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METHOD FOR CUTTING STEAM HEAT LOSSES DURING CYCLIC STEAM INJECTION OF WELLS

Contract DE-FG49-93CE 15600

SIXTH QUARTERLY REPORT

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METHOD FOR CUTTING STEAM HEAT LOSSES
DURING CYCLIC STEAM INJECTION OF WELLS

Contract DE-FG 49-93CE 15600

SIXTH QUARTERLY REPORT

PRELIMINARY SLOT-CUTTING TESTS AND MODIFIED HYDRAULIC TOOL DESIGN

ABSTRACT:

Slot-cutting tests were made in a 3.5"OD steel pipe representative of the proposed liner of the twin gravel-packed horizontal drainholes used in this Method, for the following purposes:

- 1) To determine the force required to punch through the liner wall in order to achieve its full penetration with a cutting wheel,
- 2) To select the most effective profile for the cutting wheel.

The results of these tests, made at UC-Berkeley indicated that, with four cutting wheels, as included in the tool design presented in the Fourth Quarterly Report, the total force required was nearly 60,000 lb. In view of the limited tool diameter, the creation of such a large force with a single piston required a hydraulic pressure which would exceed the capability of the Triplex pump, most commonly available in

the oil fields.

A re-design of the 4-wheel slot-cutting tool with two tandem pistons was done, but revealed a high degree of complexity, related to the difficulty of providing a high-pressure fluid path in the thin housing wall from the hydraulic cylinder above the first pair of arms to a cylinder for the tandem piston located below the first pair of cutter arms and operating the second pair of arms.

By reducing the number of cutting wheels from 4 to 3, a single piston driver was sufficient and could result in a tool much simpler to build and to maintain in the field. The 3-wheel design also makes it easily convertible to a tandem piston arrangement, in the event that an increased force would be required. It is also easily transformed into a 6-wheel tool by the addition of a second identical mechanism should this prove to be necessary.

The re-designed 3-wheel slot-cutting tool is presented here. It is currently under construction at UC-Berkeley. A second test program will follow, when this simplified modular tool has been assembled. The objective of this second series of tests is to determine the required characteristics of the opposing spring, or Belleville rings stack which, in the new design, is used for retraction of the cutters, rather than for their extension.

METHOD FOR CUTTING STEAM HEAT LOSSES
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FIFTH QUARTERLY REPORT

PRELIMINARY SLOT-CUTTING TESTS AND RE-DESIGN OF HYDRAULIC TOOL

1. PRELIMINARY TESTS DESCRIPTION AND RESULTS

It is difficult and rather unreliable to theoretically predict the amount of plastic deformation and the spring-back effect of a 3.5"OD pipe of relatively thick wall, even when the steel characteristics are fully known. With Oil Country Tubular Goods, a large variety of steels is used, all meeting specific API grade minimum requirements, which only concern their resistance to collapse under external pressure or to burst under internal pressure and the steel yield strength.

For this reason, an experimental determination on an actual

steel pipe was preferred. The pipe sample was longitudinally cut in half. The cut edges were then tangentially welded to the sides of a U-shaped welded steel channel of depth slightly greater than the pipe external radius. This welded assembly was then placed on the platen of an Instron Hydraulic Press, while the cutting arm and wheel was fastened to the piston (Fig.1).

The wheel penetration and the applied force were recorded for various penetration rates and for various profiles of the cutting wheel, all made from the same heat-treated tool steel of 53 HR hardness (Carbon Steel after Oil Quench @ 300 C following the heat-treating @ 840 C)

It was observed that plastic deformation of the pipe wall was large as indicated by the formation of a blister on the pipe's outer surface and that a wheel displacement somewhat greater than the pipe wall thickness were necessary in order to make a full penetration slot through which oil could flow freely with negligible pressure drop. The slot length was also measured for each test.

Three different wheel profiles were compared: a straight-sided profile of 37 degrees angle at the apex, a concave profile and a convex profile. The minimum applied force required to achieve a satisfactory slot was 13,000 lb with a convex wheel profile (Fig.2).

The minimum total force to be applied to two pairs of arms in order to make four parallel slots from a single piston stroke is therefore:
 $4 \times 13,000 \text{ lb} = 52,000 \text{ lb}.$

In all tests, the force required to retract the cutting wheel from the full-penetration slot was considerably smaller than 5,000 lb. This experimental result provided the opportunity to reduce the retraction rollers down to 5/16" OD.

With a tool housing ID of 2.49",the maximum force obtainable from a hydraulic tool operated at a pressure of 10,000 psi above the downhole well pressure is:

$10,000 \text{ psi} \times 3.14 \times 2.49'' \text{ sq.} / 4 = 48,670 \text{ lb}$,which is significantly lower than the 52,000 lb theoretically required by four cutting wheels.

Such a high force could only be obtained by adding a second piston operating in tandem,or by using a pump rated at a higher pressure. Although available from the manufacturer,these pump models are less common in the oil fields.

By reducing the number of arms to 3,instead of 4, the required force is reduced to 39,000 lb,which is well within the capability of the same single piston.

The corresponding excess force of 25% is expected to offset the friction forces.Nevertheless,the possibility of eventually adding a second piston operating in tandem,if necessary,remains desirable.

2.RE-DESIGN OF A SLOT-CUTTER WITH THREE ARMS AT 120 DEGREES FROM EACH OTHER

This configuration provides a more accurate centering of the tool within the pipe than that of two pairs of arms located one above the other.It also makes the tool shorter,a desirable feature for inserting it through bent pipes.

In view of the magnitude of the forces to be applied,it was decided to use a stronger steel alloy for all the moving parts.A Maraging Steel Alloy (18 % Ni),with a yield strength of 300,000 psi,after heat aging,but easily machinable prior to the aging treatment was selected.Its ultimate hardness is 65 HR.

The increased hardness of the cutting wheels, combined with their slightly increased diameter and reduced apex angle are expected to reduce below 13,000 lb the force required to achieve full penetration of the wheels of the re-designed tool through a 3.5"OD liner wall.

The over-all mechanical assembly is shown on Fig.3. The three arms pivot around three axes forming an equilateral triangle in the same plane perpendicular to the tool housing axis. The hydraulic piston drives a sliding guide bearing three pairs of rollers located respectively within the U-shaped arms, for the retraction rollers and against the arms back surface, for the extension rollers. The lower part of the sliding guide is connected to another piston applying pressure to the spring and closing the spring compartment which may also be filled with high-pressure gas, if necessary.

3.DETAILED DRAWINGS OF THE THREE-WHEEL SLOT CUTTING TOOL

Drawing Sheets 1 to 10 represent the various parts currently being machined at UC-Berkeley. Their first assembly and preliminary testing will be performed prior to the heat aging of the alloy steel, so that any minor adjustment of the parts could easily be made on the material in its relatively soft condition.

4.POTENTIAL ADDITION OF ANOTHER MECHANICAL MODULE

The pressurized hydraulic fluid may later be conveyed from the hydraulic cylinder near the top of the tool housing to a second cylinder located below the spring chamber through a small-diameter hole drilled through the middle part of the guide assembly. The fluid is then conveyed laterally through the Y Spacer to the Bottom part of the Sliding Guide and from there to the central tube of the spring

chamber. This tube passes through the head of the lower hydraulic cylinder, which is an integral part of the tool housing. It brings the hydraulic pressure through various "O" ring seals to the upper piston of the lower mechanical module.

5. POTENTIAL ADDITION OF A TANDEM HYDRAULIC PISTON

The same hydraulic fluid path may be used to convey the hydraulic pressure to the upper face of a lower hydraulic piston fastened to the end of the central tube of the spring chamber, below the lower hydraulic cylinder head.

In that case, the second modular mechanism is omitted and replaced by the tandem piston. The housing is closed at its bottom by the bull nose plug, which seals the lower gas-filled cylinder. This optional arrangement may boost the total force applied to the 3-wheel slot-cutter to nearly 90,000 lb, from a 10,000 psi hydraulic pump.

6. CONCLUSIONS

1) Preliminary tests on a fully-instrumented hydraulic press were used to determine the total force to be applied to the cutting wheels.

2) The re-designed 3-wheel slot cutter is more compact than the previously designed 4-wheel cutter.

3) The possibility of adding a second mechanical module to converted the tool into a 6-wheel cutter has been recognized.

4) The addition of only a second hydraulic piston, operating in tandem with the top one raises the capability of the tool to more than

twice the required force.

5) The use of a Maraging Steel Alloy for all the moving parts greatly increases their strength and hardness, while leaving the task of machining them relatively easy.

FIG. 1 TEST APPARATUS

Graph Press 11 CONVEX
===== 53 HRC

Date: 05/12/95 Time: 12:42:54

FORCE (lb.)

FIG. 2

TOOL ASSEMBLY

PIVOT RING (Middle Housing)

Sheet #1

Material: Carbon Steel

MIDDLE HOUSING (Bottom Threaded Nipple)

Sheet #2

Weld
Material:
Carbon Steel

CUTTING ARM

Number 3
Material: 18 Ni 300
(Maraging Steel)

1/2" OD Porous
Bronze Bushing

3/8" O.D. shaft
(Maraging Steel)

Scale 2/1

Section H H

Fork

1/2" OD
Bronze Bushing

3/8" OD shaft

Sheet # 3

Section EE

CUTTING WHEEL / ROLLERS Sheet # 4

Number: 3 Material: 18 Ni 300

Scale: 2/1

Pivot (Sheet #1)

Number:

③ 3/8" x 1" Long

③ 3/8" x 2.25" Plus ③ of 3/8" OD x 1" Long

(Pivots)

Extension Rollers

WHEEL PROFILE
DETAIL

Wheel Shaft
(Sheet #3)

beveled
or
Spherical end

Beveled End of 3 Pivots
Followed by drilling and
Threading to match
Set Screws on Sheet #1
Extension Roller Number: 3

Scale: 4/1

Retraction Roller (Sheet #7)
Number: ③

Scale: 2/1

SLIDING GUIDE (Bottom Part) Sheet # 5

Material: 18 Ni 300

SLIDING GUIDE (Bottom Part) Sheet #6

Material: 18 Ni 300

SECTION FF

Scale 2/1

SLIDING GUIDE

Sheet #7 Rev.

Pass-thru of Cutting Arm

Roller Support $\frac{5}{16}$ " ID

$\frac{1}{2}$ " deep recess
1" LD (existing)

Scale 2/1

$\frac{1}{16}$ " recess on
bottom
surface

Pass Thru of
Arm Pivot Head

Female Threads for $\frac{1}{8}$ " screw

Approx.
thickness
 $\frac{3}{8}$ "

Bottom Plug

Nut

Approx.
thickness
 $\frac{1}{2}$ "

SLIDING GUIDE

(Middle Part)

Material: 18 Ni 300

SLIDING GUIDE
CONNECTOR ROD
Material: 18 Ni 300

Number: 1

Bolt equipped w/ "O" Ring for
AIR PISTON ONLY

HYDRAULIC OR AIR
PISTON

Horiz. Scale 2/1

Vert. Scale 1/1

Bolt "O" Ring

Piston "O" Ring
Section NN

Threads Matching
Top of
Connector

Scale: 2/1

Spacer + Hole for Bolt
equipped w/ "O" Ring for AIR PISTON ONLY

Top View