SUCKER ROD MAKE-UP

ROBERT A. MORRIS
Dover Corporation/Norris Division

Most sucker rod pin and coupling failures are considered to be related to loose couplings. Correct pin prestress offers the best way to prevent loose couplings and the "circumferential displacement" method offers the best way to achieve correct pin prestress.

Sucker rod couplings are kept tight by pressure and friction on the bearing surfaces between the coupling face and the pin shoulder. This pressure will vary throughout the pumping cycle and in some couplings the pressure is overcome by the pumping stress. When this occurs, the pin and coupling faces separate. Under these conditions, the coupling eventually loses all prestress and backs off. The pin and coupling threads serve primarily to force the coupling face against the pin shoulder and play only a minor role in keeping the coupling tight; therefore, it is of the utmost importance to maintain pressure between the coupling face and the pin shoulder throughout the pumping cycle.

Several factors can cause loose joints. Excessive lubrication will reduce the friction on the bearing surfaces and thereby reduce their ability to resist movement throughout the pumping cycle. The angle of the threads tends to cause the coupling to back off and when there is little or no friction between the coupling face and the pin shoulder, a loose coupling results. A rod string that whips and vibrates can cause loose couplings. The impact of the coupling against the tubing may seem to be of little consequence but that small impact, repeated four times during the upstroke will add up to more than 86,000 impacts per day for a well pumping at 15 SPM. Threads are merely a sophisticated application of an inclined plane that has been wrapped around a shaft. It can be seen that the tendency of the slope of the threads to promote looseness is greatly increased by impacts between coupling and tubing, much like vibrating a box down an inclined plane. The static coefficient of friction and the mass inertia are overcome by the impulse force and the box moves. In the coupling and pin, the shock of the coupling striking the tubing can cause the coupling to become loose.

A tight coupling carries its load evenly distributed over the full bearing surface of its thread; a loose coupling will not. A loose coupling will become misaligned with its pin threads; and the vertical center line of the coupling and pin will not coincide at the instant that the upstroke begins. The lack of parallelism in the joint causes small areas of the threaded sections to carry all of the load for a brief unit of time. By visualizing a cut-away view of the pin and coupling, it can be easily understood that the point of maximum load (stress) in the coupling is at the point opposite the first fully engaged pin thread. This is the point where all of the well load has been transferred to the coupling. Also, by visualizing the cut-away view of the pin and coupling again, it can be easily seen that in any nonparallel configuration of the threads, the first fully engaged pin thread must engage the coupling even though it may be only a small section of that pin's threaded surface. It is at this point of limited contact that excessive ranges of stress occur and it is at this point of excessive stress that failures occur. In a well that has a PRL of 20,000 lb it would be quite easy to briefly exceed 70,000 psi for a small contact area of an eccentrically loaded coupling.

The problem of joint make-up has been a source of concern for a number of years. The S.M. Jones Company conducted a series of experiments during the late 30's in an attempt to correlate make-up prestress to make-up torque. At that time the industry was using cut threads and the pin was not undercut. A later report by that company, dated July 1, 1948, concluded that no hard and fast rule could be made for setting up the joints by using torque values. Interestingly, that same report stated, "A certain amount of practical application of marking the joint with a chalk mark across coupling and pin shoulder and then moving the two halves of this chalk mark apart a predetermined distance, has been used in the past." The API approached the problem by recommending specific torque values for each size sucker rod.

One problem encountered by this method was that a rough or dirty thread would require much more torque to achieve the correct prestress than would a clean, well lubricated thread. A great amount of the make-up torque would be expended in overcoming the resistance of the dirt or the varying resistance of an unlubricated thread.

Excessive lubrication on the pin shoulder will reduce the effectiveness of the pin prestress to hold the seating faces together. The tightness, or ability of the joint to remain seated, depends upon the friction between the coupling face and the pin shoulder. The pin and coupling threads serve primarily to transmit a compressive force to the coupling face and can be compared to adding weight to an empty box. An empty box slides quite easily across a steel deck but once that box is filled with tools it is much more difficult to slide. Keep in mind also that the box will slide more easily across an oily steel deck. This is essentially what happens when the pin shoulder or coupling face has excess lubrication. The amount of lubricant will not affect the circumferential displacement-prestress relationship but it will affect the ability of the coupling to remain fixed upon the pin shoulder under pumping conditions.

The weight added to an empty box can be compared to the pin prestress but it must be noted that excessive pin prestress can be as bad as not enough prestress. Figure 1 shows that while 7/32-in. displacement will correctly prestress a ¾-in. pin, an additional amount of displacement could cause the prestress to near the yield point of the pin. There have been cases where the operator felt that because 7/32-in. was good, 14/32-in. was better. Figure 1 shows that 14/32-in. displacement would give the pin an excess of 90,000 psi prestress which would exceed the yield point of the API Class C rod. If this yielded pin were put into operation, the additional well loads would immediately cause the joint to become loose and failure would occur in only a matter of hours. It can also be seen in Fig. 1 that even an additional amount of only 3/32 in. would cause a pin prestress of almost 70,000 psi which would also yield an API Class C rod. For this reason we caution everyone not to exceed the recommended values of circumferential displacement.

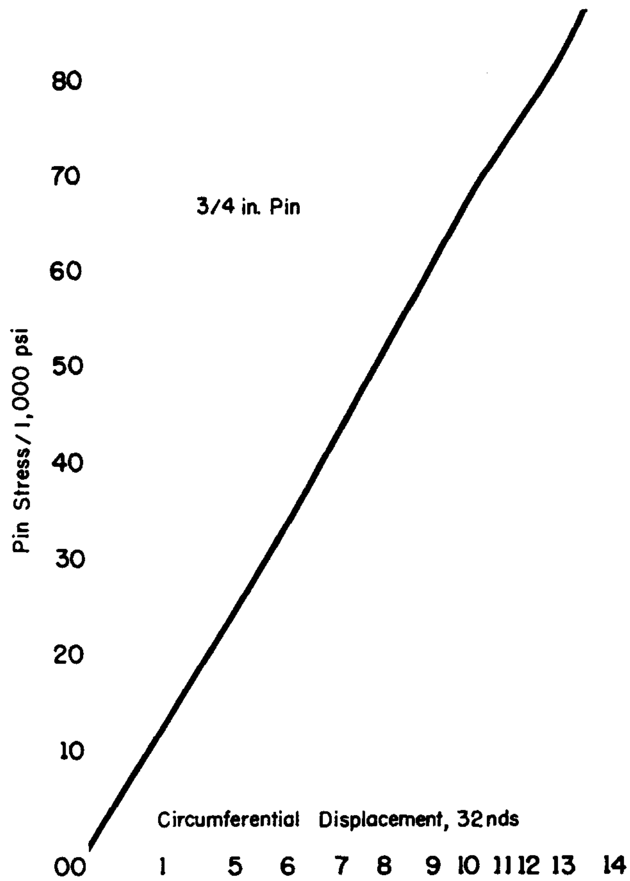

FIG. 1—CIRCUMFERENTIAL DISPLACEMENT VS PIN STRESS FOR ¾-IN. PIN

Additional studies on joint make-up were reported by Tex Ritterbusch in his article entitled, "What Torque On a Sucker Rod Joint?", and by Roger Smith in his article entitled, "Make-up of Sucker Rod Joints Using Power Tongs". Both reports dealt primarily with achieving pin prestress by applying predetermined torque to the joint, and both reports made the observation that snap wrenches were the least-accurate method of achieving correct pin prestress. Mr. Ritterbusch and Mr. Smith observed that the circumferential displacement, or chalk-line-measurement, method was an accurate way to assure proper make-up since this method was not related to joint friction.

The Norris sucker rod exhibit at the 1971 International Petroleum Exposition illustrated how impractical it is to run ⅞-in. rods with hand wrenches. Prestress by snap wrenches depends upon the skill and strength of the man using the wrenches. A wellhead mock-up was set up using a ⅞-in. joint exposed in its natural configuration.

The upper pin was welded to the coupling to aid in break-out. The lower pin had strain gages attached to the undercut and electrical leads connected the pin to a dial-type wall gage. Visitors were invited to make-up the joint to the recommended, minimum API prestress and the wall gage showed the true stress in the pin. It was estimated that fewer than 1.0% of those participating managed to achieve the minimum, recommended prestress, and then only after ten or more snaps of the hand wrenches. The message was quite clear; hand wrenches will not permit correct pin prestress for ⅞-in., and larger, sucker rods.

Power tongs eliminate variations in prestress due to fatique and human error and should be used where pin and coupling failures are a problem. The tongs may be adjusted prior to running the rods by using the circumferential displacement method. Figure 2 shows a sucker rod pin and coupling in the hand-tight position with the circumferential displacement marks placed. The second drawing in Fig. 2 shows the coupling and marks after the correct displacement has been achieved. Power tongs can be set by using this method. The coupling is made hand-tight on both ends, the marks are scribed and the tongs are set to trip (pressure relief valve lifts) when the displacement marks show that correct prestress has been achieved. Three or four joints should be carefully checked by this method and then the tongs need be checked only every 1000 ft to insure against mechanical malfunction.

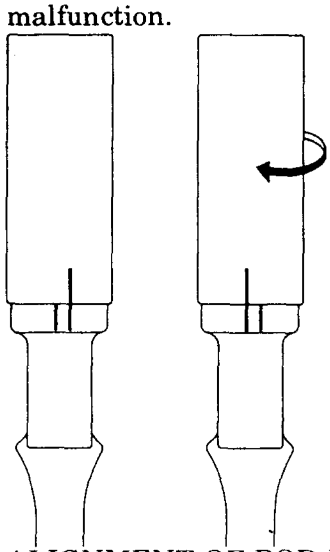

FIG. 2—ALIGNMENT OF ROD PIN AND COUPLING FROM HAND-TIGHT POSITION (LEFT) TO CORRECT CIRCUMFERENTIAL DISPLACEMENT (RIGHT) USING "NORMARK" CALIBRATIONS

Mr. Smith reports that for best results, the power tongs must be operated at moderate, consistent speeds. Repeated snapping of the joint through shifting and releasing the trigger valve was found to increase the pin stress with each application of torque. This type of operation could increase the pin stress until the pin yielded. Correct pin prestress is achieved when the tong's cutoff is activated - no additional surges of torque should be used.

Laboratory work using SR4 strain gages on the undercut section of sucker rod pins in conjunction with the tensile testing machine, has determined the following relationships with regard to prestress and well loads. Assume that a sucker rod pin had been prestressed to 40,000 psi and then a well load of 20,000 psi is applied to that joint. The 20,000-psi well load will be applied directly to the pin. However, in applying the 20,000-psi well load to the pin, the pin is elongated and the elongation of the pin reduces the compressive force in the coupling, thereby reducing the force exerted on the undercut section of the pin. The net result of these forces is that the pin is ultimately loaded to the prestress plus one-half of the well load, in this case 40,000 psi prestress, and the ultimate load would be 50,000 psi. Mr. Ritterbusch determined through calculation and experimentation that only 42-54% of the pumping load is added to the pin prestress when the string is put into service. Although this work was done in 1959, those percentages are still true today.

The Norris investigation of torque as related to prestress resulted in a lack of correlation; however, it was found that circumferential displacement was directly related to pin prestress. The method used for this determination was SR4 strain gages that were cemented to the undercut section of the pin. Small holes were drilled through the pin shoulder to permit electric leads to connect the SR4 strain gages to their associated instrumentation. The seating surfaces were then lightly lubricated with a 50-50 mixture of 40-weight oil and inhibitor, and the coupling was run to the hand-tight position. The instruments were then checked to be sure that they read zero stress. Varying increments of circumferential displacement were then applied to the joint. The prestress was recorded and after several hundred tests the resulting data provided reproducible values that were condensed into graph form. Figures 1, 3, and 4 represent some of the data determined from these hundreds of experiments. The circumferential displacement, strain gage work conducted by the W.C. Norris Engineering Dept. was submitted to the API in June, 1968 and this data was subsequently incorporated into the API 11 BR.

Once the data was reduced to graph form it became obvious that a designated prestress could be achieved by a circumferential displacement. Next it became a matter of consideration as to how much prestress would be correct for a sucker rod pin. From the determinations made earlier we knew that one-half of this well load stress would eventually be added to the prestress. As an example, assume a 40,000-psi prestress and add a 40,000-psi well load. The undercut section of the pin would then be subjected to the total of 60,000 psi. It was from this determination that it was decided to set the circumferential displacement values to achieve approximately 40,000-psi prestress in each pin. An additional result of this work is the "Normark", two vertical lines forged into all Norris sucker rods to make the circumferential displacement make-up easier.

An interesting phenomenon was observed during the strain gage tests. It was found that reproducible prestress could only be achieved by using rods that had previously been made-up and loosened. New rods would show lower than predicted prestress when made-up to the prescribed displacement, while these same rods would show the predicted stress after having been made-up and broken-out several times. It was found also that the harder rods (API Grade D) had less tendency to perform this way than did the softer rods (API Grades C and K). This same phenomenon had been observed by earlier experimenters using the preundercut, tapered thread pins. Then as now, the conclusion was reached that the pins must be made-up and broken-out in order to achieve uniform and reproducible results.

Although rod manufacturers use high precision rolling dies to make the threads on all sucker rod pins, it appears that there are some minor high

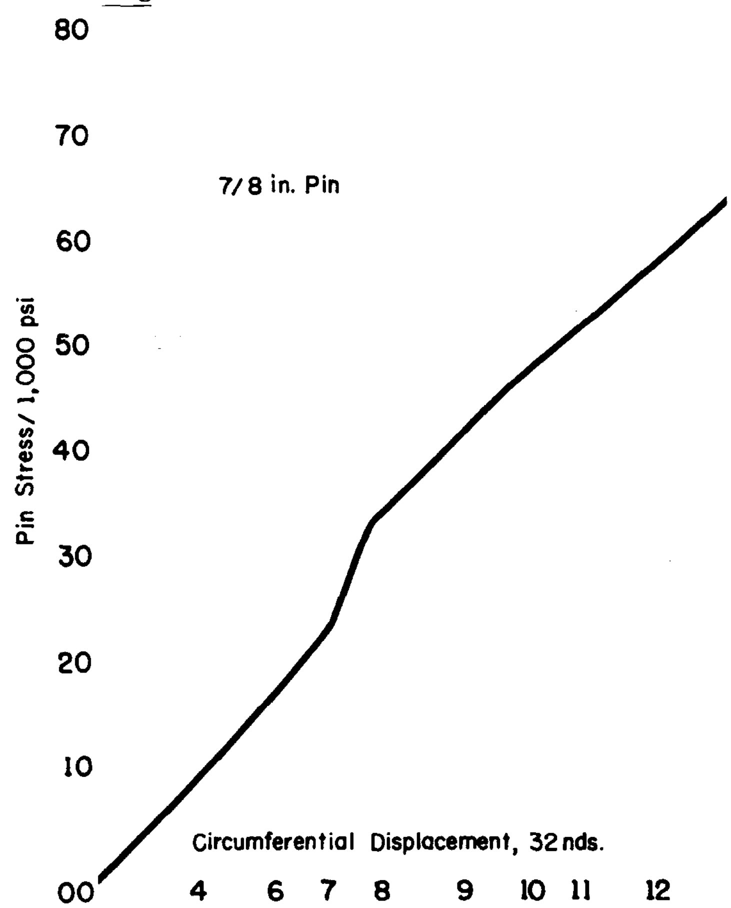

FIG. 3—CIRCUMFERENTIAL DISPLACEMENT VS PIN STRESS FOR ⅞-IN. PIN

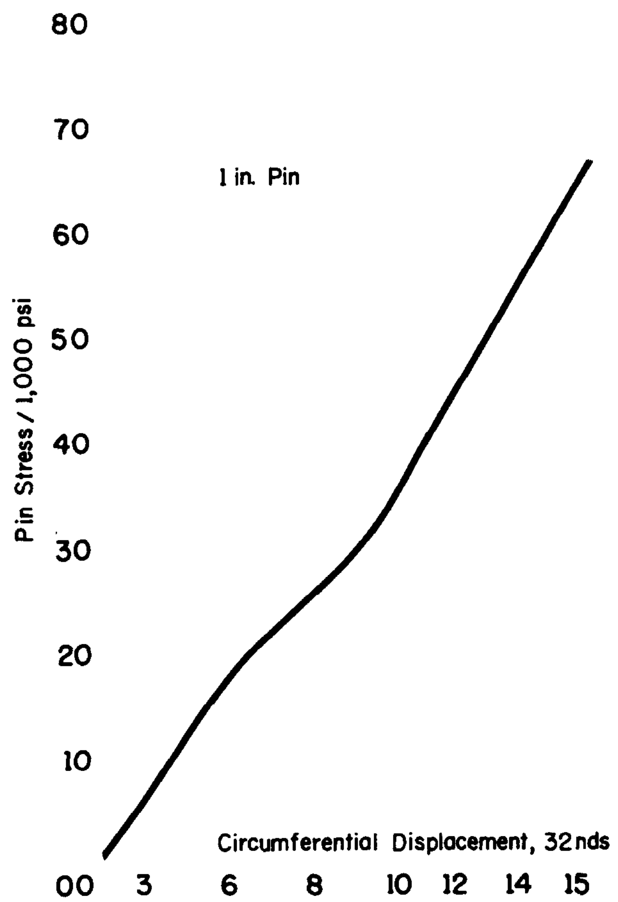

FIG. 4—CIRCUMFERENTIAL DISPLACEMENT VS PIN STRESS FOR 1-IN. PIN

spots on the mated surfaces that must be seated before the coupling threads are perfectly matched to the pin threads. This lack of uniformity is quite common in the automobile engine. Combustion cylinder intake and exhaust valves must be lapped in order to achieve a good seat even though they have been previously machined with a high degree of precision.

The API has therefore recommended two sets of values for achieving correct pin prestress by using circumferential displacement. One set of displacement values compensates for the iron-out in API Grade D rods while the second set of values are recommended for rerunning all rods. Because of the inherent variables in the API Grades C and K rods, these must be made-up and broken-out before using circumferential displacement. It should also be emphasized that both coupling pins must be ironed-out and measurement begun at the hand tight position on both ends of the coupling.

Some field men have reported that cold weather make-up will cause lower prestress due to the expansion of the joint as the metal is warmed by the production fluid. Theoretically, both the pin and coupling will expand together and therefore the prestress should remain constant. There are tests being conducted that are designed to evaluate this theory. Several pins have had SR4 strain gages attached to the undercut and will be used in conjunction with a cold box. The rods will be cooled, made-up, and then warmed to room temperature. Strain gage readings will be taken throughout this procedure and the results should provide enough information to determine whether special considerations should be given to cold weather operations on make-up.

The advent of the rolled thread greatly improved the fatigue resistance of the sucker rod pin and coupling threads. Combined with the tougher thread is the undercut pin which greatly reduced the range of stress on the pin. The total effect is to make the sucker rod joint better than ever but still not perfect. Although tubing sizes dictate joint sizes, the chief source of joint failure is still loose couplings and the best insurance against loose couplings is to have correct pin prestress. The problem has been studied for years and generally approached with an attempt to correlate pin prestress to torque. Recent investigations have shown that the circumferential displacement method of prestressing the sucker rod pin will consistently give reproducible results and has proven to be successful in the field.

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