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(54) **A SEAMLESS STEEL TUBE FOR WORK-OVER RISER AND METHOD OF MANUFACTURING**

(57) The present invention describes a seamless steel tube for work-over risers comprising in weight per cent, carbon 0.23-0.29, manganese 0.45-0.65, silicon 0.15-0.35, chromium 0.90-1.20, molybdenum 0.70-0.90, nickel 0.20 max, nitrogen 0.010 max, boron 0.0010-0.0030, aluminum 0.010-0.045, sulfur 0.005 max, phosphorus 0.015 max, titanium 0.005-0.030, niobium 0.020-0.035, copper 0.15 max, arsenic 0.020 max, calcium 0.0040 max, tin 0.020 max, hydrogen 2.4 ppm

max, the rest are iron and inevitable impurities, consisting of a geometry in which ends of the tube have an increased wall thickness and outer diameter and having a yield strength of at least of 620 MPa (90 ksi) throughout the whole length of a tube body and in tube ends. The present invention also describes methods for manufacturing a seamless steel tube for work-over risers having a yield strength at least of 620 MPa (90ksi) both in a tube body and in tube ends.

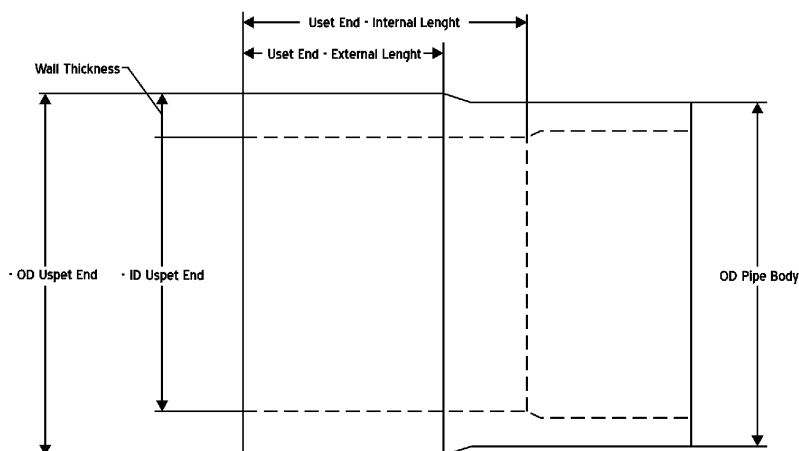


FIG. 1

Description**FIELD OF THE INVENTION**

[0001] This invention relates to a seamless steel tube for risers used in work-over operations.

BACKGROUND OF THE INVENTION

[0002] The requirements for operating a well in the seabed involve a plurality of systems and equipment including drilling, production and work-over risers.

[0003] A drilling riser is a pipe between a seabed blow-out preventer (BOP) and a floating drilling rig which is a drilling unit not permanently fixed to the seabed such as a drillship, a semi-submersible or jack-up unit. A drilling rig is meant to be the derrick and its associated machinery.

[0004] A production riser is a pipeline carrying oil or gas that joins a seabed wellhead to a deck of a production platform or a tanker loading platform.

[0005] A work-over riser is a flowline which is used to carry on a well work-over, which is performed on an existing well and may involve re-evaluating the production formation, clearing sand from producing zones, jet lifting, replacing downhole equipment, deepening the well, acidizing or fracturing or improving the drive mechanism.

[0006] In recent years such work-over operations have been increasingly carried out using coiled or continuous reel tubing as disclosed in US4281716 (Standard Oil Co. Indiana).

[0007] However, according to W09816715 (Kvaerner Eng.), there are several advantages using a continuous single tube when entering a live oil or gas well. This means the well does not have to be killed, (i.e. a heavy fluid does not have to be pumped down the production tubing to control the oil or gas producing zone by the effect of its greater hydrostatic pressure). Continuous tubing has the advantage of also being able to pass through the tubing through which the oil and/or gas is being produced, without disturbing the tubing in place.

[0008] Taking in account that work-over risers are subjected to fatigue and load stresses besides of corrosion attack, pipes used in this environment are likely to have fatigue and corrosion resistance properties to accomplish a good performance, reduce both, the weight of the riser string and the bending loads in the wellhead and the platform interface.

[0009] Also, these pipes need to have a good welding performance just to be welded to weld-on-connectors to build the string.

OBJECT OF THE INVENTION

[0010] A first object of the invention is to provide a seamless steel tube to be used as a riser in work-over operations with a specific chemistry design and microstructure consisting of a geometry in which ends of the tube have an increased wall thickness and outer diameter to reduce the weight of the riser string.

[0011] A second object is to provide a seamless steel tube for the application as a work-over riser with a specific chemistry design and microstructure consisting of a geometry in which ends of the tube have an increased wall thickness and outer diameter to reduce the bending loads in the wellhead and the platform interface.

[0012] A third object of the invention is to provide a method of manufacturing of a seamless steel tube for the application as a work-over riser with a specific chemistry design and microstructure consisting of a geometry in which ends of the tube have an increased wall thickness and outer diameter using upsetting techniques.

[0013] A fourth object of the invention is to provide a method of manufacturing of a seamless steel tube for the application as a work-over riser with a specific chemistry design and microstructure consisting of a geometry in which ends of the tube have an increased wall thickness and outer diameter using machining techniques.

[0014] A fifth object of the invention is to provide a method of manufacturing of a seamless steel tube for the application as a work-over riser with a specific chemistry design and microstructure consisting of a geometry in which ends of the tube have an increased wall thickness and outer diameter able to guarantee the mechanical characteristics to have high fatigue and corrosion resistance and a good welding performance.

[0015] Also, the tubes used as work-over risers may be reused meaning an economical saving.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016]

Figure 1 illustrates a preferred embodiment of the work over riser of the present invention with upset ends.

Figure 2 shows a graphical representation of the Tensile test results (YS and UTS) from upset and pipe body sections from material in the as-quenched and tempered condition of the different industrial trials.

Figure 3 shows a graphical representation of the HRC hardness values from upset and pipe body sections showing the achievement of the minimum % of martensitic transformation from material in the as-quenched condition of the production of both dimensions.

Figures 4 and 5 show a graphical representation of the HRC hardness values from upset and pipe body sections showing the individual hardness readings dispersion as a function of the location through the thickness (OD, MW & ID) from material in the as-tempered condition of the production of 7"OD x 17.5 mm WT dimension and 8 5/8" OD x 15.9mm WT dimension, respectively.

Figure 6 shows a graphical representation of the transverse CVN impact testing results at -20°C from upset and pipe body sections of the production of both dimensions showing the individual toughness values dispersion as per specification from material in the as-tempered condition.

Figure 7 shows the austenitic grain size reported in 9/10 ASTM in the pipe body and 8/9 ASTM in the upset end.

Figure 8 shows transverse section photomicrographs showing a microstructure constituted by martensite through the wall thickness of the pipe body section of quenched material for Nital 2% in 300X magnification.

Figure 9 shows transverse section photomicrographs showing a microstructure constituted by martensite in the upset end of as-quenched material for Nital 2% in 300X magnification.

Figure 10 shows transverse section photomicrographs, showing a microstructure constituted by tempered martensite in the pipe body of quenched & tempered material for Nital 2% in 300X magnification.

Figure 11 shows transverse section photomicrographs, showing a microstructure constituted by tempered martensite in the upset end of quenched & tempered material for Nital 2% in 300X magnification.

Figure 12 shows microstructural observations of as quenched material at the pipe machined body and the end zones revealing a prior austenitic grain size of 8/9 in both zones measured by the saturation method as per ASTM E-112.

Figure 13 shows transverse section photomicrographs showing a microstructure constituted by martensite through the wall thickness of the machined pipe body section of quenched material for Nital 2% in 300X magnification.

Figure 14 shows transverse section photomicrographs showing a microstructure constituted by martensite through the wall thickness of the pipe end section of quenched material for Nital 2% in 300X magnification.

Figure 15 shows transverse section photomicrographs showing a microstructure constituted by tempered martensite through the thickness of the pipe body section of quenched and tempered material. for Nital 2% in 300X magnification.

Figure 16 shows transverse section photomicrographs showing a microstructure constituted by tempered martensite through the thickness of the pipe end section of quenched and tempered material for Nital 2% in 300X magnification.

BRIEF SUMMARY OF THE INVENTION

[0017] The present invention describes a seamless steel tube to be used as a riser in work-over operations with a specific chemistry design and microstructure consisting of a geometry in which ends of the tube have an increased wall thickness and outer diameter. The alloy design is based on high strength requirements. The main features of the chemical composition of the tube include 0.23-0.28 wt % C, 0.45 -0.65 wt % Mn, and other alloying elements such as Mo, and Cr to achieve the required percentage of martensitic transformation. In addition, microalloying elements such as Ti and Nb are used as grain refiners. Low content of residual elements such as S and residual elements such as Cu and P are used to avoid any corrosion problem related to inclusions promotion and segregation at grain boundaries which decrease the corrosion performance, the hydrogen content was kept below 2.4 ppm to avoid any problem related to hydrogen entrapment and decrease of the corrosion performance.

[0018] The production route for manufacturing the upset seamless pipe for the application of as Work Over Riser, includes the following steps: steel casting (Continuous Cast Bar), seamless pipe rolling (MPM process), pipe ends upsetting, heat treatment, destructive testing (including microcleanliness, austenitic grain size, calculate % of martensitic transformation, tensile, hardness, toughness, SSC testing), dimensional control of pipe body and upset ends (outside diameter, out of roundness, excentricity, straightness, internal diameter, length), machining of external and internal upset end, dimensional control (internal diameter, outside diameter and machined length), drift testing at the upset ends, non-destructive testing (NDT) of upset ends, weighing, measuring and marking, external surface visual inspection, UT inspection of pipe body and UT inspection of upset ends (cylindrical section only).

[0019] The production route for manufacturing the machining seamless pipe for the application of as Work Over Riser includes the following steps: steel casting (Continuous Cast Bar), seamless pipe rolling (MPM process), heat treatment, destructive testing (including microcleanliness, austenitic grain size, calculate % of martensitic transformation, tensile, hardness, toughness, SSC testing), dimensional control of pipe body (outside diameter, out of roundness, straightness, internal diameter, length), machining from external surface the complete length of the pipe by programming CNC lath machine in order to achieve final dimensions at the ends, dimensional control (internal diameter, outside diameter, out of roundness, straightness, and length) of pipe body and machined ends, drift testing at the ends, non-destructive testing (NDT) of ends, weighing, measuring and marking, external surface visual inspection, UT inspection of machined pipe body and UT inspection of ends (cylindrical section only).

[0020] The combination of chemical composition and tight control of heat treatment parameters allows achieving the adequate microstructure after quench and temper in order to achieve the mechanical properties and pass the SSC Method A tests requirements described above.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION

[0021] The chemical composition of the seamless steel tube of the present invention comprises in weight per cent: carbon 0.23-0.29, manganese 0.45-0.65, silicon 0.15-0.35, chromium 0.90-1.20, molybdenum 0.70- 0.90, nickel 0.20 max, nitrogen 0.010 max, boron 0.0010-0.0030, aluminum 0.010-0.045, sulfur 0.005 max, phosphorus 0.015 max, titanium 0.005-0.030, niobium 0.020-0.035, copper 0.15 max, arsenic 0.020 max, calcium 0.0040 max, tin 0.020 max, hydrogen 2.4 ppm max, the rest are iron and inevitable impurities.

[0022] A more preferred composition comprises: carbon 0.25-0.28, manganese 0.48-0.58, silicon 0.20-0.30, chromium 1.05-1.15, molybdenum 0.80- 0.83, nickel 0.10 max, nitrogen 0.008 max, boron 0.0016-0.0026, aluminum 0.015-0.045, sulfur 0.0030 max, phosphorus 0.010 max, titanium 0.016-0.026, niobium 0.025-0.030, copper 0.10 max, arsenic 0.020 max, calcium 0.0040 max, tin 0.015 max, hydrogen 2.0 ppm max, the rest are iron and inevitable impurities.

[0023] The seamless steel tubes have a geometry, in which ends of tubes have an increased wall thickness and outer diameter, and following mechanical properties:

In the as-quench condition

90% of martensitic transformation when evaluated according to the following formulae: $HRC_{min} = (58 \times \%C) + 27$
Austenitic grain size as per ASTM minimum 5 or finer

In the as-quench and temper condition

Longitudinal Tensile Test (round standard specimens when wall thickness equal or above 1" and longitudinal strip specimens when wall thickness below 1").

Minimum Yield Strength: 90ksi (620 MPa)

Maximum Yield Strength: 105ksi (724 MPa)

Minimum Ultimate Tensile Strength: 100ksi (690 MPa)

Minimum Elongation (L = 4D): 18%

Yield to Tensile Ratio ≤ 0.92

Transverse Charpy Test (using 10x10 mm specimen)

Minimum individual Absorbed Energy: 30 Joules

Minimum Average Absorbed Energy: 40 Joules

Maximum Hardness value: 25.4 Hrc (value as per API 5CT means average per row)

Microcleanliness acceptance criteria as per ASTM E-45 A: A, B, C, D all below 2

Compliance with NACE, acceptance criteria: Passing SSC

Method A test as per NACE TM0177-2005, using test solution (A), testing at 85%SMYS, test period 720 hours.

[0024] The geometry of seamless steel tube of the present invention and the mechanical characteristics are obtained by two methods of manufacturing: upsetting and machining.

[0025] The upsetting manufacturing method comprises the following steps:

(a) providing a steel tube containing a composition in weight per cent, carbon 0.23-0.29, manganese 0.45-0.65, silicon 0.15-0.35, chromium 0.90-1.20, molybdenum 0.70- 0.90, nickel 0.20 max, nitrogen 0.010 max, boron 0.0010-0.0030, aluminum 0.010-0.045, sulfur 0.005 max, phosphorus 0.015 max, titanium 0.005-0.030, niobium 0.020-0.035, copper 0.15 max, arsenic 0.020, calcium 0.0040 max, tin 0.020 max, hydrogen 2.4 ppm max, the rest are iron and inevitable impurities, obtained by rolling process (MPM process)

(b) upsetting of tube ends;

(c) austenitizing between 850-930°C the full length of the tube; and

(d) quenching and tempering between 630-720°C

(e) destructive testing (including microcleanliness, austenitic grain size, calculate % of martensitic transformation, according to the formulae $HRC_{min} = (58 \times \%C) + 27$, tensile, hardness, toughness, SSC testing)

(f) dimensional control of pipe body and upset ends (outside diameter, out of roundness, eccentricity, straightness, internal diameter, length)

(g) machining of external and internal upset end

(h) dimensional control (internal diameter, outside diameter and machined end)

(i) drift testing at the upset ends

(j) non-destructive testing of upset ends, weighing, measuring and marking, external surface visual inspection, UT inspection of pipe body and UT inspection of upset ends.

[0026] The machining manufacturing method comprises the following steps:

(a) providing a steel tube containing a composition in weight per cent, carbon 0.23-0.29, manganese 0.45-0.65, silicon 0.15-0.35, chromium 0.90-1.20, molybdenum 0.70- 0.90, nickel 0.20 max, nitrogen 0.010 max, boron 0.0010-0.0030, aluminum 0.010-0.045, sulfur 0.005 max, phosphorus 0.015 max, titanium 0.005-0.030, niobium 0.020-0.035, copper 0.15 max, arsenic 0.020, calcium 0.0040 max, tin 0.020 max, hydrogen 2.4 ppm max, the rest are iron and inevitable impurities, obtained by rolling process (MPM process)

(b) heat treatment of pipes (austenitizing between 850-930°C the full length of the tube; and quenching and tempering between 630-720°C)

(c) destructive testing (including microcleanliness, austenitic grain size, calculate % of martensitic transformation according to the formulae, tensile, hardness, toughness, SSC testing)

(d) dimensional control of pipe body (OD, out of roundness, straightness, ID, length)

(e) machining from external surface the complete length of the pipe by programming CNC lathe machine in order to achieve final dimensions at the ends,

(f) dimensional control (ID, OD, out of roundness, straightness and length) of pipe body and machined ends

(g) drift testing at the ends,

(h) non destructive testing (NDT) of ends, weighing, measuring and marking, external surface visual inspection, UT inspection of machined pipe body and UT inspection of machined ends (cylindrical section only).

[0027] Both methods are also performed providing a seamless steel pipe with the preferred composition, as disclosed above.

[0028] The seamless steel tube of the present invention may be divided into two zones. As shown in Figure 1, there is an increased wall thickness and diameter end with internal and external length (upsetting or machined zone) and the tube body. Due to a combination of the manufacturing methods and the chemistry design, both the whole tube body and the ends have the same yield strength of at least 620 MPa (90 ksi) (YS) and at most 724 MPa (105 ksi), a Yield to Tensile Ratio not greater than 0.92, also, the same ultimate tensile strength (UTS) of at least 690 MPa (100 ksi), elongation of at least 18%, hardness Rockwell of at most 25.4 HRC (value as per API 5CT means average per row) and corrosion resistance (Compliance with NACE, acceptance criteria: Passing SSC Method A test as per NACE TM0177-2005, using test solution (a), testing at 85%SMYS, test period 720 hours). Prior Austenitic Grain Size is 5 or less. The product after the quench heat treatment process shall comply with Prior Austenitic Grain Size (PAGS) is 5 or less a microstructure of at least 90% martensite in the as-quench condition.

[0029] The tubes may be utilized in sour and non-sour service.

[0030] The tubes' nominal diameter to be upsetted ends may be from 4 ½" to 10 ¾".

[0031] The tubes' nominal diameter which ends will to be machined may be from 4 ½" to 18" due to the manufacturing facilities.

[0032] The tubes' thickness ranges from 10 mm to 50 mm.

Examples

Example 1

[0033] Two industrial development trials for two dimensions of tubes (8 5/8" ODx15.9 mm WT and 7" OD x 17.5 mm WT) were carried on. The chemistry design is shown in Table 1 and the desired ranges of mechanical properties are shown in Table 2.

Table 1

Element	Minimum	Maximum
C	0.25	0.28
Mn	0.48	0.58
Si	0.20	0.30
P	0	0.010
S	0	0.0030
Mo	0.80	0.83
Cr	1.05	1.15

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(continued)

Element	Minimum	Maximum
Nb	0.025	0.030
Ni	0	0.10
Cu	0	0.10
Sn	0	0.015
Al	0.015	0.045
Ti	0.016	0.026
As	0	0.020
Ca	0	0.0040
B	0.0016	0.0026
N	0	0.008
H	0	2.0

Table 2

Property	Min	Max
Yield Strength EUL 0.5% (MPa)	620	724
Ultimate Tensile Strength (MPa)	690	n/a
Yield to Tensile Ratio (Y/T)		0.92
Elongation (%) (L=4D)	18	-
Individual Absorbed Energy At -20°C (J)	30	-
Average Absorbed Energy At -20°C (J)	40	-
Hardness Rockwell HRC-value (tempered condition)	n/a	25.4*
Microcleanliness (acceptance criteria as per ASTM E-45A: A, B, C, D)	-	2
Corrosion	Test period	Solution
NACE TM0177-2005 SSC Method A- 85% SMYS	720 hrs.	A
*API 5CT: value= average per row		

[0034] The upsetting manufacturing operation was performed following the steps of:

- The pipe ends in the as-rolled condition were heated up to the appropriate forging temperature heating the calculated pipe length. The upsetting operation takes place at a minimum temperature of 1000°C.
- Once the heating cycle was accomplished, pipe ends were upset with the appropriate die and tooling design for each particular dimension.
- Inspection was then made on pipes' external and internal surfaces after each strike/punch in order to find any possible defect generated by the upsetting operation.

[0035] Special care was taken into consideration when designing the heating curve to be use during the heat treatment process in the austenitizing furnace (860-940°C) and the tempering furnace (640-720°C) for the upset ends of the 8 5/8"OD product. After austenitizing heat treatment process, the pipe must enter the quenching process above AC3 to guaranteed through-wall transformation. Then, for the 7"OD product, a few heat treatment adjustments were made on the heating curves based on the results obtained from the other dimension 8 5/8" OD pipe.

[0036] The actual temperatures from the pipe body and upset ends outer surface were carefully measured throughout the trial stages right at the entrance of the pipes into the quenching head by using a manual pyrometer in addition to the furnace pyrometers.

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[0037] After the heat treatments, a mechanical characterization was performed. From the as-quenched material, the % of martensitic transformation was calculated. Tensile, hardness, and toughness tests were performed on the quenched and tempered material on both upset and pipe body sections. Specifications were met; good hardenability, yield strength values of over 92 ksi as-tempered HRC values below the maximum allowed (25.4 HRC) and absorbed energy higher than 100 Joules at the specified temperature of -20°C.

[0038] Extensive destructive characterization and corrosion SSC Method A (NACE Standard Tensile Test, TMO177-96) were also conducted.

[0039] Homogeneity in tensile properties, hardness and toughness test results are a consequence of a very homogeneous microstructure through the wall on both upset end and pipe body in the as quenched and tempered condition. Figures 2 through 5 illustrate several graphical representations of the mechanical properties including hardness.

[0040] The austenitic grain size was measured on as-quenched material by the saturation method as per ASTM E-112. As shown in Figure 6, the grain size reported on the samples were 9/10 in the pipe body which was above the required size since the minimum required was 5. The upset samples showed a grain size of 8/9 and 9/10 complying with the specifications as illustrated in Figure 6.

[0041] The transversal face to the rolling axis was metallographically prepared and etched with Nital 2% to perform microstructural observations with an optical microscope. (Nital: Solution of 2% of Nitric acid in Ethyl Alcohol).

[0042] In the as-quenched samples, a martensitic microstructure was observed on OD, ID and MW sections through the thickness achieving a martensitic transformation of over 90% measured from the HRC hardness values as shown in Figures 8 and 9.

[0043] In the as-quench and tempered material, a microstructure constituted by tempered martensite was observed through the thickness as shown in Figures 10 and 11.

[0044] The microstructures observed in as-quenched material were mainly martensitic with over 95% of martensitic transformation through the entire thickness of the pipe on both pipe body and upset which indicates that the temperature at which the pipe entered the quenching stage and the quenching itself were homogeneous. On the other hand, the microstructures observed in tempered material, tempered martensite was present through the thickness.

[0045] The material passed the SSC Method A test at 85%SMYS as per NACE TM0177-96 accomplishing the 720 hours.

Corrosion Testing Results as per NACE Method A

NACE TM-0177-96 Method A										
	Sample	Location	Heat	Specimen	Initial Diameter	Initial PH	Final Diameter	Final PH	Stress Applied SMYS%	Result
	98449	Upset	19874	A	6,39	2,69	6,21	3,64	85	NF*
	98449	Upset	19874	B	6,42	2,69	6,33	3,62	85	NF*
	98449	Upset	19874	C	6,4	2,69	6,29	3,69	85	NF*
	8448	Pipe Body	19874	A	6,36	2,66	6,24	3,53	85	NF*
	8448	Pipe Body	19874	B	6,41	2,66	6,31	3,51	85	NF*
	8448	Pipe Body	19874	C	6,4	2,66	6,29	3,52	85	NF*
	98448	Upset	19874	A	6,37	2,66	6,22	3,5	85	NF*
	98448	Upset	19874	B	6,37	2,66	6,2	3,5	85	NF*
	98448	Upset	19874	C	6,4	2,66	6,33	3,49	85	NF*
*NF: Not failed										

Example 2

[0046] An industrial development trial for a dimension of tube (8.26" OD x 44 mm WT and 9.97" OD x 41 mm WT) were carried on. The chemistry design is shown in Table 1 and the desired ranges of mechanical properties are shown in Table 2 of Example 1.

[0047] The pipe was rolled in a heavy wall condition. The wall thickness was about 44 mm.

[0048] After rolling, heat treatment is performed. Similar considerations about this step were made such as in Example 1 to obtain through wall transformation.

[0049] After heat treatment of pipes, detail mechanical characterization was performed such as in Example 1. Dimensional control of the outside diameter (OD), out of roundness, inside diameter (ID) and length of pipes was carried on followed by the UT inspection.

[0050] In order to achieve final dimensions, the complete length of pipe body was machined from external surface by programming CNC lath machine.

[0051] Once again, a dimensional control of pipes after machining was carried out.

[0052] For quality purposes, non destructive inspection of straight pipe body section using automatic UT and manual for the cylindrical ends.

[0053] As in Example 1, a mechanical characterization was performed, calculating the % of martensitic transformation from the as-quenched material. On the quenched and tempered material, tensile, hardness, and toughness tests were performed on both machined ends and pipe body sections. Specifications were met; good hardenability, yield strength values of over 94 ksi as-tempered HRC values below the maximum allowed (25.4 HRC) and absorbed energy higher than 100 Joules at the specified temperature of -20°C.

[0054] Extensive destructive characterization and corrosion SSC Method A (NACE Standard Tensile Test, TMO177-96) were also conducted.

[0055] Homogeneity in tensile properties, hardness and toughness test results are a consequence of a very homogeneous microstructure through the wall on both machined ends and pipe body in the as quenched and tempered condition.

[0056] Microstructural observations of as-quenched material at the pipe machined body and the ends zones reveal a prior austenitic grain size of 8/9 in both zones measured by the saturation method as per ASTM E-112. The modified end on the analyzed sample showed a grain size of 8/9 complying with the specifications as shown in Figure 12.

[0057] The transversal face to the rolling axis was metallographically prepared and etched with Nital 2% to perform microstructural observations with an optical microscope. (Nital: Solution of 2% of Nitric acid in Ethyl Alcohol).

[0058] In the as-quenched sample, a martensitic microstructure was observed on OD, ID and MW sections through the thickness achieving a martensitic transformation of over 90% measured from the HRC hardness values as shown in Figures 13 and 14.

[0059] In the as-quench and tempered material, a microstructure constituted by tempered martensite was observed through the thickness as shown in Figures 15 and 16.

[0060] The material passed the SSC method A test at 85%SMYS as per NACE TM0177-2005 accomplishing the 720 hours.

Claims

1. A seamless steel tube for work-over risers comprising in weight per cent, carbon 0.23-0.29, manganese 0.45-0.65, silicon 0.15-0.35, chromium 0.90-1.20, molybdenum 0.70- 0.90, nickel 0.20 max, nitrogen 0.010 max, boron 0.0010-0.0030, aluminum 0.010-0.045, sulfur 0.005 max, phosphorus 0.015 max, titanium 0.005-0.030, niobium 0.020-0.035, copper 0.15 max, arsenic 0.020 max, calcium 0.0040 max, tin 0.020 max, hydrogen 2.4 ppm max, the rest are iron and inevitable impurities, consisting of a geometry in which ends of the tube have an increased wall thickness and outer diameter and having a yield strength of at least of 620 MPa (90 ksi) throughout the whole length of a tube body and in tube ends.

2. A seamless steel tube for work-over risers comprising in weight per cent, carbon 0.25-0.28, manganese 0.48-0.58, silicon 0.20-0.30, chromium 1.05-1.15, molybdenum 0.80- 0.83, nickel 0.10 max, nitrogen 0.008 max, boron 0.0016-0.0026, aluminum 0.015-0.045, sulfur 0.0030 max, phosphorus 0.010 max, titanium 0.016-0.026, niobium 0.025-0.030, copper 0.10 max, arsenic 0.020 max, calcium 0.0040 max, tin 0.015 max, hydrogen 2.0 ppm max, the rest are iron and inevitable impurities consisting of a geometry in which ends of the tube have an increased wall thickness and outer diameter and having a yield strength of at least 620 MPa (90 ksi) throughout the whole length of a tube body and in tube ends.

3. A seamless steel tube for work-over risers according to claim 1 wherein the following mechanical properties in the as-quench condition 90% of martensitic transformation when evaluated according to the following formulae: $HRC_{min} = (58 \times \%C) + 27$, austenitic grain size as per ASTM minimum 5 or finer in the as-quench and temper condition, longitudinal Tensile Test (round standard specimens when wall thickness equal or above 1" and longitudinal strip specimens when wall thickness below 1"), at least Yield Strength of 620 MPa (90ksi), Maximum Yield Strength of 724 MPa (105ksi), Minimum Ultimate Tensile Strength, 690 MPa (100 ksi), Minimum Elongation (L = 4D), 18%, Yield

to Tensile Ratio ≤ 0.92 , Transverse Charpy Test, Minimum individual Absorbed Energy: 30 Joules, Minimum Average Absorbed Energy: 40 Joules, Maximum Hardness value, 25.4 HRC (value as per API 5CT means average per row), Microcleanliness acceptance criteria as per ASTM E-45 A: A, B, C, D all below 2, Passing SSC Method A test as per NACE TM0177-2005, using test solution (A), testing at 85%SMYS, test period 720 hours, throughout the whole length of a tube body and in tube ends.

4. A seamless steel tube for work-over risers according to claim 2 wherein the following mechanical properties in the as-quench condition at least 90% of martensitic transformation when evaluated according to the following formulae: $HRC_{min} = (58 \times \%C) + 27$, austenitic grain size as per ASTM minimum 5 or finer in the as-quench and temper condition, longitudinal Tensile Test (round standard specimens when wall thickness equal or above 1" and longitudinal strip specimens when wall thickness below 1"), at least a Yield Strength of 620 MPa (90ksi), a Maximum Yield Strength of 724 MPa (105ksi), a Minimum Ultimate Tensile Strength, 690 MPa (100 ksi), a Minimum Elongation (L = 4D), 18%, Yield to Tensile Ratio ≤ 0.92 , Transverse Charpy Test, Minimum individual Absorbed Energy: 30 Joules, Minimum Average Absorbed Energy: 40 Joules, Maximum Hardness value, 25.4 HRC (value as per API 5CT means average per row), Microcleanliness acceptance criteria as per ASTM E-45 A: A, B, C, D all below 2, Passing SSC Method A test as per NACE TM0177-2005, using test solution (A), testing at 85%SMYS, test period 720 hours, throughout the whole length of a tube body and in tube ends.

5. A method for manufacturing a seamless steel tube for work-over risers having a yield strength at least of 620 MPa (90ksi) both in a tube body and in tube ends comprising the following steps of:

(a) providing a steel tube containing a composition in weight per cent, carbon 0.23-0.29, manganese 0.45-0.65, silicon 0.15-0.35, chromium 0.90-1.20, molybdenum 0.70- 0.90, nickel 0.20 max, nitrogen 0.010 max, boron 0.0010-0.0030, aluminum 0.010-0.045, sulfur 0.005 max, phosphorus 0.015 max, titanium 0.005-0.030, niobium 0.020-0.035, copper 0.15 max, arsenic 0.020 max, calcium 0.0040 max, tin 0.020 max, hydrogen 2.4 ppm max, the rest are iron and inevitable impurities;

(b) upsetting of tube ends;

(c) austenitizing between 850-930°C the full length of the tube; and

(d) quenching and tempering between 630-720°C

6. A method for manufacturing a seamless steel tube for work-over risers according to claim 5 further comprising the following steps:

(e) destructive testing (including microcleanliness, austenitic grain size, calculate % of martensitic transformation, tensile, hardness, toughness, SSC testing)

(f) dimensional control of pipe body and upset ends (outside diameter, out of roundness, eccentricity, straightness, internal diameter, length)

(g) machining of external and internal upset end

(h) dimensional control (internal diameter, outside diameter and machined end)

(i) drift testing at the upset ends

(j) non-destructive testing of upset ends, weighing, measuring and marking, external surface visual inspection, UT inspection of pipe body and UT inspection of upset ends.

7. A method for manufacturing a seamless steel tube for work-over risers having a yield strength at least of 620 MPa (90ksi) both in a tube body and in tube ends comprising the following steps of:

(i) providing a steel tube containing a composition in weight per cent, carbon 0.23-0.29, manganese 0.45-0.65, silicon 0.15-0.35, chromium 0.90-1.20, molybdenum 0.70- 0.90, nickel 0.20 max, nitrogen 0.010 max, boron 0.0010-0.0030, aluminum 0.010-0.045, sulfur 0.005 max, phosphorus 0.015 max, titanium 0.005-0.030, niobium 0.020-0.035, copper 0.15 max, arsenic 0.020, calcium 0.0040 max, tin 0.020 max, hydrogen 2.4 ppm max, the rest are iron and inevitable impurities, obtained by rolling process (MPM process)

(j) heat treatment of pipes (austenitizing between 850-930°C the full length of the tube; and quenching and tempering between 630-720°C)

(k) destructive testing (including microcleanliness, austenitic grain size, calculate % of martensitic transformation, tensile, hardness, toughness, SSC testing)

(l) dimensional control of pipe body (OD, out of roundness, straightness, ID, length)

(m) machining from external surface the complete length of the pipe by programming CNC lathe machine in order to achieve final dimensions at the ends.

8. A method for manufacturing a seamless steel tube for work-over risers according to claim 7, further comprising the following steps:

(n) dimensional control (ID, OD, out of roundness, straightness and length) of pipe body and machined ends
(o) drift testing at the ends,
(p) non destructive testing (NDT) of ends, weighing, measuring and marking, external surface visual inspection, UT inspection of machined pipe body and UT inspection of machined ends (cylindrical section only).

9. A seamless steel tube for work-over riser according to claim 1, wherein the as-quenched and tempered material has a microstructure constituted by tempered martensite through the thickness, throughout the whole length of a tube body and in tube ends.

10. A seamless steel tube for work-over riser according to claim 2, wherein the as-quenched and tempered material has a microstructure constituted by tempered martensite through the thickness, throughout the whole length of a tube body and in tube ends.

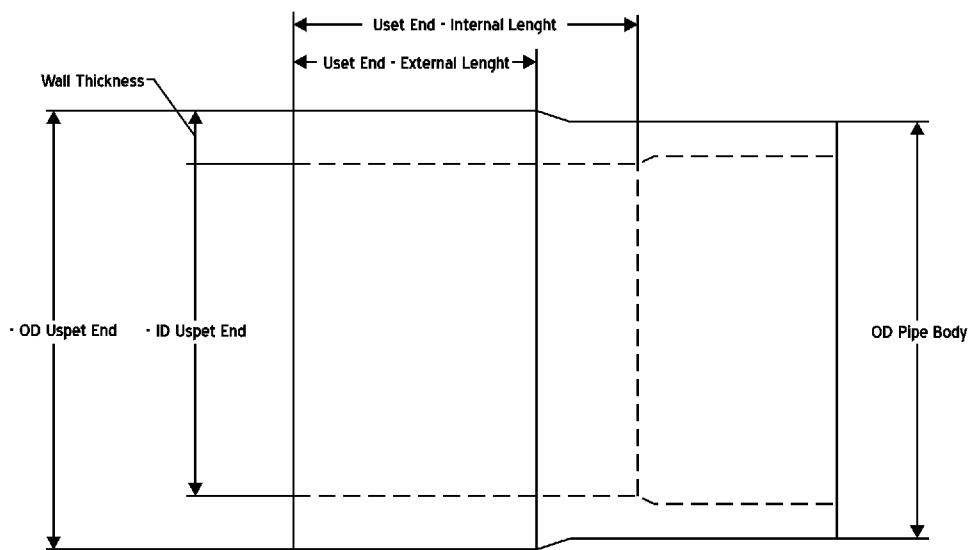


FIG. 1

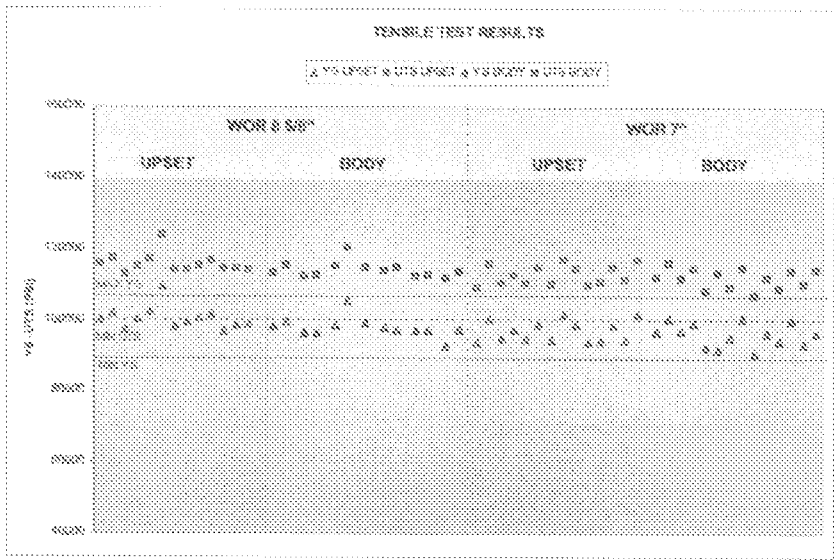


FIG. 2

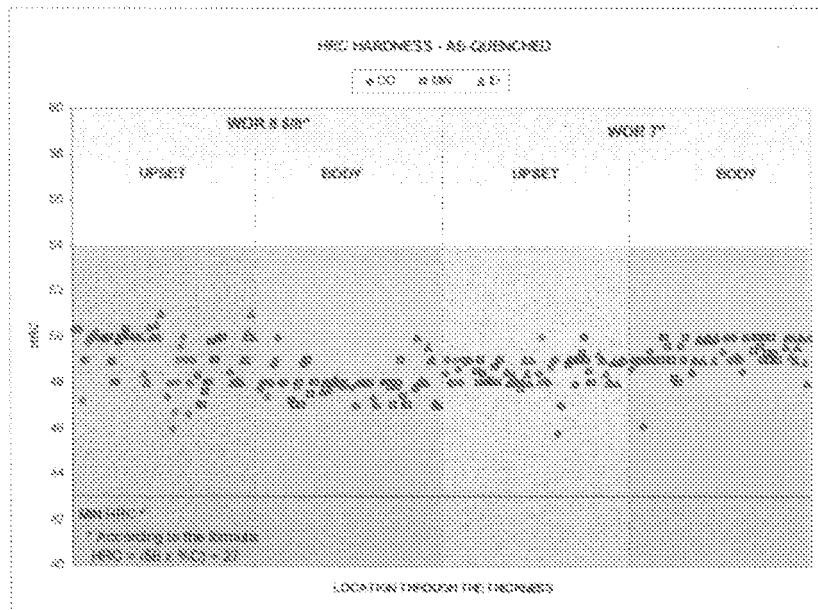


FIG. 3

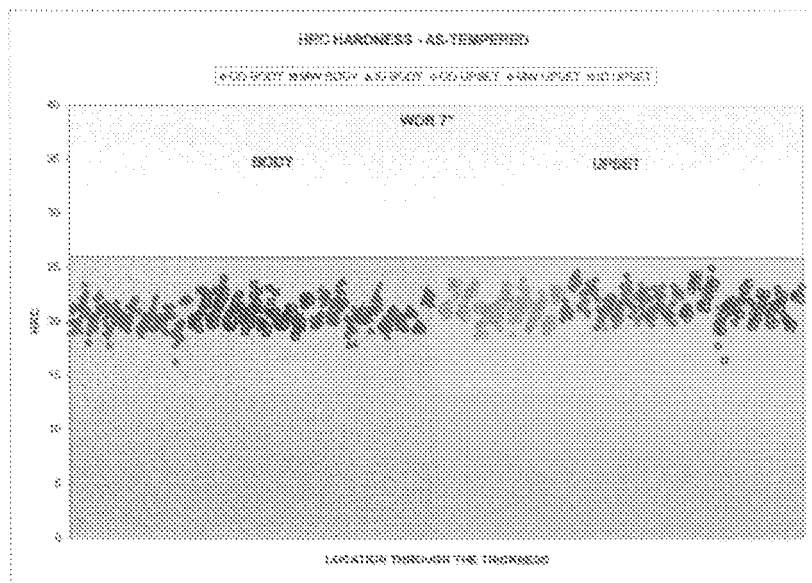


FIG. 4

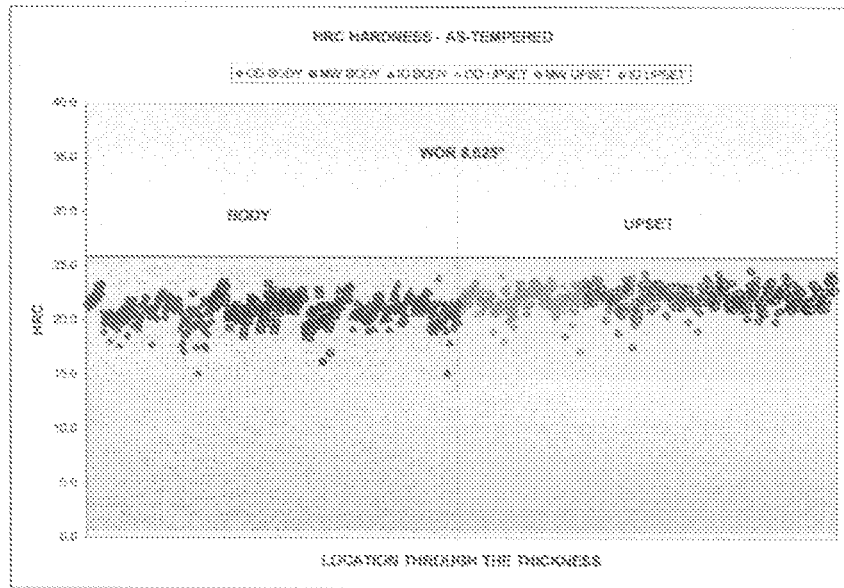


FIG. 5

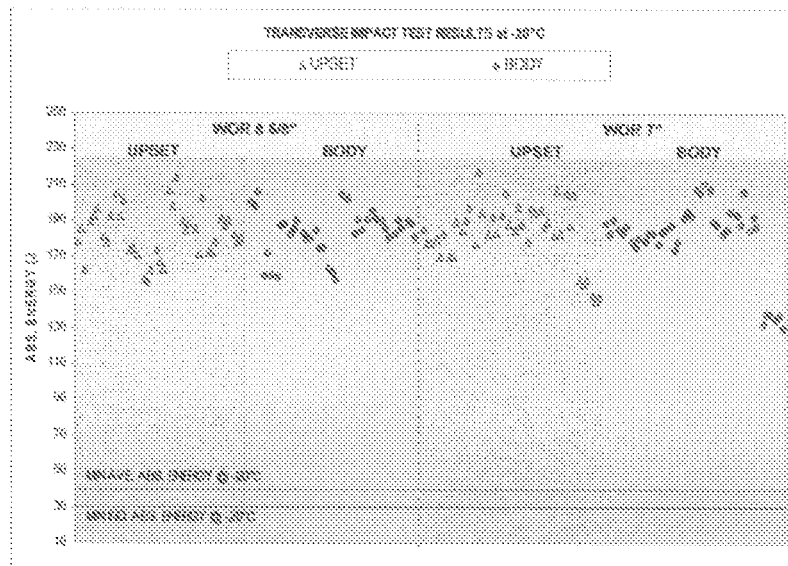
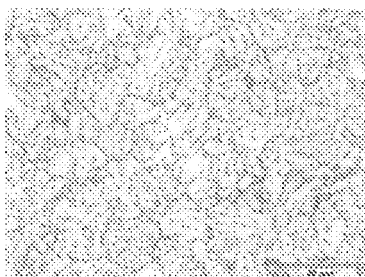
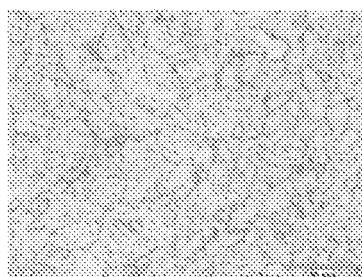


FIG. 6

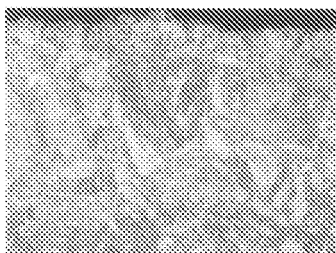


Pipe body-9/10 ASTM

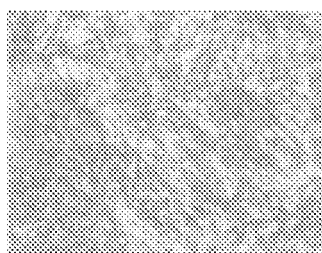


Upset end-8/9 ASTM

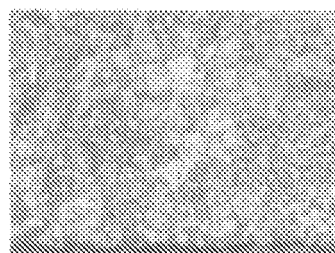
FIG. 7



OD

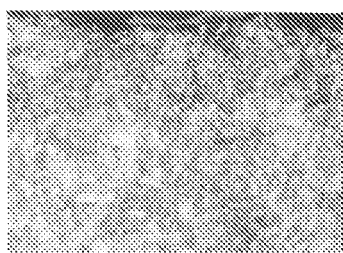


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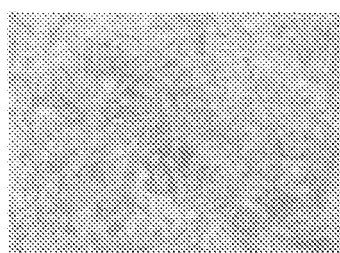


ID

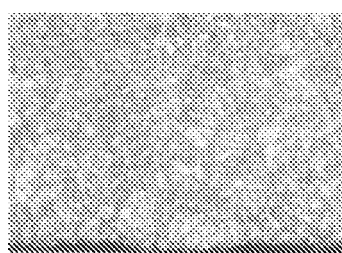
FIG. 8



OD

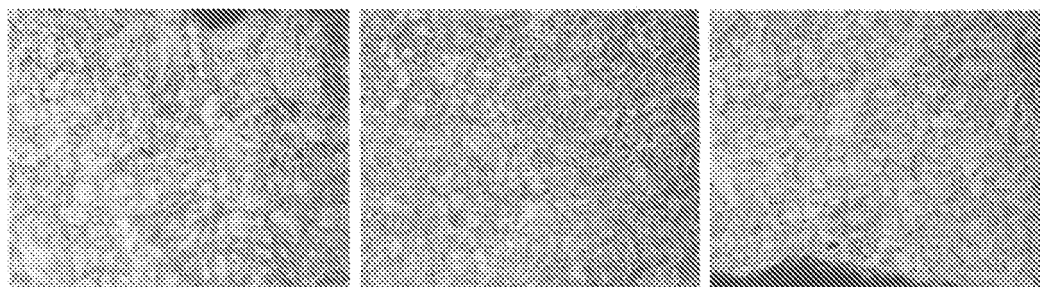


MW



ID

FIG. 9

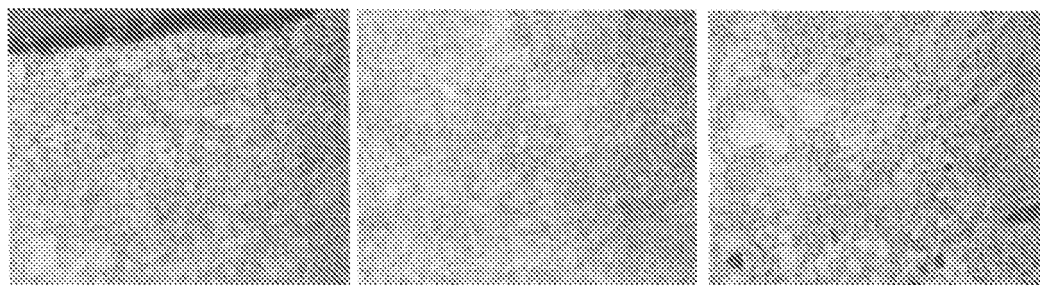


OD

MW

ID

FIG. 10

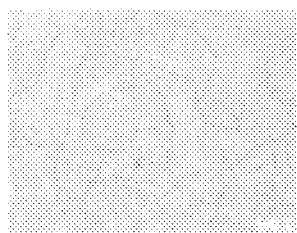


OD

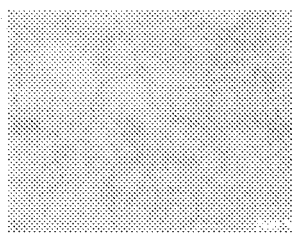
MW

ID

FIG. 11

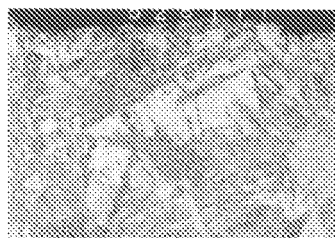


Machined pipe body

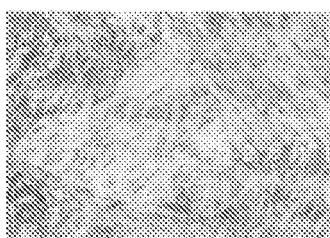


Modified end

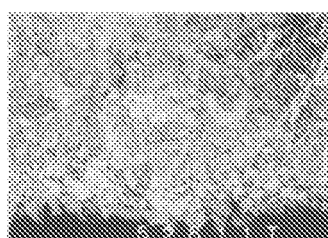
FIG. 12



OD

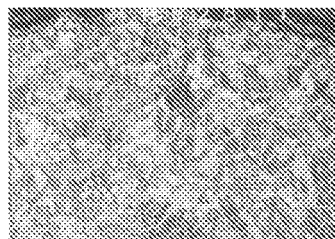


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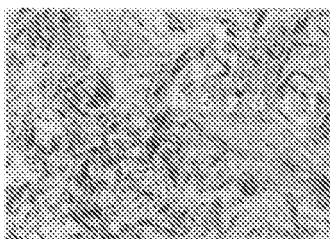


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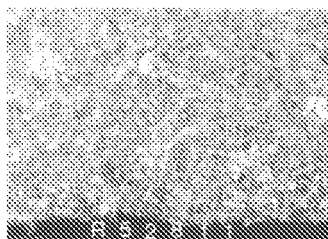
FIG. 13



OD



MW



ID

FIG. 14

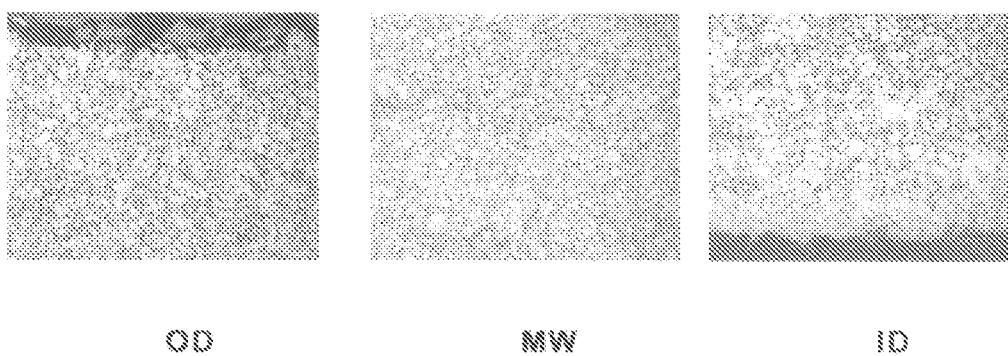


FIG. 15

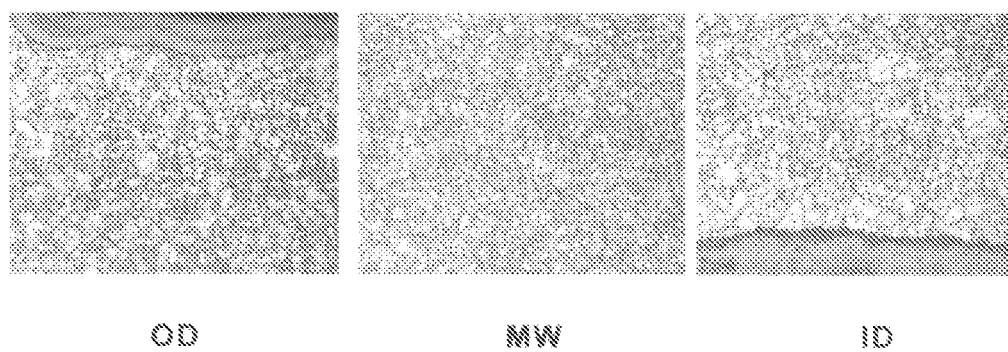


FIG. 16

REFERENCES CITED IN THE DESCRIPTION

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- US 4281716 A [0006]
- WO 9816715 A [0007]