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STRESS ANALYSIS OF RECTANGULAR BARS

SUBJECTED TO TORSION

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To

My Grand Parents

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DASARI RAMAKRISHNA

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THESIS

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ABSTRACT

The purpose of this thesis was to perform the stress analysis for the rectangular bars made from different manufacturing methods such as welding and riveting subjected to torsion using the Finite Element Method proposed by Norma Elia Ramos in her recommendations. The exact solutions to the torsion problem are known only for circle, ellipse, and equilateral triangle cross sections. The present work involves the modeling and analysis of bars rectangular in cross section using the Finite Element Method. The commercially available ALGOR software was used for the modeling and analysis of the bars. Two different cross sections were analyzed, a solid rectangular cross sectioned bar and bar made from two rectangular bars joined by two different methods, with riveting and welding. A comparison of the results for total angle of twist was done with the experimental results, theoretical results, and the results from the membrane analogy.

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CHAPTER 1

INTRODUCTION

Engineering design is aided by engineering analysis, the calculation of performance of a trial design. To predict the performance it is often necessary to calculate a field, which is defined as a quantity that varies with position within the device analyzed. One of the main field of interest of engineers today is the 'mechanical stress'. The mechanical stress of the device being designed should be calculated to make sure the device will not break. The mechanical stress produced in a machine member when subjected to torsion is one of the concerns in designing the machine parts.

A body is said to be in a state of 'torsion' when applied forces or couples cause it to twist. Shafts with circular cross section are the most commonly used shafts to transmit torque. A twisting couple applied at one section of a shaft is transmitted to another section by the shearing stresses set up in the intervening transverse sections. In circular shafts the torque transmitted is constant over most of its length. For cylindrical bars with circular cross sections, the torsion formulas are readily derived by the special methods of mechanics of materials.

The cross sections of many members of machines and structures are made up of narrow rectangular parts. These members though used mainly to carry tension, compression, and bending loads are also required to carry torsional loads. In circular shafts subjected to torsion the behavior is such that all cross sections normal to the axis remain plane. The

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problem of twist of a shaft of rectangular cross section is complicated, due to the warping of the cross section during twist. Due to this peculiar behavior of the rectangular cross sectioned shafts the analysis applicable to circular shafts is no longer valid. More over the exact solutions to the torsion problem are known for the circle, ellipse and equilateral triangle only. Murphy[7] proposed four different methods that can be used for the evaluation of shearing stresses in a member subjected to torsion which are discussed in the next section. In this thesis the Analytical procedure suggested by Murphy is used to evaluate the stress distribution of the rectangular bars. The purpose of this thesis is to evaluate the stress analysis of the rectangular bars for this eight different models are used. The first one is a solid rectangular in cross section and the remaining are two rectangles of equal area held together by different manufacturing methods such as welding, and riveting.

1.1 Methods proposed

Murphy in his book "Advanced Mechanics of Material" proposed four different methods that can be used in the analysis of stresses in a member subjected to torsion. They are Exact or Saint Venant Theory, Experimental Procedures, Application of analogies, and the Analytical procedure. In the Exact or Saint venant theory we determine the solution of a differential equation that satisfies the equation of equilibrium and the stress, strain relationships at every point in the member. As an experimental procedure the Strain measurements can be considered. In the application of analogies the Fluid Flow Analogy and Membrane Analogy can be considered. Fluid Flow Analogy involves streamlines of a

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circulatory flow of an ideal fluid with constant vorticity over the cross section. The Membrane Analogy is based upon the fact that the differential equation for the equilibrium of a membrane subjected to lateral pressure. In the analytical procedure the approximate distribution of shearing stress throughout the cross section is deduced from the observation of strains and the relationship between the torque and stress developed by statics for the approximate stress variation. Norma Elia Ramos attempted the experimental methods to obtain the torsional rigidity as well as the total angle of twist for all cross sections. The two methods used by her are the direct torsion mechanism, where a direct torsion couple was applied to the samples and the other one is the Membrane Analogy. In this thesis her recommendation to perform the analysis of the rectangular cross sections using Finite Element Method is attempted.

1.2 Shear stresses in rectangular members

To define relation between shear stress and torsion for a circular member in torsion the following are assumed

I) The shaft is in equilibrium; that is, in a state of rest or uniform angular velocity.

ii) The shaft has a circular cross section, solid or hollow.

iii) The shearing proportional limit of the material is not exceeded.

iv) A plane transverse section in the unstressed shaft remains a plane transverse section after the shaft is twisted.

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v) A diameter of a transverse section of the unstressed shaft remains a straight line after the shaft is twisted.

The assumptions 'iv' and 'v' are true only for the circular cross sections. A rectangular shaft subjected to torsion shows warping at the transverse sections. It is necessary to determine the manner in which the shearing stresses are distributed over in a transverse section. It may be said that the shearing stress no longer varies as the distance from the center of the cross section as in the circular shafts. It is assumed that the shearing stress varies as the distortion in a rectangular bar. The shearing stress is maximum at the middle of the sides and zero at the corners of the cross section.

1.3 Objective of the study

The objective of this study is to develop finite element models for different specimens used and perform the analysis on the stress distributions that result when they are subjected to torsion and compare the results with the experimental results obtained by Norma Elia Ramos. The first model is a solid bar with rectangular cross section and the remaining are two equal dimensioned bars with rectangular cross section joined together by different means. The widely available commercial finite element software, ALGOR is used for performing the stress analysis of the models. Type 5 (Brick Elements) available in the ALGOR have been used for modeling. The stress distributions of the different specimens are also compared graphically to see any similarities so that any one of the joined shafts can substitute the solid shaft in the interest of material saving for manufacturing purposes.

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