

Elastic Static Analysis of Chain Links in Tension and Bending

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ABSTRACT

The significant loading conditions applied to each link of a mooring chain during its operation are first identified. Then the resulting stresses and displacements within the elastic limit are calculated using both analytical and finite element methodologies. The calculations are performed for both studded and studless links. A comparison of the obtained analytical and numerical results shows good agreement. Finally, recommended values for the effective modulus of elasticity of a mooring chain are derived.

INTRODUCTION

Although chain has been around for a long time, there still remain several issues related to its in-service performance that have not been adequately studied, such as the permanency of the stud during operation. The latter is related to the process used to manufacture the chain (die-lock forging, casting and flash butt welding) and, in the case of studs separated from the link, to the method used to fit the stud to the link (smooth, press or interference fit and tack or structural weld).

Studs are generally designed based on the assumption that they act as a compression member, serving primarily to maintain the dimensional integrity of the link, to prevent link collapse under excessive tensile loading and to help prevent kinking of the chain (Linnenbank, 1969). The role of the stud under chain bending and torsional loading conditions is not often discussed in the literature, even though in certain design configurations (primarily in non integral stud chains) the stud can be lost, resulting in the weakening of the whole anchoring system. Furthermore, the lack of scientific consideration given to the role of the stud often results in not enough care being given to the design and fabrication of the stud-ring connection, especially if it is to be done by welding. Residual stresses and stress concentrations may thus arise in these locations that can potentially lead to catastrophic failures.

To address these concerns, a research study has been initiated at the National Technical University of Athens. In particular, the following objectives have been set :

- Investigation of the role of the stud and development of procedures for its design, including the influence of the stud on the stress distribution in a link under tension, bending and torsional loading conditions; of the residual stress distributions if the stud is welded onto the ring; and of the stress concentrations in the stud-ring interface and of methods to avoid them.
- Investigation of the chain's structural response under different loading conditions, including not only static but also repeatedly and/or suddenly applied loads.

This paper reports results obtained from the elastic static analy-

sis of studded and studless chain links subjected to tensile and bending loads, as a first step towards meeting these objectives.

Even though the chain has been considered primarily to be a tension member, there are very few theoretical investigations of the stress distribution in a link subjected to tensile loading. All were based on the simple curved beam theory, which neglects the effect of shear and radial stresses (Goodenough and Moore, 1907; Otterson, 1913; Gough et al., 1934; Marsh and Thurston, 1961). More recently, Lereim (1985, 1987) has presented results using the finite element method.

Similarly, there have been few studies of a complex significant problem in bending : The potential of chain failure if the radius of the curved surface over which the chain passes is too small. In the past 15 years some researchers have attempted to analyze the problem (Buckle, 1974), sometimes confirming analysis with actual tests (Berg and Taraldsen, 1980; Flory and Woehleke, 1980). However, while the bending problem is complex, the analyses were overly simple. More recently, Lereim (1987) presented results from a more accurate numerical analysis using three-dimensional finite elements.

LINK GEOMETRY AND BASIC LOADING CONDITIONS

A systematic search through the available scientific literature on chains, as well as through the technical brochures of various chain manufacturers, revealed that neither open (studless) nor studded chain links are manufactured in standard geometric forms. It was therefore decided that a common link of general geometry be studied, according to ISO 1704 (1973), with a circular cross-section of diameter d , length equal to $6d$ and maximum width equal to $3.6d$, and consisting at most of one straight and three circular segments, as shown in Fig. 1. This geometry is defined by the following parameters referring to the link's geo-

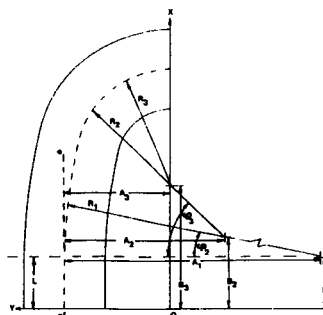


Fig. 1 Schematic geometry of link

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KEY WORDS : Chain links, elastic analysis, finite element method.