JFE TECHNICAL REPORT
No. 7 (Jan. 2006)

Premium Joint, “JFEBEAR” for OCTG†

1. Introduction

In recent years, the number of easily-developed oil and gas wells has decreased, while deep wells and high-temperature and high-pressure wells have increased. On the other hand, with the improvement of drilling technology, wells with complex configurations, such as directional and horizontal wells, have also increased. The trend in the horizontal well rig count in North America is shown in **Fig. 1**. Therefore, the requirements placed on connections of casings and tubings under combined loads such as tension and compression, internal and external pressure, and bending, have also become increasingly severe. JFE Steel developed a premium joint, JFEBEAR, which was designed to use in such environments. An outline was presented in the previous report[1].

In the past, API RP5C5[2], the Recommended Prachce of the American Petroleum Institute, was widely used as a connection evaluation procedure, but evaluation procedures have also become stricter, as seen in the new procedure, ISO 13679[3], which was issued officially in 2002.

In this report, the features of JFEBEAR, tests according to ISO 13679, and the production status are described.

2. Features of JFEBEAR

The features and design concept of JFEBEAR are presented below.

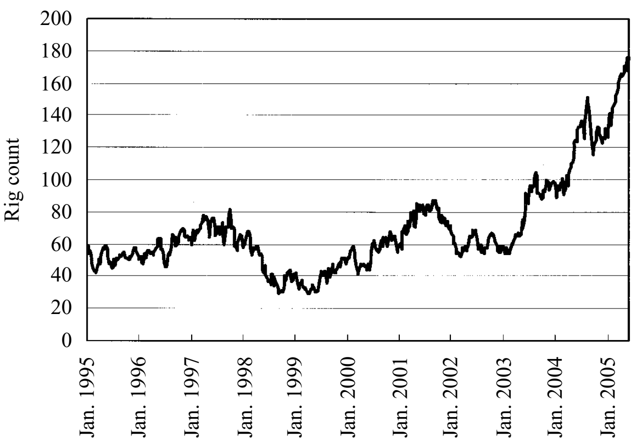


Fig. 1 Horizontal well rig count in North America

† Originally published in *JFE GIHO* No. 9 (Aug 2005), p. 46–50

The following performance is required in the threaded connection.

(1) Tensile strength
(2) Sealability under combined load of tension, compression, internal and external pressure, bending, etc.
(3) Galling resistance to make-up/break-out of the connection
(4) Stabbing performance during running operation
(5) Resistance to thread and seal deformation due to dope pressure during make-up
(6) Tool life and accuracy in thread cutting

The design features of JFEBEAR are shown in **Fig. 2**, and the design concept is presented in **Fig. 3** from the viewpoint of the relationship between features and performances requirement.

2.1 Thread Form

A hook thread, which has a negative load flank angle of −5°, is applied in JFEBEAR. In companson with the API buttress-type thread, a hook thread is advantageous in terms of joint tensile strength and sealability under tension and bending. However, a hook thread generally has a negative effect on galling resistance and tool life. In order to solve this problem, the corner radius of the load flank was optimized in JFEBEAR, resulting in superior galling resistance. JFEBEAR also has a larger stabbing flank angle of 25° for better stabbing of the pin into the coupling. The larger corner radius and stabbing flank angle also contribute to improved tool life.

A smaller gap between the pin and coupling stabbing flank is preferable in terms of the compression rating, but an insufficient gap carries the risk of galling associated with lead error. The gap of the JFEBEAR stabbing flank is optimized considering both of these requirements. JFEBEAR also has a large gap between the pin crest and coupling root to ensure disposability of the dope during make-up, and this prevents deformation of the thread and seal due to dope pressure.

2.2 Seal Geometry

The major characteristic of a premium joint is a metal-to-metal seal. Both galling resistance and sealability are important performance factors for the seal.

The seal of JFEBEAR is composed of a contoured pin surface and cone-shaped coupling surface. **Figure 4** shows an example of the Von Mises equivalent (VME)

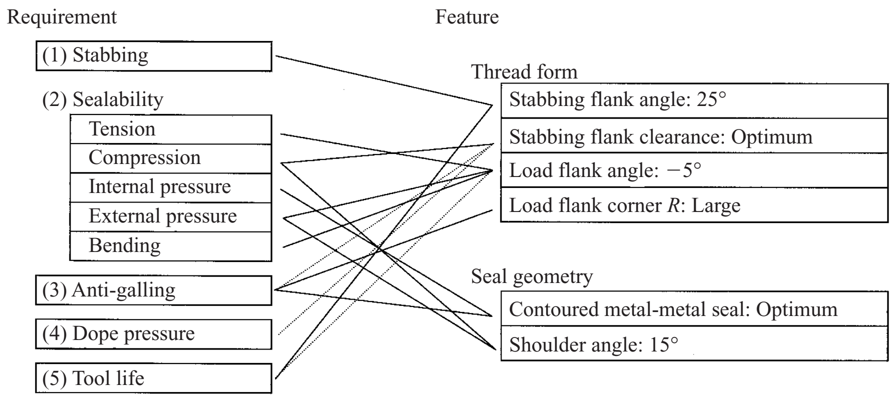


Fig. 3 JFEBEAR design concept

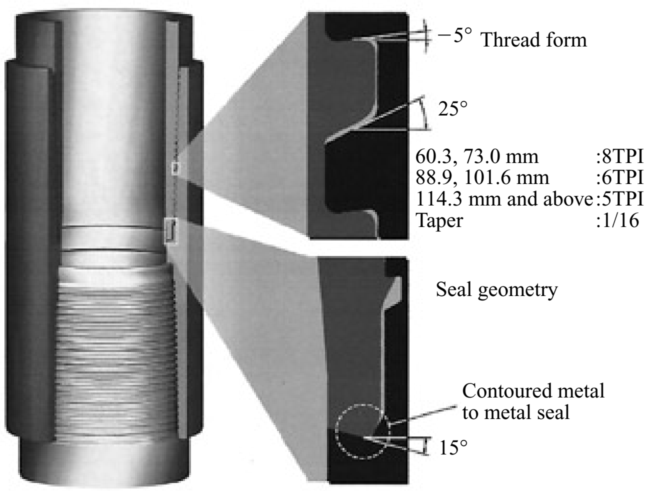


Fig. 2 JFEBEAR design features

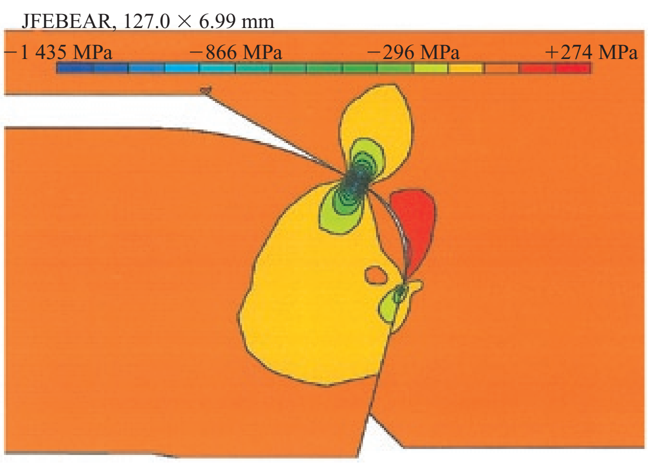


Fig. 4 Stress distribution of JFEBEAR seal

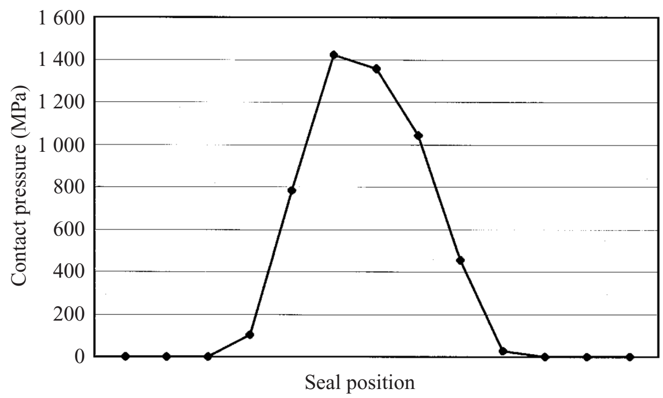


Fig. 5 Contact pressure distribution on JFEBEAR seal surface

stress of the seal area, and **Fig. 5** shows the seal contact pressure on the seal surface. The contact pressure has a convex distribution, in which the maximum stress appears in the middle of the contact area. On the other hand, in a seal with a cone shape in both the pin and the coupling, the contact pressure shows a concave distribution[4]. If there is deviation in local dimensions or surface roughness, a seal with a concave contact pressure seems preferable for minimizing negative effects and achieving the designed sealability. In addition to the contact pressure, the travel length of the contact surface should be considered in order to prevent galling. If the contact length is not too long, the contact area may change during make-up, and the actual travel length of each contact portion may become short. This contoured-type seal has also been applied in JFE Steel's FOX connection[5] with excellent results.

A larger shoulder angle is advantageous for sealability, but a smaller angle is preferable for minimizing deformation due to external pressure and compression. The shoulder angle of JFEBAER is 15°.

3. Performance Evaluation of JFEBEAR

3.1 Connection Testing Procedure

Formerly, API RP5C5 was widely used as a connection testing procedure, but currently ISO 13679 is a standard testing procedure which is recognized by major oil companies, etc.

The features of ISO 13679 are outlined below.

3.1.1 Number of specimens

There are 4 connection application levels (CAL).

CAL 4 is the highest level, and 8 specimens are used for each evaluation. In case of threaded and coupled connections, one specimen consists of 2 pin ends and one coupling.

3.1.2 Thread dimensions

Each specimen must be prepared with the required thread-seal interference, such as high-low, low-high, high-high, low-low. As new connection testing factors, the thread taper combinations pin fast-box slow, pin slow-box fast, and pin nominal-box nominal have been added to evaluate the change of the actual interference of thread and seal.

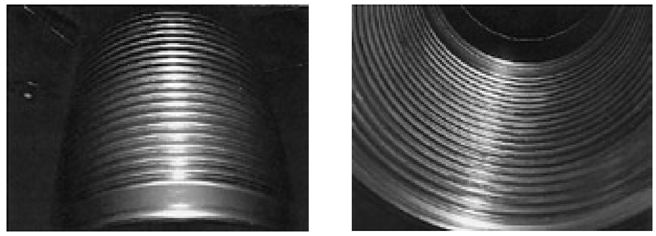
3.1.3 Make-up

For all A ends of the pins and coupling single make-up is required. For the other B ends, multiple make-up/break-out is required to evaluate galling resistance and a final make-up.

Photo 1 is an example of the pin and coupling surface of an HP2-13CR-110 JFEBEAR joint after multiple make-up/break-out. Blasting is performed on the pin surface, to remove chromium alloy beads and copper plating is applied to the coupling surface to improve galling resistance. An API-modified thread compound was used as a lubricant for make-up.

3.1.4 Baking

Baking of the connection is performed to eliminate the sealing effect of the thread compound.



Specimen #3B make and break test (HP2-13CR-110)

Photo 1 Make and break test result

3.1.5 Sealability tests

Three sealability tests, series A, B, and C, are specified.

Series A consists of sealability tests with a combined load of tension, compression, and internal and external pressure. **Figure 6** shows an example of the load path in test series A. Oil and gas wells are designed based on the specified minimum yield strength. In the internal pressure region, testing is carried out along the 95% VME yield stress envelope. For external pressure, the maximum load is limited to the API collapse pressure. The compression rating can be determined based on advice from the supplier, but 80% compression is currently the general requirement. JFEBEAR has been tested at up to 80% compression. Another feature of ISO combined load testing is that the load path of quadrant 1 to 4 is repeatedly applied. This is due to check sealability after the load path because slight deformation of seal may occur due to the combined load, especially compression. Gas and liquid are used for internal and external pres-

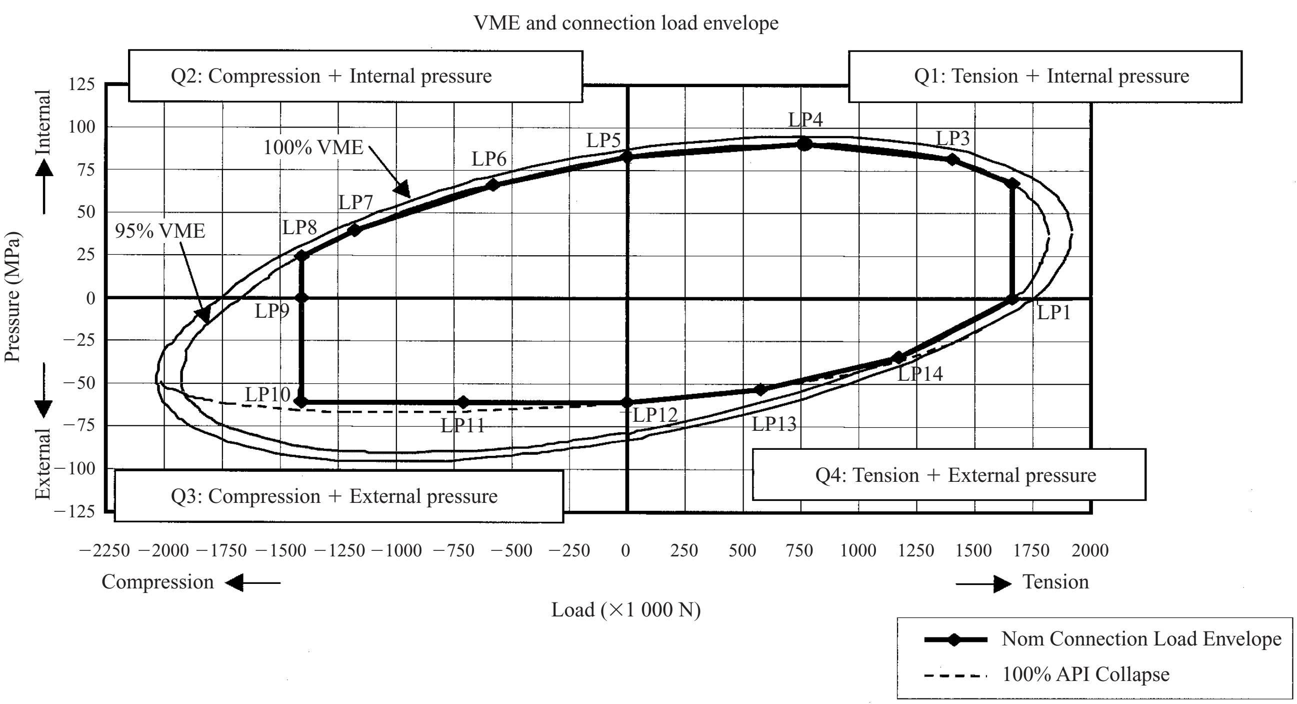


Fig. 6 Test series A load path

sure testing, respectively.

An example of finite element analysis (FEA) for an HP1-13CR-110 JFEBEAR joint is described below. Current FEA has some limitations, in that 3-dimensional distributions (thread spiral, for example) are not considered as this is an ax-symmetric model, and the setting of boundary conditions such as the coefficient of friction is not sufficiently accurate. However, the tendency or trend in the contact pressure distribution is considered to be worth analyzing and evaluating. The combined load path in this FEA is shown in **Fig. 7**. The trend of the contact area pressure, which is an area shown in Fig. 4, at each load point is given in **Fig. 8**. The contact area pressure appears first on the seal surface due to make-up, and then decreases as a result of tension. It then increases again under internal pressure, and continues to increase as the axial loading mode changes to compression and the load reaches its maximum. However, after thus, when both external pressure and tension are applied, the contact area pressure decreases to its minimum. If the same load path is applied again, the contact area pressure under tension is lower than in the first path, whereas the minimum contact area pressure under external pressure and tension is almost the same as in the first path.

Series B consists of combined load tests with bending in addition to tension, compression and internal pressure.

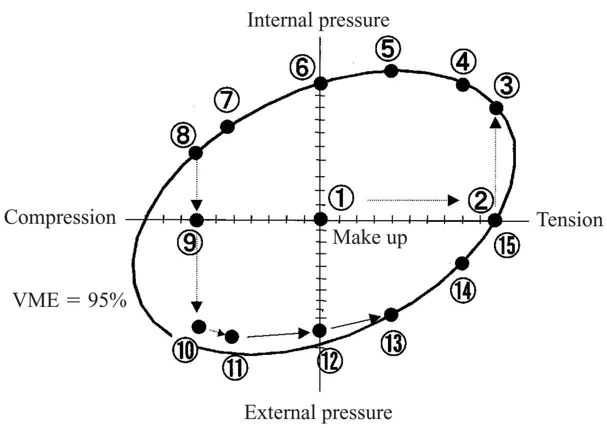


Fig. 7 Load step for FEA

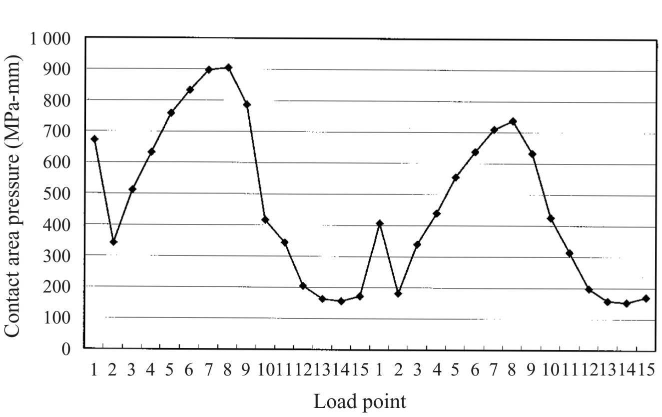


Fig. 8 Contact area pressure change

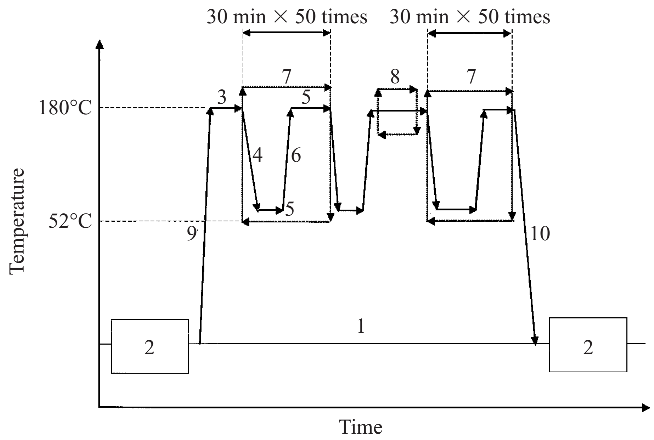


Fig. 9 Thermal cycle test condition

Series C is called thermal cycle tests, and its purpose is to evaluate sealability with tension and internal pressure by applying 100 thermal cycles from 52°C to 180°C (**Fig. 9**). This cycle is adopted because the temperature of the well remains high during production due to the production fluid, but drops during shut downs. The purpose of Series C is to evaluate the effect of these changes in temperature.

Series A is performed for specimens 1, 4, 5, and 7, and series B for specimens 2, 3, 6, and 8. This is followed by series C for specimens 1 to 4.

3.1.6 Limit load tests

Limit load tests are carried out to investigate the structural and sealing limit by applying a combined loads greater than the VME yield stress or API collapse pressure (**Fig. 10**). These are performed after finishing the sealability tests and are for information purposes.

3.2 Status of Connection Testing

JFE Steel has been carrying out JFEBEAR connection testing according to ISO 13679. Several sizes have already passed these tests successfully.

4. Production of JFEBEAR

The basic design and development of JFEBEAR were completed in 1999, and testing based on various procedures was carried out. Users highly appreciate the advantages of JFEBEAR, which include easy make-up in running operation and has superior sealability, and production is increasing consistently. In 2004, JFEBEAR was used in a deep-water project in the Gulf of Mexico.

JFE Steel will continue to improve its technical service system as well as production to enhance the status of JFEBEAR as the company's standard premium joint.

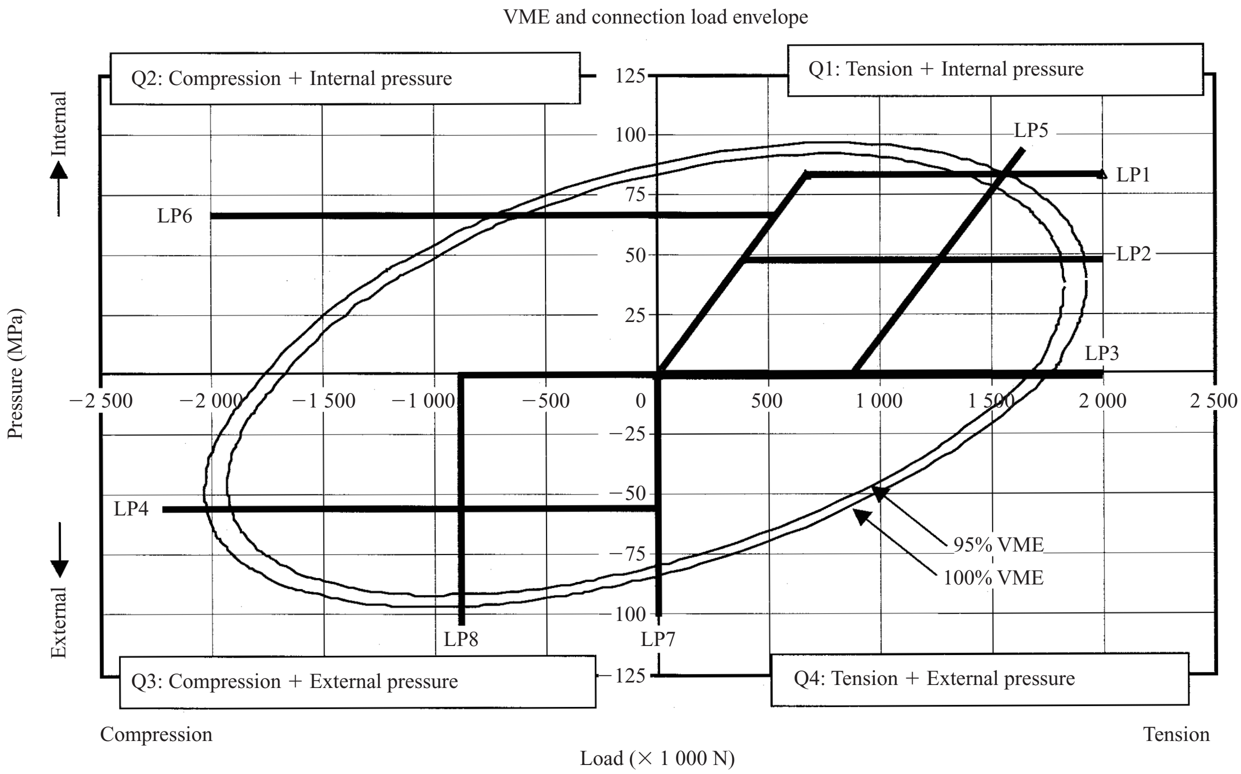


Fig. 10 Limit load test path

5. Conclusion

(1) JFE Steel developed a premium joint, JFEBEAR, which is applicable to severe environments such as deep wells, high-temperature and high-pressure wells, and directional and horizontal wells.
(2) JFEBEAR is composed of a hook thread and contoured metal-to-metal seal. Its unique design achieves high sealability, galling resistance, and easy make-up operation.
(3) Connection tests of JFEBEAR according to the ISO 13679 CAL 4 have been carried out, and several sizes have successfully passed these tests.
(4) JFE Steel will continue to perform connection testing and enhance production and technical service for JFEBEAR.

References

1) Takano, J.; Yamaguchi, M.; Kunishige, H. Kawasaki Steel Giho. vol. 34, no. 1, 2002, p. 21–28.
2) API Recommended Practice 5C5(RP5C5). 1st Ed. 1990-01.
3) ISO 13679. 1st ed. 2002-12.
4) Narita, A.; Maeda, J.; Nagasaku, S. Sumitomo Metals. vol. 46, no. 1, 1994, p. 65.
5) Yamamoto, K.; Kobayashi, K.; Maguchi, T.; Ueno, K. Kawasaki Steel Giho. vol. 21, no. 3, 1989, p. 202–207.