# DEVELOPMENT AND APPLICATION OF SPRAYED METAL SUCKER ROD COUPLINGS

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## INTRODUCTION

It became apparent some 20 years ago that oil wells produced by artificial lift were becoming more corrosive and more demanding of downhole equipment. This paper relates to the case history of sucker rod coupling failures that caused accelerated attention by manufacturers toward product improvement programs and ultimately the development of the sprayed metal coupling. The metals used and the processes involved in the manufacture of couplings are discussed in some detail.

## FAILURE PREVENTION

Failure prevention of any component, metallic or nonmetallic, starts with a knowledge of failure mechanisms. Design and test engineers and manufacturing personnel should have a working knowledge of failure prevention; otherwise, failures may be unintentionally designed or built into a product.

To prevent failures, it is necessary to understand the many ways a product can fail. Each failure should be considered as a valuable specimen from which to extract as much information as possible. Such information improves technical skills, and a gradual improvement in product quality and reliability should result.[1]

Understanding of product failures is important to users as well as designers and manufacturers since service life of components may be shortened by improper field handling or by the service environment, or both.

## REVIEW OF THE VARIOUS GRADES OF SUCKER ROD COUPLINGS - PAST AND PRESENT

### *Couplings Manufactured in 1960*

Couplings manufactured in 1960 did not have the burnished or full-formed thread. These innovations were not available until a few years later. Table 1 is a listing of the popular grades manufactured at that time, the class of materials used, and hardnesses.

TABLE 1—SUCKER ROD COUPLINGS MANUFACTURED IN 1960

| GRADE | MATERIAL | HARDNESS CORE | HARDNESS SURFACE |
|---|---|---|---|
| Regular | Carbon Steel (No Heat Treat) | 217-243 BHN | 217-243 BHN |
| Through-Hardened | Alloy Steel (Quenched,Tempered) | 223-265 BHN | 223-265 BHN |
| | | 212 BHN 16 HRC<br>243 BHN 23 HRC | |
| Surface-Hardened | Carbon or Alloy Steels | 217-243 BHN<br>223-265 BHN | 55 HRC Minimum |

(Surface Hardened by Induction or Carburizing)

### *Couplings Manufactured in 1975*

The couplings listed in Table 2 may be furnished with or without cold-formed threads.

TABLE 2—SUCKER ROD COUPLINGS MANUFACTURED IN 1975

| GRADE | MATERIAL | HARDNESS CORE | HARDNESS SURFACE |
|---|---|---|---|
| API 'T' | Carbon or Alloy Steel | 212-243 BHN | 212-243 BHN |
| | (Alloy Steel may be quenched and tempered.) | | |
| Sprayed | Carbon or Alloy Steel | 200-243 BHN | 50-56 HRC<br>56-62 HRC |

## THE CAUSE OF SUCKER ROD COUPLING FAILURES

Failures in sucker rod couplings are caused by one or more of the following factors:

1. Deficiencies in design

2. Imperfections due to faulty processing
3. Service abuses
4. Environmental factors
5. Metallurgical factors

A simplified definition relating these factors as a failure source of sucker rod couplings follows.

*Deficiencies in Design*

Sucker rod couplings are made to API specifications. The design is certainly adequate; nevertheless, a weakness did occur when the slim-hole coupling was made with wrench flats for the smaller OD tubing. Early failures occurred at the wrench flats adjacent to the last engaged thread in the box. If the slim-hole coupling had wrench flats and was surface-hardened, stress concentration at the weak area increased and fatigue endurance was substantially reduced. Present API specifications on couplings list two styles — the fullsize that may be furnished without wrench flats when agreed upon between the purchaser and the manufacturer, and the slim-hole style that is furnished without wrench flats. However, the one-inch slim-hole coupling may be furnished with wrench flats conforming to the wrench-flat dimensions listed for one-inch couplings when so specified on the purchase order.

*Imperfections Due to Faulty Processing*

The nucleus of a fatigue crack has its origin at a surface notch, flaw, or change of section. The roots of a thread are a series of notches with a high stress concentration; they are located at the smallest cross section.[2] Manufacturing imperfections, such as tool marks at the root of flat-root or radius-root threads are found to be a site for the initiation of early fatigue. Circumferential tool marks on the OD surface of couplings are not severe notches compared to cut threads; however, they are stress risers, and for that reason they are considered undesirable. For a situation such as a mill seam that is parallel to the direction of loading, there is virtually no stress concentration.[3] Such conditions can be tolerated without jeopardizing service performance.

*Service Abuses*

During the period of surface-hardening couplings by induction and carburizing, a high percentage of coupling failures were caused by surface cracks in the hard surfaces. These cracks were the result of hammer blows during joint disassembly or from mishandling practices. The cracks are stress risers and a site for corrosion fatigue. Hammer blows to soft couplings do not cause cracks; however, the marks can be points where localized corrosion will start its attack.

Improper make-up or looseness is a cause of both sucker rod pin and coupling fatigue or corrosion fatigue failures.

*Environmental Factors*

Service environmental factors that cause box failures are wear, corrosion, and sulfide stress cracking.

Wear is the deterioration of the coupling contacting surface with the tubing and may be modified by the simultaneous effects of corrosion or other chemical attack.

Coupling failures due to corrosion exhibit two modes of attack. One mode is the general corrosion attack and removal of body material from the OD surface so that the remaining metal will not support the design loads. The second mode is by localized corrosion pitting at the thread root to initiate corrosion fatigue.

Sulfide stress cracking occurs in areas where the produced fluids contain hydrogen sulfide. It is generally agreed that the mechanism of hydrogen sulfide corrosion cracking is one of hydrogen embrittlement rather than stress corrosion cracking.[4,5] Coupling materials with hardnesses over 23 HRC become more susceptible to cracking. Materials with hardnesses of 23 HRC and below are considered safe from this type of failure.

*Metallurgical Factors*

Metallurgical factors deal with the thermal treatment, hardness, and resultant microstructure. Failures in this category have been attributed to sulfide stress cracking due to the high hardnesses specified at the time and by an unfavorable microstructure.

## FAILURE PREVENTION MEASURES

Five factors that affect the performance of sucker rod couplings have been discussed. In recognizing the mechanisms of these failures, coupling manufacturers pursued a course of development to improve product reliability, and users initiated field training programs to reduce handling-caused failures and corrosion.

The following failure prevention measures were implemented.

1. The API slim-hole couplings are now furnished without wrench flats except the one-inch which is optional.
2. Manufacturers made a breakthrough in cold-forming box threads. This innovation in threading produced a smooth radius thread root, free of cutting tool scratches and tears. The cold-forming improves the fatigue endurance properties by eliminating the nucleus for fatigue by increasing the strength properties at the thread root and by the residual compressive stresses developed at the thread root from metal displacement. Heat-treating subsequent to threading removes the cold-work properties at the thread root.
3. Field training programs by users have been helpful for reducing handling-caused failures of couplings and rods and corrosion problems in rods and other downhole equipment.
4. Sulfide stress cracking failures have been reduced by lowering the hardness requirements to 23 HRC maximum and eliminating surface hardening by induction and carburizing methods. This coupling is presently specified by API as the 'T' grade with hardness limits of 16-23 HRC. This is the only class API specifies.
5. In view of the severe corrosion and breakage problems users were experiencing with the soft and induction-hardened or carburized couplings, manufacturers started experimenting with high alloy sprayed metal coatings that are resistant to both corrosion and wear. In the early stages of development, there were problems of breakage in the sprayed metal coupling caused by sulfide embrittlement of boxes with core hardnesses above 23 HRC, fatigue failures in the slim-hole coupling originating at the thread root due to low strength properties and tool marks, and corrosion fatigue failures starting from the outside surface in circumferential cracks in the hard surface alloy.

With the development of cold-formed threads, the fatigue strength of threads was improved, and the core hardness is controlled by proper selection of base material with an appropriate thermal treatment subsequent to fusing.

Circumferential cracks located at highly stressed areas in slim-hole couplings have been found by field tests to be a potential failure. It was also determined by experimental tests that cracks in the hard surface material were prevalent with the harder and thicker coatings. As a result of three years of extensive laboratory research and correlated field testing, a new development of softer and more ductile coatings (50-56 HRC) are now being applied to couplings without sacrificing wear or corrosion resistance.

Field performance data to date indicate that the sprayed metal coupling, manufactured by present-day standards of hard surfacing with cold-formed threads after metal spray, is appropriately designed for application of extreme wear and corrosion.

## REFERENCES


1. Wulpi, D.J.: Failure Prevention Starts with Education. "ASM Source Book in Failure Analysis," 1974, p. 146.
2. Davis, J.R.: The Root of Thread is Root of Fatigue. *The Iron Age*, April 13, 1967, p. 90.
3. Juvinall, Robert C.: "Stress, Strain, and Strength". McGraw-Hill Series in Mechanical Engineering, 1967, p. 241.
4. Vollmer, L.W.: The Behavior of Steels in Hydrogen Sulfide Environments. *Corrosion*, Vol. 14, July 1958, p. 38.
5. Cain, W.M., and Troiano, A.R.: Steel Structure and Hydrogen Embrittlement. *Petr. Eng.*, May 1965, p. 78.