Design and Application of Sucker Rod Joints

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INTRODUCTION

Increasing the service life of the sucker rod joint is a continuing goal of both manufacturers and users. Whether or not the goal is reached depends on how well the manufacturer designs and builds the component parts of the joint system and how carefully the user applies it in service. The man who makes the product gets one crack at producing the best engineered joint he can; the man running the sucker rods has recurring opportunities to increase or decrease the joint life by field practice. Included in the latter is control of the well environment to minimize corrosion, the service factor affecting joint life as pointed out in Mr. A. A. Hardy's comments to this Petroleum Short Course last year.[1] It will be assumed that sucker rod joints are running in effectively inhibited wells; varying degrees of wishful thinking may be assigned to that premise.

CARE

To repeat Mr. Hardy's caution of a year ago (the same warning stressed many times and outlined carefully by the API), improper handling of sucker rods and couplings is far more effective in shortening joint life than any design improvements can be in lengthening service.[2] Proper attention to the API care and handling rules in "RP 11BR" makes good economic sense.

DESIGN IMPROVEMENTS

With the twin ogres of corrosion and improper makeup dogging our efforts at increasing joint life, let's quickly review design steps that have led to better sucker rod joints. Remember that the joint is a system involving three threaded metal members, various conditions of pre-stress, various coatings and lubricants, and a final makeup which imparts varying stress distributions in each member. Included herein are comments only on those design concepts adopted by more than one manufacturer, leaving others to be further evaluated and more widely adopted. Most of the following design ideas are interdependent and represent industry developments over several years.

Microstructure in Pins

The old tapered sucker rod joint used for many years suffered failures in the square vanishing thread pin largely blamed on poor makeup. However, pin failures seemed to be less frequent when the metal pin had a fine-grain, quenched and tempered martensitic structure.

Microstructure in Boxes

In highly-stressed slim-hole couplings, again quenched and tempered structures gave improved performance because of better toughness and higher fatigue strength.

New Pin Design

The change to the new API undercut pin has greatly reduced pin failures, as pointed out by Mr. Hardy. Stress distribution in the pin joint is greatly improved.

Rolled Threads

A major reason for the success of the undercut pin is the freedom it gives the manufacturer to roll the threads on the pin, increasing fatigue strength by cold-working and pre-stressing. Figure 1 shows the amount of cold work present in a rolled thread pin.

Armored Couplings

Contributing to longer joint life has been the change in wear-resistant couplings from carburized or induction-hardened O.D. surfaces which were prone to hammer cracks to hardfaced (spray-welded) couplings relatively immune to damage from hammer blows. Also very helpful has been the educational program by users to convince field personnel that hammering can damage a joint. Here again, upgrading of core microstructure has given longer life in armored couplings; however, core hardness is not covered by API standards.

ROLLED THREAD ON API GRADE D SUCKER ROD PIN

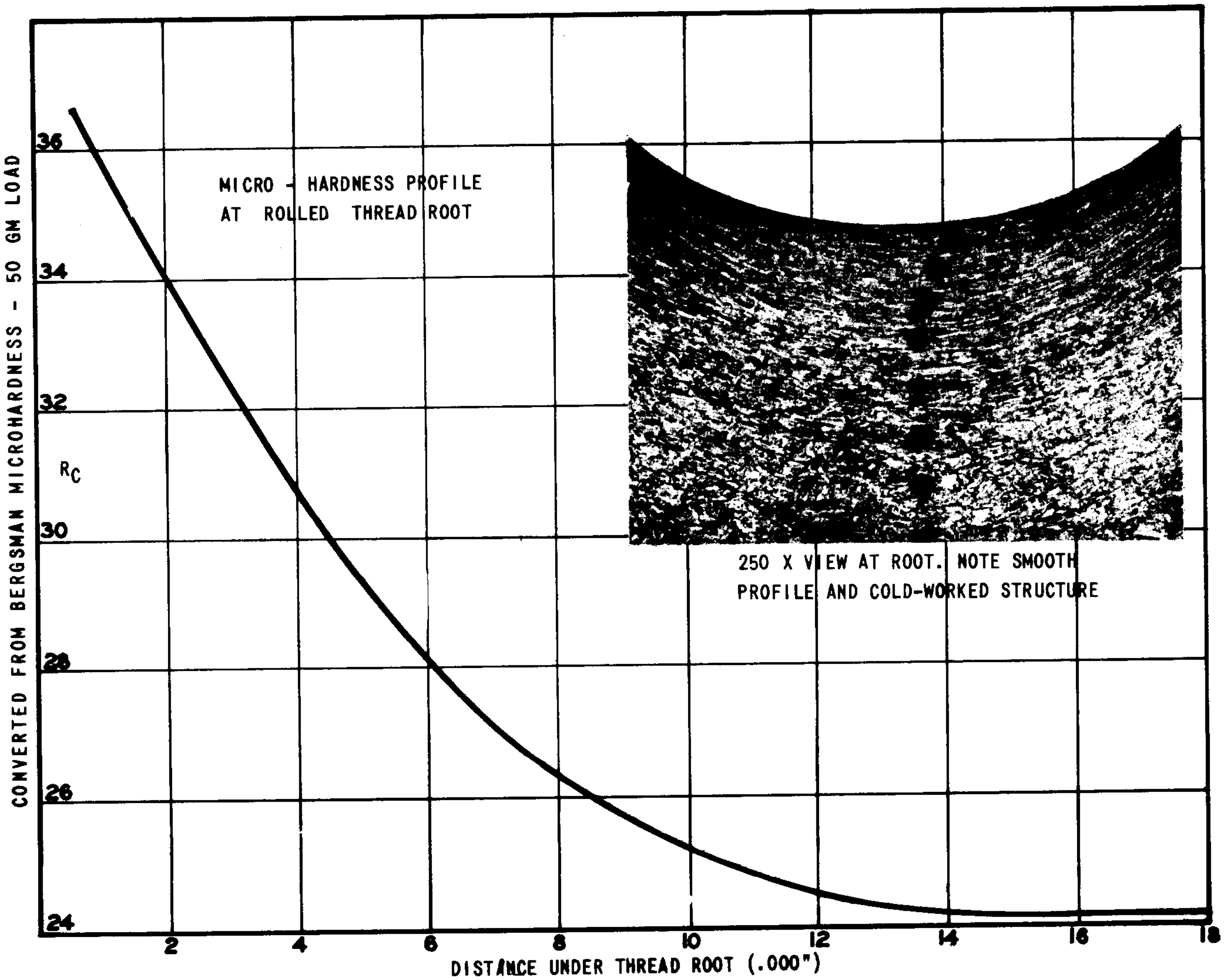


FIGURE 1—Plot of Hardness vs. Depth Beneath Thread Root API Grade D Sucker Rod Pin, with Microphotograph of Root Section.

Coatings

The use of phosphatizing and other surface conversion coatings has improved the anti-seizing properties of coupling threads and reduced the galling of boxes and pins.

Coupling Strength

Minimum specified core strength (hardness) of API couplings has gradually increased with experience to the latest API Class T range of 16-23R_c with deletion of the old Class U (first 12-20 R_c, then 16-22 R_c). We found that standard couplings softer than 16 R_c flared plastically when made up to standard API torques. All slim-hole couplings flare at these torques but the increased yield strength of quenched and tempered steels was found prevent excessive plastic flare.

Cold-worked Box Threads

With the improved performance of rolled, undercut pin threads, couplings became the weakest member of the joint system (soft 7/8-in. slim-hole boxes had always been so). A change to semi-rolled box threads, giving increased fatique strength by cold-working and prestressing, has considerably reduced box failures, in some areas spectacularly. Figure 2 shows the microstructure evidence of cold work and the resultant increase in hardness at the thread root. Figure 3 is a demonstration of the residual compressive stress present in a cold-worked thread coupling. The stress present is a longitudinal slice from the coupling; a similar section from a conventional coupling does not distort, showing an absence of residual compressive stress on the I. D.

EQUIPMENT

The development and improvement of power tongs has been a major factor in increasing sucker rod joint life. An excellent paper "Make-up of Sucker Rod Joints Using Power Tongs" by Roger Smith, Jr., points out that properly maintained power tongs operated with a limited speed range are more reliable than hand-operated impact wrenches in obtaining specified torque values.[3] Mr. Smith emphasizes that power wrenches must be maintained and operated

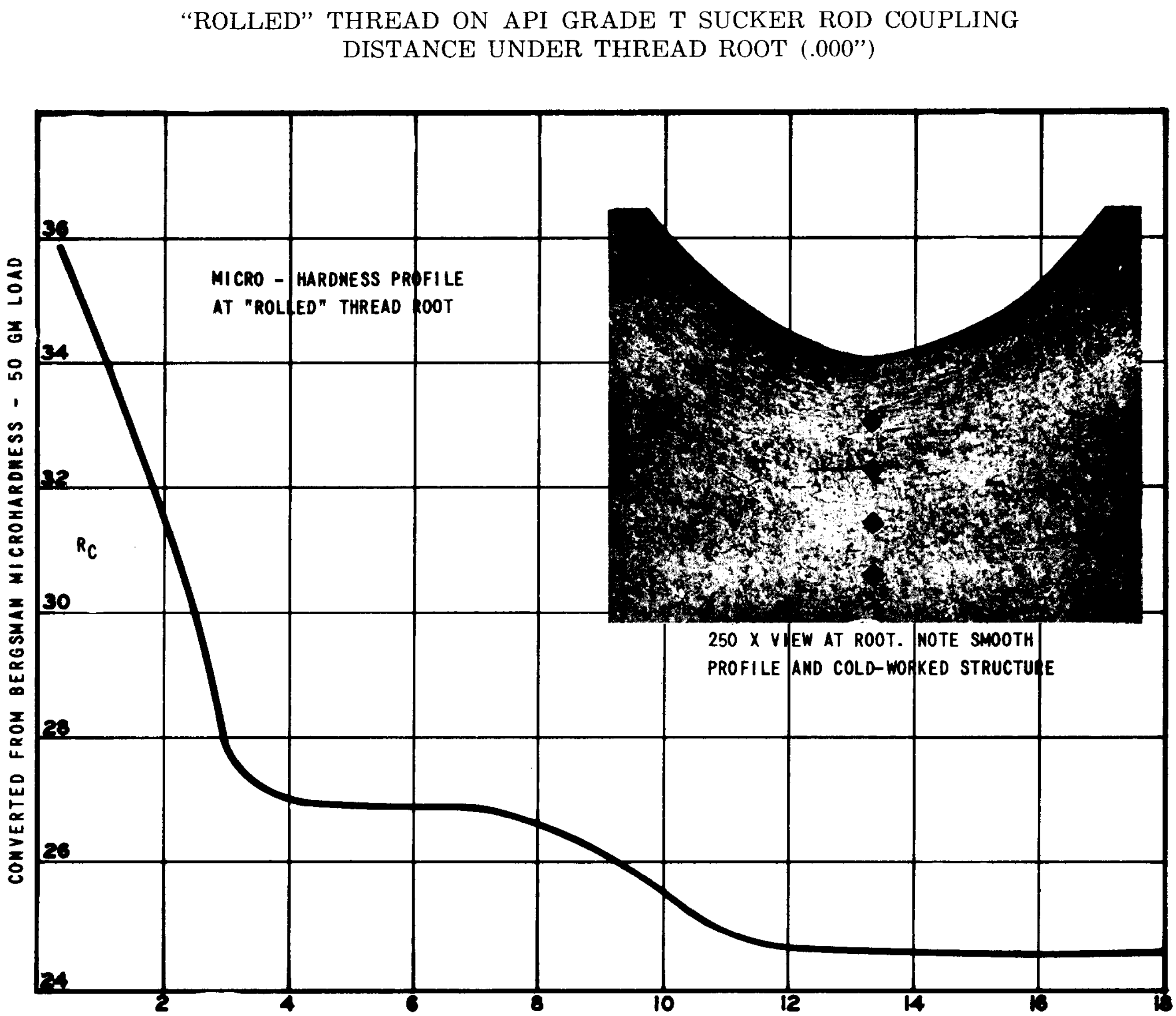
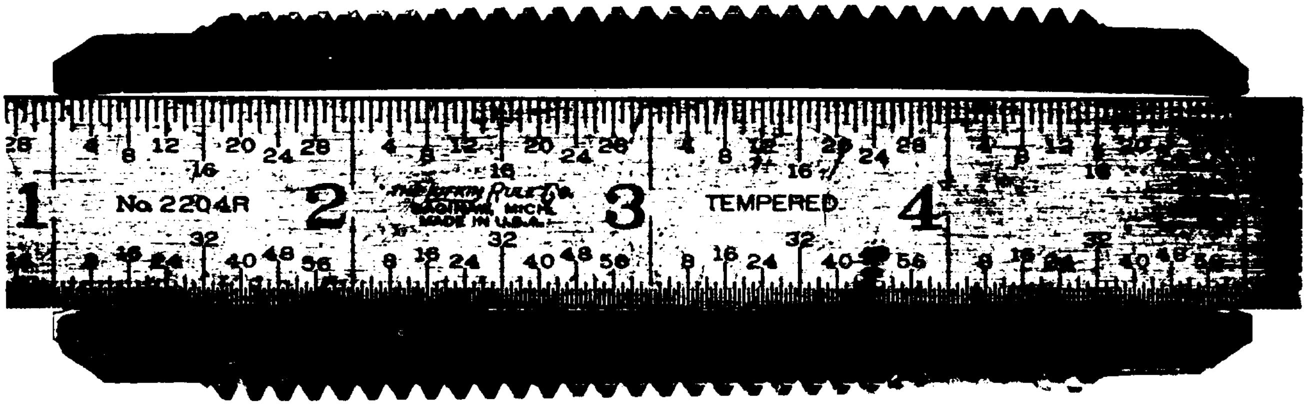


FIGURE 2—Plot of Hardness vs Depth Beneath Thread Root, API Grade T Sucker Rod Pin, with Microphotograph of Root. Section.



PRESTRESS TEST OF "ROLLED" THREAD COUPLING

Shown above are two 3/16" wide longitudinal slices cut from couplings. They are laid against a machinists scale to serve as a straight edge.

The bottom section is from a conventionally tapped coupling. It retained a straight longitudinal edge.

The top section is from an API grade T coupling with "rolled" threads. This section has bowed considerably indicating compressive prestress present at the thread roots.

FIGURE 3—Comparison of Conventional to API Grade T Coupling. Prestressed Test of "Rolled" Thread Coupling.

in accordance with the manufacturer's recommendations in order to be effective. He cautions that power tongs should not be operated under partial throttle until the joint shoulders nor should the joints be snapped up by a series of throttle actuations. This practice results in erratic axial pin stress.

WRENCH FLATS

In conjunction with the better control of joints preload with power tongs, the use of sucker rod couplings without wrench flats (now API) also minimizes the chance of overtorquing pins by head wrenching. API is currently considering the elimination of wrench flats from all couplings included in API Standard 11B.[4]

MAKEUP PRELOAD

All of the foregoing factors (steady improvement in sucker rod joint design and tightening equipment) should then logically make possible uniform preload of the joint. It is recognized that other variables such as lubricants, corrosion in threads, power wrench gaging and maintenance can influence the actual amount of preload obtained with a given "indicated" torque. While the API and sucker rod manufacturers have published various recommended makeup torques, an API task group has completed work on the use of circumferential displacement values to control the desired preload stress loads in a sucker rod joint. This will be appended to the API RP 11BR as a tentative recommended practice and will include procedures for calibration of power tongs by circumferential displacement.

The basic reason for preloading the rod joint is to prevent separation of the pin shoulder and coupling face during application of the service tensile load. We have seen many failures in which undertightening was involved; conversely, well failures due to apparent overstressing on makeup are extremely few. Advantages of using circumferential displacement as an indicator are its improved accuracy and consistency over torque wrenches shown in many tests (and by some users in everyday usage in the field) as well as its usefulness in calibrating and checking power equipment.

Scribing the joint to measure displacement is done as in Fig. 4 after hand tightening. Table I shows the tentative optimum recommended displacements as determined by calculations, strain gage tests and field data gathered from many sources, studied and approved by the API Task Force on Sucker Rod Makeup Torque. The iron-out (or wear-in) of new pins is apparently predictable for higher tensile sucker rods and equally erratic for API Grade C and K rods. On running new Grade D rods, then, the displacement values shown in column 2 are valid and include additional displacement to allow for iron-out; new Grade C and K rods should be made up to column 3 displacements, broken loose, and remade again to the values shown in column 3. All rerun rods should be loaded as indicated in column 3.

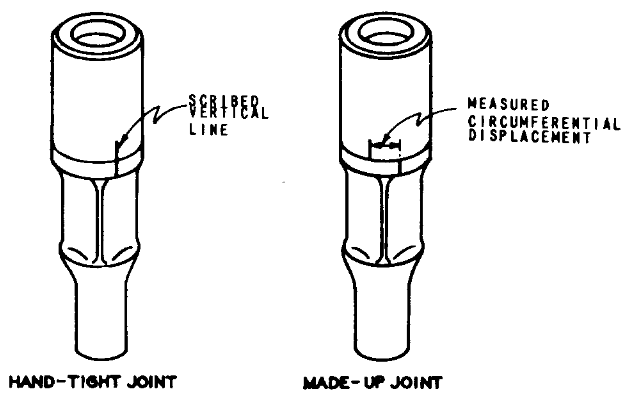


FIGURE 4 — Schematic Diagram of Circumferential Displacement Method of Preload Stress Measurement.

The minimum values listed in Table I are conservative and will give a safe amount of preload stress; the maximum displacement figures are perhaps more tentative. Some users regularly use a higher circumferential displacement in the field than the maximums shown here and with great success. As more and more rods are run using this method of measuring preload, better data can be accumulated that will probably be reflected in higher maximums. The ranges are narrow and may not be easy to control and the ability to read 64ths of an inch under field conditions may be questioned. Our laboratory tests would suggest that the total tolerance range of 1/16 in. is not attainable.[5] Keep in mind that development of new practices such as this require refinement through use; this represents another step forward to increased joint life.

We would emphasize two points:

(1) Be sure to achieve the minimum prestress, to overshoot and slightly yield is better than to be loose.

(2) If field conditions prevent close control, use materials whose design (as outlined above) makes them tolerant of over-preload.

FURTHER WORK

Study of ways to improve sucker rod joint life will continue. Better corrosion control, better heat-treated and machined pins and couplings, better ways to measure preload are pos-

TABLE I

Circumferential Displacement Values (Inches)

1	2		3	
Rod Size	New Grade D		New Grades C, K Rerun All Grades	
	Minimum	Maximum	Minimum	Maximum
1/2"	6/32	8/32	4/32	6/32
5/8"	8/32	9/32	6/32	8/32
3/4"	9/32	11/32	7/32	17/64
7/8"	11/32	12/32	9/32	23/64
1"	14/32	16/32	12/32	14/32
1-1/8"	18/32	21/32	16/32	19/32

sibilities. An example of one approach to better preload is to utilize the measurable elastic flare of a properly preloaded coupling end as the indicator which automatically would stop the power tong. Given a uniform joint system strength-wise and dimension-wise, there should be no need to determine circumferential displacement. The tools that measure steel and paint thickness on the fly and strength of materials non-destructively in an instant should be adapted to the sucker rod string.

CONCLUSION

A combination of efforts has extended sucker rod joint life. Each advancement is wasted if all are not used. And all are useless in the face of corrosion and poor practice. Require quality design and workmanship from the manufacturer, intelligent application and competent practice from the user and sucker rod joint life should be satisfactory.

REFERENCES

1. Hardy, A. A., "Common Causes of Failures in Sucker Rod Strings", Proceedings of the Fifteenth Annual Meeting of the Southwestern Petroleum Short Course, Page 81, April, 1968.

2. API RP 11BR, "Recommended Practice for Care and Handling of Sucker Rods", Third Edition, American Petroleum Institute, March, 1962.

3. Smith, Roger, Jr., "Makeup of Sucker Rod Joints Using Power Tongs", ASME Paper 67-PET-36, Petroleum Mechanical Engineering Conference, 1967.

4. API Standard 11B (Sixteenth Edition) American Petroleum Institute, March, 1965.

5. Unpublished data, OILWELL Division U. S. Steel, 1967-1968.