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# Pipeline Material Strain Monitoring System in Permafrost Pipeline of MoHe-DaQing Pipeline

**Pengchao Chen**
Jiagedaqi oil&gas Pipeline sub-company
Jiagedaqi City Heilongjiang Province, China

**Shibin Zhang**
Jiagedaqi oil&gas Pipeline sub-company
Jiagedaqi City Heilongjiang Province,China

**Shimei Yang**
Jiagedaqi oil&gas Pipeline sub-company
Jiagedaqi City Heilongjiang Province, China

**Zhengbin Li**
Jiagedaqi oil&gas Pipeline sub-company
Jiagedaqi City Heilongjiang Province, China

**Yanguang Ren**
petrochina Pipeline sub-company
Langfang City HeBei Province, China

## ABSTRACT

Mohe-Daqing pipeline is the first pipeline to be buried, passing through the permafrost regions of North China where the temperature in winter is about minus thirty degrees Celsius. This pipeline has been transporting large quantities of crude oil per day to northern markets of China since January 1st, 2011. It's a significant cooperation for both Russia and China.

This paper reviews the design, construction, and operational challenges of the first pipeline buried in the permafrost regions of North China. The pipeline is in so complicated geography environment that many kinds of geotechnical disaster could happen easily, including frost heave, thaw settlement, slope instabilities, and collapse and so on. Monitoring pipeline material strain in specific region is important and significant. Ground movement of the pipeline induces sufficiently large strains to the pipeline, which would cause wrinkling on the compression side of the pipe, or alternatively tensile fracture on the tensile side of the pipe. Brag fiber sensors have been located and composed on the surface of the pipe, which were used to monitor material strain real-time data at any time.

Finite element pipe soil interaction and ground movement models in specific sites have been developed according to the monitoring data. Whether the generated pipeline strain is exceeded the strain capacity or not could be estimated by comparing with the strain capacity of the pipeline, which can help us to make decision for pipeline safety management and prevent pipeline damage from geotechnical disaster.

**Key word**
Monitoring Technology, Permafrost, Mohe-Daqing pipeline, pipeline material strain, Brag fiber sensors

## 1. INTRODUCTION

With the development of China's national economy， the domestic crude oil continued rapid growth is expected. The dependence on foreign oil resources in China will rise to 60 percent in 2020. The Sino-Russian crude oil pipeline operations opened up a land of imported crude oil from the Russian Far East to the north of the country oil trunk channel of the land area. China is pushing the diversification of the supply of oil resources, which is a major strategic measure to improve the economic efficiency of oil and petrochemical enterprises, promoting regional economic development and having a very important practical significance and strategic significance. It is the first pipeline to be buried through the permafrost regions of North China in the past several years. The extremely ambient temperature along this pipeline has arrived -52.3℃[1]. The length of the pipeline is about 965 km, passing through the large areas of continuous and discontinuous permafrost, length of 441 km. As Eurasia permafrost is near the southern boundary, high environment temperature, permafrost to climate change is extraordinarily sensitive. Affected by the rapid warming of regional climate, in recent years, permafrost has been degraded significantly. It will bring an important effect to the underground oil pipeline safe operation.

Due to the special permafrost ground conditions of the MoDa pipeline route as described in Table 1.

**TABLE 1-MOHE - DAQING CRUDE OIL PIPELINE ALONG THE PERMAFROST DISTRIBUTION**

| Location | Altitude （m） | The annual Average temperature | The lowest temperature | Rainfall （mm） | Permafrost thickness （mm） | Maximum freezing depth （m） | Statistical time |
|---|---|---|---|---|---|---|---|
| Mohe | 435 | -4.3 | -52.3 | 460 | ~60 | 2.9 | 1959~2005 |
| Tahe | 357 | -2.8 | -45.8 | 463 | ~46 | 2.0 | 1972~25 |
| Xinlin | 494 | -2.6 | -46.9 | 514 | ~48 | 3.1 | 1972~2005 |
| Songling | 556 | -2.2 | -48.3 | 550 | ~35 | 2.8 | 1974~2005 |
| Jiagedaqi | 382 | -1.2 | -45.4 | 495 | <10 | 2.5 | 1967~2005 |
| Dayangshu | 288 | -0.8 | -41.0 | 480 | <10 | 3.0 | 1957~2005 |
| Nenjiang | 242 | -0.4 | -39.5 | 450 | | 2.1 | 1951~2005 |
| Nehe | 203 | 0.7 | -42.2 | 450 | | 2.4 | 1951~2005 |
| Lindian | 154 | 2.4 | -39.2 | 412 | | 2.3 | 1951~2005 |
| Qiqihaer | 146 | 3.7 | -39.5 | 416 | | 2.2 | 1951~2005 |
| Daqing | 149 | 3.2 | -39.2 | 438 | | 2.1 | 1953~2005 |

The difference between the oil temperature and ground temperature can result in ground movement ,associated strains and deformations of the pipeline[2] .The effects of discontinuous permafrost on a pipeline are significant and different which included frost heave, thaw settlement and slope instabilities in Figure 1. This slope movement can generate significant axial and bending loads to the pipeline.

**FIGURE 1-FROST HEAVE AND THAW SETTLEMENT**

If the ground movement of the pipeline produce strains in the pipeline that are sufficiently large, it would cause wrinkling of the pipeline on the compression side of the pipe, or alternatively tensile fracture on the tensile side of the pipe .Coinciding with these challenges ， fiber Bragg grating (FBG) sensors used to monitor material strain is significant in permafrost and geotechnical regions. FBG sensor has a number of advantages such as high sensitivity, resistance to corrosion, simple and convenient[3] .

In this paper, it will focus on the principle and application of material strain monitoring system which has already been used in some high-risk regions of the Moda pipeline as well as the result during the past several months, its effectiveness is discussed.

## 2. MATERIAL STRAIN MONITORIN SYSTEM

Permafrost zone pipeline strain monitoring system consists of a data acquisition subsystem, automatic data processing system and information dissemination subsystem. The data acquisition system consists of sensors, data acquisition equipment, communications and transmission equipment to complete the monitoring of the underlying data is automatically read and transmitted. Automatic data processing subsystem completed the changes in pipeline mechanical index generated. As pipeline mechanical index change generated by the information subsystem for visual expression, pipeline manager's grasp pipeline mechanical change in time.

The fiber is total internal reflection of light in the fiber made of glass or plastic products as a transmission medium. The basic principle is: the light from the light source through the optical fiber into the modem, test parameters and entered the optical of the modulation area are interacted. Which change the optical properties of light, such as intensity, wavelength, frequency, phase, polarization state changes, after the fiber into the detector, the modulation parameters were measured. The FBG is the use of the photosensitivity of the fiber material, formed in the core within the space made by the phase grating. Fiber Bragg Grating Sensor is the use of a photosensitive optical fiber under ultraviolet light irradiation of light-induced refractive index change effects, the refractive index of the core along the axial direction, showing a periodic distribution of the fiber optic sensor and a wavelength modulation.

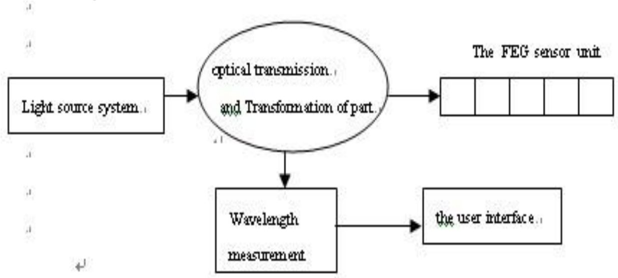


**FIGURE2-THE COMPOSITION OF THE FBG SENSOR**

The pipeline strain conditions are significant in discontinuous permafrost for difference in oil and ground temperatures which can degrade permafrost or cause ground freezing, ground movement stress acting on the pipeline. Frost heave thaw disaster role stress on the pipeline's key performance in the axial direction, pipeline axial stress measurement will be able to better judge the acceptability of the stress state of the pipeline. Fiber Bragg grating strain sensors are used only for measuring the axial strain of the pipeline[4], based on the theory of elasticity of steel, if known to the pipe cross-section of radius r, and through the sensor to measure to three separated by 90 °arc position A, B, C uniaxial longitudinal strain, It can calculate the circumference at any point of the longitudinal strain. All around the circumference of the longitudinal strain are located in a plane passing through a pipe.

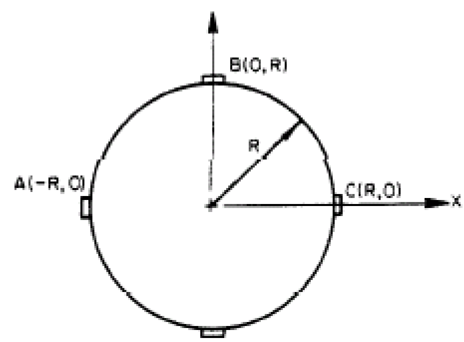


**FIGURE 3-SKETCH MAP OF EACH STRAIN MONITORING SYSTEM**

Defined as follows:

$$mx + ny + pz = 1 \qquad (1)$$

Coordinates on the circumference axis were shown in Figure 3.

z is the longitudinal strain of the point (x, y);

m, n, p is an arbitrary constant.

The measured strain A, B, C, gives the following boundary conditions:

In the point of $x = -r$ , $y = 0$, $z = A$; In the point of $x = 0$ , $y = r$ , $z = B$ ; In the point of $x = r$ , projected strain z at any point of (x, y) at $y = 0$ , $z = C$ ; and , because the pipeline is circular, $r = \pm\sqrt{x^2 + y^2}$ , using the above boundary conditions, it can be estimated that the value of the constants m, n, p as follows are:

$$-mr + pA = 1 , \qquad (2)$$
$$nr + pB = 1 ,$$
$$mr + pC = 1$$

According to the formula (2) are can get:

$$p = \frac{2}{A + C} , \qquad (3)$$
$$m = \frac{1}{r}\left(\frac{2A}{A + C} - 1\right) ,$$

$$n = \frac{1}{r}(1 - \frac{2B}{A+C})$$

Solving equation of (1), May get z expression that:

$$z = \frac{A+C}{2} + (\frac{C-A}{2})\frac{(x)}{(r)} - (\frac{A+C-2B}{2})\frac{(y)}{(r)} \qquad (4)$$

According to the measured strain A, B, C, equation of (4) is given the strain z of any point (x, y). Obtained the derivative of x with equation of (4), to find the maximum or minimum strain, the value is set to zero, solving maximum or minimum coordinate values of x, y .

The Y in the equation (4) replaced by:

$$Z = \frac{A+C}{2} + \left(\frac{C-A}{2}\right)\frac{x}{r} - \left(\frac{A+C-2B}{2}\right)\left(\frac{1}{r}\right)(r^2 - x^2)^{\frac{1}{2}} \qquad (5)$$

$$\frac{dz}{dx} = \left(\frac{C-A}{2}\right)\left(\frac{1}{r}\right) - \left(\frac{A+C-2B}{2}\right)\left(\frac{1}{r}\right)\left(\frac{1}{2}\right)(-2x)(r^2 - x^2)^{-\frac{1}{2}} = 0 \qquad (6)$$

$$(C-A)(r^2 - x^2)^{\frac{1}{2}} = -(A+C-2B)x^2 \qquad (7)$$

Squared on both sides, obtained
:

$$(C^2 - 2AC + A^2)r^2 = (2A^2 + 2C^2 + 4B^2 - 4AB - 4BC)x^2 \qquad (8)$$

Arranged expression:

$$\frac{y}{r} = \pm\sqrt{1 - (\frac{x}{r})^2} \qquad (9)$$

Maximum or minimum strain appeared in this x, y values

Used in stress monitoring sensor tube is temperature compensation FBG sensor, the sensor is pasted in the tube test, according to the experimental results can obtain the change sensitivity coefficient after fitting the sensor pasted in the tube $\phi$ = 1.089pm/ $\mu\varepsilon$ . set 0 °, 90 °, 180 °three positions point sensor wavelength changes are a $\Delta\lambda_1$, $\Delta\lambda_2$, $\Delta\lambda_3$, respectively, sensor pasted on the strain 's sensitivity coefficient of the tube for $\phi$, the three position of strain values were as follow: $\frac{\Delta\lambda_1}{\phi}$ 、 $\frac{\Delta\lambda_2}{\phi}$ 、 $\frac{\Delta\lambda_3}{\phi}$ .According to the formula (9), location coordinates of the point of maximum strain values x, y, respectively:

$$x = \frac{(\Delta\lambda_1 - \Delta\lambda_3)r}{\sqrt{2\Delta\lambda_1{}^2 + 2\Delta\lambda_3{}^2 + 4\Delta\lambda_2{}^2 - 4\Delta\lambda_1\Delta\lambda_2 - 4\Delta\lambda_2\Delta\lambda_3}} \qquad (10)$$

$$y = \pm r\sqrt{\frac{\Delta\lambda_1{}^2 + \Delta\lambda_3{}^2 + 4\Delta\lambda_2{}^2 + 2\Delta\lambda_1\Delta\lambda_3 - 4\Delta\lambda_1\Delta\lambda_2 - 4\Delta\lambda_2\Delta\lambda_3}{2\Delta\lambda_1{}^2 + 2\Delta\lambda_3{}^2 + 4\Delta\lambda_2{}^2 - 4\Delta\lambda_1\Delta\lambda_2 - 4\Delta\lambda_2\Delta\lambda_3}} \qquad (11)$$

Combining with the Hooke law, it can be obtained the maximum stress of the pipe body cross-section:

$$\sigma = E\left\{\begin{aligned}&\frac{\Delta\lambda_1 + \Delta\lambda_3}{2\phi} + \frac{(\Delta\lambda_1 - \Delta\lambda_3)^2}{2\phi\sqrt{2\Delta\lambda_1{}^2 + 2\Delta\lambda_3{}^2 + 4\Delta\lambda_2{}^2 - 4\Delta\lambda_1\Delta\lambda_2 - 4\Delta\lambda_2\Delta\lambda_3}}\\ &+\frac{(\Delta\lambda_1 + \Delta\lambda_3 - 2\Delta\lambda_2)}{2\phi}\sqrt{\frac{\Delta\lambda_1{}^2 + \Delta\lambda_3{}^2 + 4\Delta\lambda_2{}^2 + 2\Delta\lambda_1\Delta\lambda_3 - 4\Delta\lambda_1\Delta\lambda_2 - 4\Delta\lambda_2\Delta\lambda_3}{2\Delta\lambda_1{}^2 + 2\Delta\lambda_3{}^2 + 4\Delta\lambda_2{}^2 - 4\Delta\lambda_1\Delta\lambda_2 - 4\Delta\lambda_2\Delta\lambda_3}}\end{aligned}\right\} \times 10^{-6}(MPa) \qquad (12)$$

Solving the derivative of x for equation (4), the maximum or minimum strain were obtained, set the derivative values to zero, it can be solved in a maximum or minimum x, y coordinate values.

Based on this theory, FBG sensor is installed in the position as shown in Figure 4，which can monitor pipeline stress. According to the above formula, not only can calculate the maximum stress of the pipeline and its occurrence, but also get the variation of the stress on the pipe cross-section, and thus a more accurate judgment of the pipeline safety.

Used in stress monitoring sensor tube for temperature compensation FBG sensor, the sensor is pasted in the tube test. Exclude the impact of temperature on the measurement results[5]. All these works have to finish before the pipe is buried into the pipeline ditch. Also special protection layers must be used to keep all the sensors lived. In figure 3 shows the photo during construction time[6].

All the sensors welded to the pipe metal surface adopted cold welding process of metal repair. Welding, corrosion must be in strict accordance with the process requirements that *Mo-Da pipe displacement monitoring system construction program*.

Cross-section sensor group string access to the transmission cable and spare transmission cable loss is not greater than 0.02db. Pipeline under the ditch requires the use of rubber sheets to protect the cross-section single-core fiber optic cable and fiber optic cable connection between the subsequent box ，to prevent the next trench and backfill damage.

Arrange for someone on duty to the entire process of backfill Pipeline. Using a portable grating demodulator to read all of the wavelength of the sensor signal can not read or to read the data which is not normal must repair in time. After pipeline big backfilling is completed, all the sensor data must be sure to read.

All surface cables wells is installed within the scope of 5 m on both sides of pipeline, the depth of cable wells underground sections is not less than 700millimeter, the cable well do prevention frost treatment. The displacement monitoring system before the commissioning in the pipeline completed all equipment commissioning and trial run.

**FIGURE 4-STRAIN MONITORING SENSORS INSTALL ON SITE**

According to *Pipeline engineering design specification* the provisions of GB50253-2003 (2006 Edition) 5.2.4 Terms “Pipe and the axial stress generated by the permanent load, variable load, It should not exceed 80% of the minimum yield strength of steel pipes, but had to include in the earthquake and wind loads at the same time.”. At the same time with reference to the latest version of the standard ASME_B31.8-2007 833.3 *Summation of Longitudinal Stress in Restrained Pipe*, which provides buried by the constraining pipe, the maximum net vertical stress to allow the value is 0.9 times of the minimum yield strength. So checking pipe tensile stress the conservative formula should follow conditions:

$$\sigma L \leqslant 0.8\sigma S$$

*Pipeline engineering design specifications* GB50253-2003 (2006 Edition) 5.5.5 terms have been provided for the checking condition of the equivalent stress

So checking pipe compression stress the compression formula should follow conditions:

$$\sigma h - \sigma L \leqslant 0.9\sigma S$$

## 3. FIELD APPLICATION

### *3.1. Monitoring point selection*

Six typical disaster areas, frost heave and thawing settlement were selected in the north of Jiagedaqi, the pipeline fiber stress monitoring system was installed to ensure that the operators can grasp mechanical state and have the carrying capacity of pipeline in the typical permafrost disaster and be more proactive and controllable, accumulation of basic data for the study permafrost - pipeline interaction laws.

Considering power and special environment on site, the monitoring system is used distributed fiber optic technology[7], the laying of pipe on the following six typical permafrost zone (monitoring unit A ~ F) implemented contingency monitoring, each monitoring unit is about 230m, on the permafrost region of the Jiagedaqi north .Every system is composed with 18 unit sensors which located on the surface of the pipes and composed with four FBG sensors. The distance for each monitoring unit is about 12 meter and all connected with fiber one by one.

Specific points as follows:

A monitoring unit: the junction point of the thermal insulation pipes and PE pipes, slope overflow, full of frozen soil.

B monitoring Unit: PE pipes, river terraces, full of frozen soil.

C monitoring Unit: insulating pipe and PE pipe at the junction point depressions overflow.

D monitoring unit: insulation pipe, frost heaving mound, replacement processing.

E monitoring unit: insulation pipes, swales overflow, ice cone, replacement processing.

F monitoring unit: PE pipes, swales overflow, frost heaving mound.

(Stake number listed for the location of the center of the monitor unit).

A, B, and C, three monitoring unit adopted automatic transmission base station data collection methods. D, E, F three monitoring units uses artificial field data collection. The data processing center is located in the first station.

### *3.2. Monitoring data*

Data collection time points for the daily 0, 6:00, 12:00, 18:00, 6 hours interval time, continuous acquisition and storage. A, B, C, three unit timed wireless transmitted to the data center. D and E, F, three units per five days of manual collection were sent to the data center. Displacement monitoring system piping analysis software outputs pipe stress and strain changes and displacement by data monitoring statements and graphics at the first station of data center. It can achieve One-stop multi-point remote forecast，At the same time set the threshold value overrun warning.

Take the A and F monitoring unit as example in the six units: A-F, A and F monitoring unit monitored the cross-section the stress state in Table 2 and in Table 3.（The maximum tensile stress or compressive stress in the position on the cross-section "means: along the oil flow direction on the circumference of the pipe section ,clockwise rotation angle from the top of the pipe）.

## Table 2 -A MONITORING THE CROSS-SETION THESTRESS STATE

| Cross-section serial number(Along the oil flow direction) | The maximum tensile stress on the cross-section | | The maximum compressive stress on the cross-section | | Section Bending Stress (Mpa) |
|---|---|---|---|---|---|
| | Values (Mpa) | Position on the cross-section | Values (Mpa) | Position on the cross-section | |
| 1 | 1.85 | 167.87 | -11.80 | 347.87 | 6.83 |
| 2 | 37.95 | 2.49 | -53.81 | 182.49 | 45.88 |
| 3 | 37.13 | 198.64 | -42.34 | 18.64 | 39.73 |
| 4 | 3.19 | 272.92 | -35.78 | 92.92 | 19.48 |
| 5 | 20.36 | 26.75 | -52.77 | 206.75 | 36.56 |
| 6 | 4.83 | 62.68 | -6.37 | 242.68 | 5.60 |
| 7 | 5.10 | 287.35 | -1.94 | 107.35 | 3.52 |
| 8 | 3.78 | 220.69 | -3.28 | 40.69 | 3.53 |
| 9 | -0.58 | 6.81 | -7.51 | 186.81 | 3.47 |
| 10 | 3.61 | 342.76 | -22.55 | 162.76 | 13.08 |
| 11 | 3.02 | 321.25 | -9.42 | 141.25 | 6.22 |
| 12 | 18.83 | 173.87 | -0.93 | 353.87 | 9.88 |
| 13 | 20.93 | 182.42 | -20.03 | 2.42 | 20.48 |
| 14 | 4.83 | 178.96 | -11.59 | 358.96 | 8.21 |
| 15 | 9.43 | 177.75 | -6.41 | 357.75 | 7.92 |
| 16 | 6.73 | 218.41 | -10.38 | 38.41 | 8.56 |
| 17 | 4.90 | 18.31 | -3.72 | 198.31 | 4.31 |
| 18 | 4.69 | 186.79 | -12.17 | 6.79 | 8.43 |

## TABLE 3-F MONITORING THE CROSS-SETION THESTRESS STATE

| Cross-section serial number (Along the oil flow direction) | The maximum tensile stress on the cross-section | | The maximum compressive stress on the cross-section | | Section Bending Stress (MPa) |
|---|---|---|---|---|---|
| | Values (MPa) | Position on the cross-section | Values (MPa) | Position on the cross-section | |
| 1 | 52.83 | 5.63 | -32.84 | 185.63 | 42.83 |
| 2 | 63.96 | 179.93 | -48.41 | 359.93 | 56.19 |
| 3 | 3.71 | 150.10 | -9.83 | 330.10 | 6.77 |
| 4 | 96.33 | 4.40 | -112.12 | 184.40 | 104.23 |
| 5 | 128.48 | 176.60 | -102.59 | 356.60 | 115.54 |
| 6 | 48.54 | 142.66 | -22.95 | 322.66 | 35.74 |
| 7 | 52.90 | 351.03 | -38.51 | 171.03 | 45.70 |
| 8 | 25.12 | 351.99 | -24.14 | 171.99 | 24.63 |
| 9 | 19.77 | 182.48 | 9.05 | 2.48 | 5.36 |
| 10 | 57.16 | 177.36 | -30.03 | 357.36 | 43.60 |
| 11 | 24.26 | 1.52 | 3.60 | 181.52 | 10.33 |
| 12 | 37.76 | 11.49 | -33.63 | 191.49 | 35.69 |
| 13 | 87.63 | 18.58 | -89.45 | 198.58 | 88.54 |
| 14 | 49.17 | 12.23 | -41.56 | 192.23 | 45.36 |
| 15 | 11.23 | 358.72 | -7.19 | 178.72 | 9.21 |

A and F monitoring unit monitored cross section stress Current Situation in Figure5 and in figure 6 .

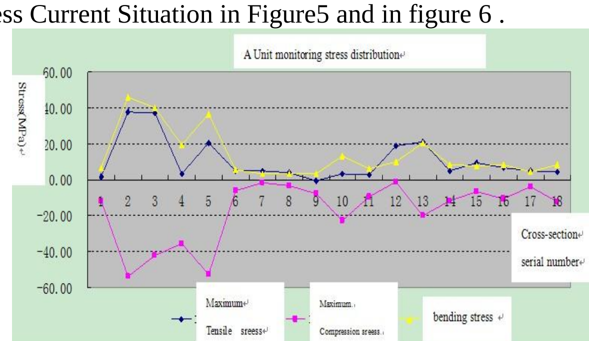


**FIGURE 5- STRESS SITUATION**

From the diagram of each cross section the current stress state and stress distribution, in Figure 5 , Pipe section between the X1 and X2 (length of about 72m, in the top of the road, X1 to X9 is Insulating pipe), where X2 and X5 the top of the monitoring of cross-section subjected to tensile stress (X2 in the position of 2.49° , X5 in the position of 26.75 °) , Bottom subjected to pressure stress (X2 in the position of 182.49 °, X5 in the position of 206.75 °), indicating that the pipe section between the X1 to X6 pipe sections appeared bent downwards phenomenon , pipe happened settlement.

The calculated settlement with maximum subsidence displacement is about 0.16 meter.

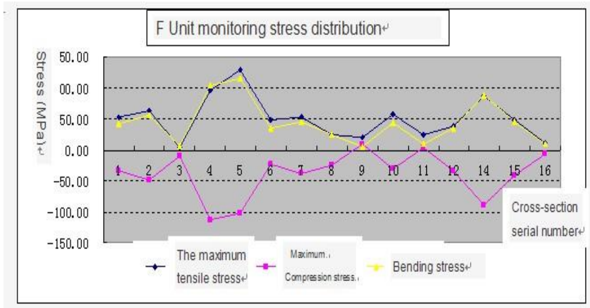


**FIGURE 6-STRESS SITUATION**

From the diagram of each cross section the current stress state and stress distribution, in Figure 6 Monitoring unit pipe has differential settlement in X16 upstream. Bending point X4 and X5's bending stress are 104.23Mpa and 115.54Mpa respectively. Calculated maximum subsidence is about 0.6m by Monitoring tube segment.

The other four-point analysis method of the data chart is similar to analysis methods of A and F monitoring units.

### *3.3. Stress Checking*

#### *3.3.1 Check of the calculation conditions*

Six monitoring points the type of pipe, stress check of calculation conditions are listed in Table 4.

**TABLE 4-PIPELINE STRESS CHECK OF THE CALCULATION CONDITION TABLE**

| Monitoring Unit | pipeline type | Diameter D (mm) | Wall thicknes s t (mm) | Steel grade | Poisson ratio | Coefficient of linear expansion of steel (℃-1) | temperature of the pipe installation (°C) | working temperature of The Pipeline (°C) | Pipeline operating pressure (Mpa) | Modulus of elasticity (Mpa) | Minimum yield strength (Mpa) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **A** | Insulating pipe | 813 | 16 | L450 | 0.3 | 0.000012 | -20 | 14.3 | 8.6 | 210000 | 450 |
| | PE pipe | 813 | 14.2 | L450 | 0.3 | 0.000012 | -20 | | 8.6 | 210000 | 450 |
| **B** | PE pipe | 813 | 14.2 | L450 | 0.3 | 0.000012 | -20 | 12.7 | 8.6 | 210000 | 450 |
| **C** | Insulating pipe | 813 | 14.2 | L450 | 0.3 | 0.000012 | -20 | 8.1 | 8.6 | 210000 | 450 |
| **D** | Insulating pipe | 813 | 16 | L450 | 0.3 | 0.000012 | -20 | 7.8 | 8.6 | 210000 | 450 |
| **E** | Insulating pipe | 813 | 16 | L450 | 0.3 | 0.000012 | -20 | 6.7 | 8.6 | 210000 | 450 |
| **F** | PE pipe | 813 | 16 | L450 | 0.3 | 0.000012 | 75 | 7.7 | 8.6 | 210000 | 450 |

#### *3.3.2 Monitoring unit stress check of results analysis*

Calculated method according to the previously described pressure check, from the monitoring results currently, unit F, X5-sectional strain monitoring has the largest numerical change, according to Hook's law calculated, pipeline axial tensile stress in the elastic range is 125.7Mpa, maximum axial compressive stress is -104.4 MPa. Therefore, this report only checked of the stress of the cross section.

Monitoring sensors and pipeline are installed during the same period, therefore, monitoring of the pipe axial stress change values ,which may be deemed to include that the pipeline axial stress changes was caused by the difference in temperature and internal pressure, external pipeline stress changes is caused by load axial.

In addition, the checking did not consider the laying of flexibility.

1) The axial tensile stress checking:

128.48Mpa＜360MPa（450×0.8）

At present monitoring of the pipeline axial tensile stress are 35.7% of the allowable values, Pipeline axial tensile stress met the design requirements.

2) The axial compression stress checking:

-112.12 MPa ＞ (8.6×781)÷(2×16)－(450×0.9)=-195.11 MPa

At present monitoring calculation of pipeline axial compression stress is 57.5% of the allowable values, pipeline combination of equivalent stress met the design requirements.

## 4. ANALYSIS OF RESULTS

F monitoring Unit in the X16 upstream pipeline existed a larger settlement , calculated pipeline's settlement is 0.6m. X1 to X8 settlement segment formed a large bending stress, Although stress check met the requirements, the monitoring data is still slowly increasing, recommended that necessary to take the engineering control measures, and prevention frozen disaster to damage the pipeline.. It's much more desirable than the conventional methods. This monitoring method has a good reference value for the Pipeline safe operation of other future permafrost zone.

## 5. CONCLUSION

It was the first application in the Permafrost zone in China and played an important role to ensure that China-Russia crude oil pipeline operate safely. Sino-Russian crude oil pipeline has been safe and stable operate for more than a year, the field experiments and analytical methods have demonstrated that stress monitoring system can be practical and provide adequate results to assess the pipeline integrity. We can get the real strain data at any time. From the monitoring data we can estimate that if the pipeline strain is exceeded of the strain capacity of the pipeline, achieve real-time monitoring of the pipeline is safely operating or not, which prevents the damage of frozen disaster from the pipeline. It's much more desirable than the conventional methods. This monitoring method has a good reference value for Pipeline safe operation of other future permafrost zone.

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