EFFECT OF GEOMETRY ON THE STRESS DISTRIBUTION USING FINITE ELEMENT ANALYSIS

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THESIS

Presented to the Faculty of the Graduate School of

The University of Texas at El Paso

in Partial Fulfillment

of the Requirements

for the Degree of

MASTER OF SCIENCE

Department of Mechanical & Industrial Engineering

THE UNIVERSITY OF TEXAS AT EL PASO

May 1993

ACKNOWLEDGEMENTS

I would like to express my gratitude and sincere thanks to Dr. Juan M Herrera, for the encouragement and support he has given me in completing this study. He has acted as advisor and friend to me and I am indebted to him.

Dr. W.C.Johnson has helped and guided me during my graduate studies and I would like to extend my thanks to him and appreciation for serving on my thesis committee.

I would also like to thank Dr.H.S.Oey for taking the time and interest to be on my committee.

My parents and brother have always been a constant source of support to me throughout my studies and I am deeply indebted to them. I am always grateful to my friends especially Rajendra, Satish, Swapnesh, Kundan, Anand, Pandu and others for their constant support and encouragement.

Special thanks are due to Mr. Raymond Stone, Director of Computer Applications Learning Center, College of Business for providing computing facilities during the completion of this thesis.

April 15, 1993

Dedicated to

My Parents

and

My Brother

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CHAPTER 1

INTRODUCTION

A sucker rod is essentially a part of the pumping unit used in the down hole oil well drilling. The pump is used to pump crude oil out of oil wells. Sucker rod functions as a link between the pump unit and the prime mover. It actuates a remotely located plunger, and pump oil to the surface of the earth.

Steel sucker rods were predominant in the oil well industry for well over seven decades. Statistics proved that corrosion and stress were the main causes for catastrophic failures in the operation of steel sucker rods. Hence many composite materials have been examined by the industry to find better structural materials. This has resulted in the experimentation of resin bonded fiberglass.

In spite of the various problems encountered in the design of the fiberglass sucker rods, these designs were successful as far as practical application and commercial aspects were concerned. A stage has been reached, where existing steel sucker rods are being upgraded to fiberglass rods, at a rapid pace.

Primarily fiberglass sucker rods were designed to minimize failure frequencies but the design also yielded additional fringe benefits, like the high tensile

strength,low modulus of elasticity, reduction in weight and low density. Hence the resulting operational costs were reduced, culminating in increased production rates.

Despite infinitesimal failure of fiberglass sucker rods, they do have certain limitations. This may be due to the inherent weakness of the fiberglass rod in compression, as a result they are susceptible to failure under compressive loads caused by fluid pound, gas pound and pump tagging.

Failures are also caused by abrasion due to the friction in deviated wells, as the glass comes in contact with the tubing, due to wear and tear of the resin. The rate of failure is also directly dependent on the manufacturing process of sucker rods. The known manufacturing defects are:

i) End fitting pinch offs

ii) End fitting pull-outs

iii) Knots and Loops

iv) Air voids in the body and adhesive.

These defects can be efficiently eliminated during the design process by selecting optimal design parameters. The existing structure of the sucker rod assembly was found to have stress concentration areas under loading. It was also observed that the stress distribution was uneven in the steel casing. The presence of stress differentials and

unevenness in stress distribution throughout the geometry of the rod is also partly due to the existing geometry of the pocket.

These defects result in the failure of the sucker rod. These failures can be significantly reduced by modifying the inner geometry of the pocket.

An attempt has been made in this thesis to reduce stress concentration and have a better stress distribution, by remodeling the inner geometry of the pocket. The existing sucker rod had a conventional inner geometry for the pocket, i.e a straight line with a four degree slope, which was remodelled to a second order curve, i.e a parabolic curve with zero slope. The resulting stress distribution and concentration was analyzed under load.

Gap elements were used to simulate contact between steel and resin parts of the sucker rod. The significance of positioning the Gap element in a model was analyzed. The role of these elements in stress distribution was also studied.

In terms of design considerations, the shear and tensile stresses can be considered to be more significant in the practical usefulness of the fiberglass sucker rods.

The finite element software used in modeling and analysis is ALGOR, a PC based package. The module used in modeling was Superdraw II. The Gap/Cable Analysis module was used for processing and Superview is the post-processor. An IBM-PC 486 with 120 MB of harddisk and 4MB of RAM was used to support the software.

CHAPTER 2

SUCKER ROD AND THE OIL INDUSTRY

2.1 Product Design and Manufacturing

It is very important to know the manufacturing process that was used in making the fiberglass rods in order to have a more realistic approach along with the effects and causes that every process carries in its own particular way.

The sucker rod consists of a fiberglass rod with constant cross-sectional area and is produced in different diameters and lengths. This rod has a piece of alloy steel on each end commonly called adapter.

The end fitting is attached to the rod by filling the void space between the rod and connecter with epoxy resin. The inside of the metal connector is shaped so the cured epoxy resin forms a series of wedges as shown in Figure 2.1 . These wedges bond to the rod but can slip against the metal surface of the connector so that tensile forces on the rod produce compressive holding forces. These compressive forces efficiently grip the rod surface.

Sucker rods are subjected to high cyclic stresses. Stress concentration

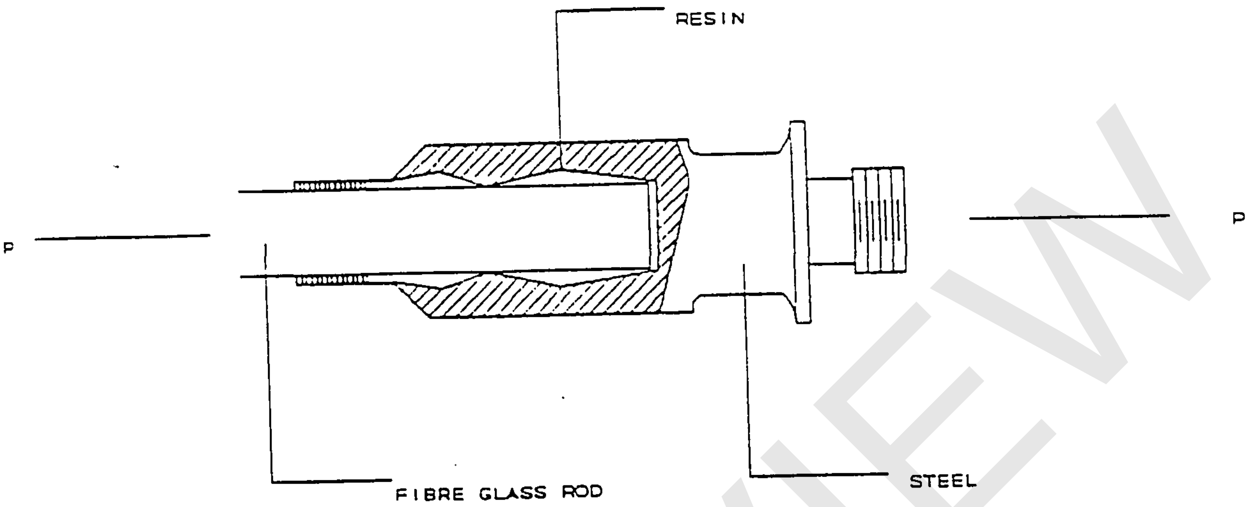

Figure 2.1 Schematic diagram of Sucker rod

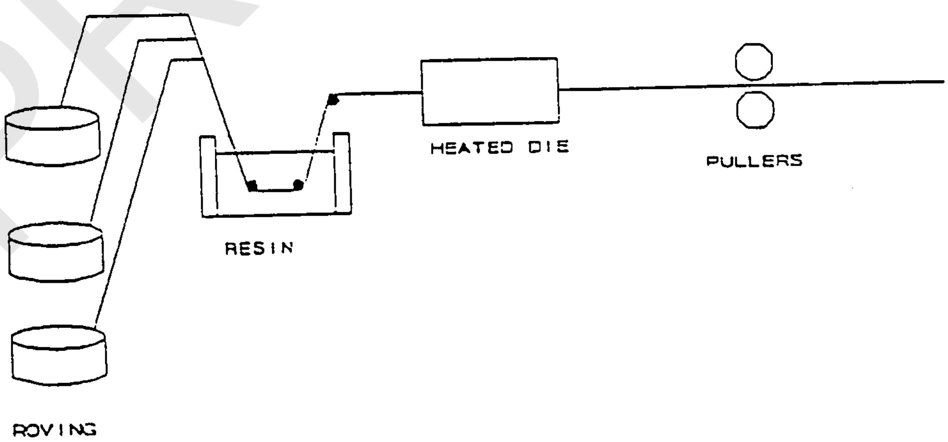

Figure 2.2 Schematic of Pultrusion process

may occur in the area of rod entry into the fitting and within rod end fittings. The rod induces stress perpendicular to its axis causing pinch problem in the receptacle and shear, which causes delamination in the composite. The taper surface introduces sliding between the epoxy and steel.

The construction of the fiberglass sucker rod is such that, the fiberglass rod is tensioned between two steel end-fitting adaptors. The end-fittings are joined together by a coupling which also acts as a guide in the tubing. This string is then lowered into the well with adequate weights or sinker bars. Sinker bars are used to maintain tension in the lower part of the string. The usage of sinker bars is modified, based on the application.

The load carrying ability of the fiberglass rod comes from the strength of individual glass fibers. Figure 2.2 is a schematic of the pultrusion process used to manufacture fiberglass sucker rods. The process entails saturating bundles of continuous glass filaments with a thermosetting resin and pulling the wet mass through a heated forming die. In the heated die, a chemical reaction cures the liquid resin and changes it to a solid. The resulting product is a solid rod composed of resin-bonded glass fibers. Because of this construction, these rods have high tensile strength and are anisotropic.

The rods are then sawed to the required length. The ends of the rod are