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Allowable Contact Stresses in Jacking Gear Units Used in the Offshore Industry

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[The statements and opinions contained herein are those of the author and should not be construed as an official action or opinion of the American Gear Manufacturers Association.]

Abstract

An offshore jack-up drilling rig is a barge upon which a drilling platform is placed. The barge has legs which can be lowered to the sea floor to support the rig. Then the barge can be "jacked-up" out of the water providing a stable work platform from which to drill for oil and gas. Jack-up drilling rigs were first introduced in the late 1950's. Rack and pinion type jack-up units were introduced soon after that and have dominated the industry ever since. The rack and pinion systems used to raise and lower the rig are enormous in terms of gear pitch, or module, by gear industry standards. Quarter pitch (101.6 module) pinions are common, with both larger and smaller teeth used. Lifetime number of cycles for these units are – again, by gear industry standards – tiny, rack teeth typically have 25 year lifetime cycles measured in the low hundreds. That is off the charts for AGMA (and ISO or DIN) design rules which draw a straight line to zero cycles for contact stress cycles less than 10,000. Use of any standards was abandoned from the start in the offshore industry for jacking applications. The author presents methods, and experience of that industry and suggested allowable contact stresses in such applications.

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Introduction

The new and inexperienced designer of rack and pinion jacking systems with no experienced mentor will often initially turn to AGMA, ISO, or DIN rules for the design of gears. Once he gets started, and has had a chance to look at commercial systems on the market, he will wonder how on earth his competition can have gears so much smaller cheaper and lighter than those he comes up with using those standard design methods. This paper is intended to address that issue, and aid the designer as to how this is done, and show what allowable contact stresses have been used and seem to work in this industry for these applications. The designer is cautioned against using these values for other applications, especially at relatively high mesh speeds, or larger numbers of cycles than discussed in this paper, without careful consideration and experienced engineering judgment. Note also that in consideration of other applications, the mesh speeds of jacking systems is quite low, 500 mm per minute for jacking pinions engaged with racks is now the industry standard.

Historical overview

The offshore oil and natural gas industry got started in the period following WWII with the introduction of what are now commonly called lay barges or swamp barges, which were converted cargo barges with a land type drilling rig placed on it, that were moved to a spot in the swamp or in other waters shallow enough that the top deck of the barge would be above the water when the barge was sunk. Which is exactly what was done, the barge was sunk in a controlled manner such that it grounded on the mud and provided a secure stable platform from which to drill for oil or natural gas.

Prior to that time, it was held by a many geologists that little or no oil or gas was offshore, but the success of these ventures and the fact that "slant" drilling from such rigs showed that oil and gas existed in deeper waters eventually resulted in the first "jack-up" type rigs being introduced by the

Bethlehem Steel Company in the mid 1950's. The "jack-up" type drilling rig is a barge much as the previous lay barges, but with the introduction of structural legs that could be lowered to the sea floor, then the rig could be "jacked-up" onto these legs to provide a fixed stable platform from which to drill. (A stable platform with respect to the earth is critical to drilling operations.) These legs allowed jack-up rigs to be used in waters many miles from shore and so opened up enormous areas of the sea to oil and gas exploration.

The Bethlehem rigs were not of the rack and pinion type, but rather had a hydraulic cylinder pin and yoke system. While this system worked well enough, and was reasonably safe, they were slow and labor intensive to operate. The success of these first rigs caused a boom in offshore oil rig construction, and in the late 1950's LeTourneau introduced the first true rack and pinion type jacking system rig.

Since that time in waters up to about 400 + foot water depth rack and pinion type jack-up drilling rigs have been the dominant type of offshore oil and natural gas drilling rig. Other jack-up rigs were also used for maintenance and numerous other use type of use in the oil and gas industry. In addition recently jack-up type rigs have started to be employed in the offshore wind energy business as installation and maintenance vessels.

The author was introduced to this industry and to jacking systems through being hired as an engineer by a firm that rather than designing jack-up rigs or jacking systems was primarily concerned with making spare parts for jacking systems of offshore oil rigs - including orphaned rigs - who's original manufacturers had gone out of business especially during the oil bust of the 1980's.

Thus, the author was presented with the machinery that obviously did work, and had been working in many cases over 30 years at the time the author started in this business, and did not at all conform to AGMA or other standardized contact or even bend-