(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
14 February 2008 (14.02.2008)

PCT

(10) International Publication Number
WO 2008/018980 A3

(51) International Patent Classification:
C21D 7/00 (2006.01) *B32B 15/18* (2006.01)
C21D 10/00 (2006.01) *B23K 5/00* (2006.01)
B32B 5/14 (2006.01) *B23K 28/00* (2006.01)

(21) International Application Number:
PCT/US2007/016495

(22) International Filing Date: 20 July 2007 (20.07.2007)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
11/499,800 4 August 2006 (04.08.2006) US
11/643,526 21 December 2006 (21.12.2006) US

(71) Applicant *(for all designated States except US)*: **EXXONMOBIL RESEARCH AND ENGINEERING COMPANY** [US/US]; 1545 Route 22 East, P.O. Box 900, Annandale, NJ 08801-0900 (US).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **VAUGHN, Glen, A.** [US/US]; 1825 East Cottage Blvd., Ozark, MO 65721 (US). **BANGARU, Narasimha-rao, Venkata** [US/US]; 5 Asher Smith Road, Pittstown, NJ 08867 (US). **KOO, Jayoung** [US/US]; 17 Constitution Way, Somerset, NJ 08873 (US). **AYER, Raghavan** [US/US]; 8 Springfield Lane, Bernards Township, NJ 70920 (US). **BEESON, Danny, Lee** [US/US]; 12450 Greenspoint Drive, Houston, TX 77210 (US). **THIRUMALAI, Neeraj, Srinivas** [IN/US]; 104 Arrowhead Court, Apt. C6, Phillipsburg, NJ 08865 (US). **BAKER, David, Alan** [US/US]; 4906 Mayfair Street, Bellaire, TX 77401 (US). **NORMAN, David, Ashley** [US/US]; 5214 Stillbrooke Drive, Houston, TX 77035 (US). **FORD, Steven, Jeffery** [US/US]; 3310 Charleston Ct., Missouri City, TX 77459 (US). **FAIRCHILD, Douglas, Paul** [US/US]; 4814 Scot Ct., Sugar Land, TX 77479 (US).

(74) Agents: **MIGLIORINI, Robert, A.** et al.; EXXONMOBIL RESEARCH AND ENGINEERING COMPANY, 1545 Route 22 East, P.O.box 900, Annandale, NJ 08801-0900 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

(88) Date of publication of the international search report:
30 October 2008

(54) Title: FRICTION WELDING AND LASER SHOCK PROCESSING

(57) Abstract: The use of friction stir and laser shock processing in oil & gas and/or petrochemical applications is provided by the present invention. The use includes subjecting friction stir weldments, fusion weldments, and other critical regions of ferrous and non-ferrous alloy components used in oil & gas and petrochemical applications to laser shock processing to create residual compressive stresses near the surface of the treated area. The residual compressive forces in the ferrous or non-ferrous components improve properties including, *inter alia*, surface strength, fatigue life, surface hardness, stress corrosion resistance, fatigue resistance, and environmental cracking resistance. Friction stir and laser shock processing find particular application in high strength pipelines, steel catenary risers, top tension risers, threaded components, liquefied natural gas containers, pressurized liquefied natural gas containers, deep water oil drill strings, riser/casing joints, and well-head equipment.

WO 2008/018980 A3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US07/16495

A. CLASSIFICATION OF SUBJECT MATTER
IPC: **C21D 7/00**(2006.01),**10/00**(2006.01);**B32B 5/14**(2006.01),**15/18**(2006.01);**B23K 5/00**(2006.01),**28/00**(2006.01)

USPC: 148/515,320;428/610,681;219/617
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 148/515,320; 428/610,681; 219/617

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
WEST: Laser Shock Peen or processing, compressive residual stress, welding, oil, gas, petrochemical.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,E	US 2008/0032152 A (VAUGHN et al) 07 February 2008 (07.02.2008) claims 1-34	1-84
Y	LASER SHOCK PEENING FOR FATIGUE RESISTANCE, Allan H Clauer, Surface Performance of Titanium, J Gregory, (1996) p. 217-230	1-84
Y	LASER SHOCK PEENING, Revolutions, Gear Technology, Nov/Dec 2001 p. 9-10	1-84
A	US 4,721,536 A (GROB et al) 26 January 1988 (26.01.1988), column 1, lines 5-32 and column 4, ln. 18-41)	1-84
A	US 5,780,804 A (WHITE et al) 14 July 1998 (14.07.1998), column 1, lines 24-30 and column 4, lines 49-67.	1-84

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"B" earlier application or patent published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
04 August 2008 (04.08.2008)	07 AUG 2008
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450 Facsimile No. (571) 273-3201	Authorized officer Keith Hendricks Telephone No. 571-272-1700

Form PCT/ISA/210 (second sheet) (April 2007)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US07/16495

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:
Please See Continuation Sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of any additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US07/16495

BOX III. OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING

Group I, claim(s) 1-21, drawn to a method.

Group II, claim(s) 22-84, drawn to an article.

The inventions listed as Groups I-II do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons: Group I requires that the component is a ferrous component (see line 5 of the claim) while Group II has no such limitation on the materials used for the component. Furthermore Group I requires a method of forming compressive residual stress by laser shock processing while Group II would not necessarily be limited to forming the compressive residual stress by laser shock processing and could be formed by another method.