve the fatigue resistance of the threaded connection by reducing the stress amplitude in the coupling when subjected to cyclic loading. A coupling will remain locked as long as the mating surfaces of the pin and box sections remain in compression, resisting rotational motion or loosening. The fatigue evaluation was accomplished in two parts: nominally and locally. In the nominal evaluation, a set of equations based on the gross dimensions of the coupling were derived which describe how a load applied to a sucker rod is distributed throughout a preloaded coupling. The local fatigue evaluation characterized the fatigue performance of the various couplings using the local stresses predicted in the finite element simulations and a stress equivalencing criterion for multiaxial stress states. This criterion is based on Sines' equivalent stress theory which states that the permissible effective alternating stress is a linear function of the mean hydrostatic stress. Perhaps the most significant finding in this study was the characterization of the coupling parameters which affect these two stress measures. The mean hydrostatic stress, which determines the permissible effective alternating stress, is a function of the coupling make-up. Whereas, the alternating effective stress is a function of the relative stiffnesses of the pin and box sections of the coupling and, as long as the coupling does not separate, is unaffected by the amount of circumferential displacement applied during make-up. The results of this study suggest approaches for improving the fatigue resistance of sucker rod couplings.

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