Experimental Study on Prestressed BFRP Reinforced Mental Pipelines

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Abstract. Based on the working mechanism of metal pipelines strengthened by basalt fiber reinforced polymers (BFRP), the properties of the new stretching and anchoring integral anchorage for prestressed BFRP are studied. The results show that BFRP could be prestessed by rotating anchor rod, and that bolt could anchor BFRP effectively. And the strain distribution law of prestressed BFRP is analyzed. It provides the test basis for the design and construction of prestressed BFRP reinforced metal pipelines.

Introduction

Metal pipelines have been widely used in the fields of municipal engineering, petrochemical industry and water conservancy[1,2]. The metal pipelines in service are inevitably damaged, and it is necessary to solve the technical problems in the engineering field to seek economical and efficient repairing technology of metal pipelines. BFRP reinforced metal pipelines has the advantages of simple transmission, corrosion resistance and easy construction.

At present, there are few researches on prestressed BFRP reinforced mental pipelines at home and abroad, the key factor is the lack of effective method of applying circumferential prestress, while the method of prestressed BFRP reinforced mental pipelines is safer than wrapping with BFRP[3,4]. Therefore, the development of an effective prestressed device becomes the precondition of prestressed BFRP reinforced mental pipelines.

Based on the mechanics principle and method of BFRP reinforced mental pipelines, combining with the advantages of the existing prestressed device, the research group developed a set of stretching and anchoring BFRP with circumferential prestress. The paper introduces its working mechanism and analyzes the strain distribution of prestressed BFRP reinforced mental pipelines.

Design of stretching and anchoring integral anchorage

Device design and production

Based on the mechanical principle of BFRP reinforced mental pipelines with internal pressure, and considering the stress characteristics of mental pipelines, a stretching and anchoring integral anchorage applying prestress is put forward under the precondition of guaranteeing long-term stability of prestress. The integral anchorage is composed of bottom plate, anchor plate, anchor rod and bolt.

The test apparatus uses Q235 steel, the length of the anchor rod is 260mm, and the diameter is 30mm; the thickness of the anchor plate is 20mm, the width is 100mm, and the height 50mm; the diameter of A-class bolts is 12mm, and the length is 50mm; the thickness of the bottom plate is 200mm; the E43 electrode is selected and welded manually, the weld form is fillet weld, the leg length is 10mm, and the two ends are not used run-on plate, each anchor plate is welded on both sides.

The working principle of the anchorage

The principle of stretching and anchoring BFRP with anchorage is that BFRP can be tensioned beforehand to produce prestress by rotating anchor rod, and when the prestress reaches predetermined value, the anchor rod is fixed by using bolts and prestressed BFRP is locked avoiding the loss of prestress due to the shrinkage of BFRP.

When the anchorage is applied to BFRP reinforced mental pipelines, BFRP is subjected to tension and the interface of mental pipelines is under positive pressure. The anchor base is under pressure from

the upper anchor rod, and the interface is under positive pressure on the contact interface of the anchorage and mental pipeline to form a closed ring-shaped confinement effect. The stretching and anchoring device for prestressing is simple in structure, concise in transmission force and reliable in anchoring prestressed BFRP, and it is simple and easy to operate.

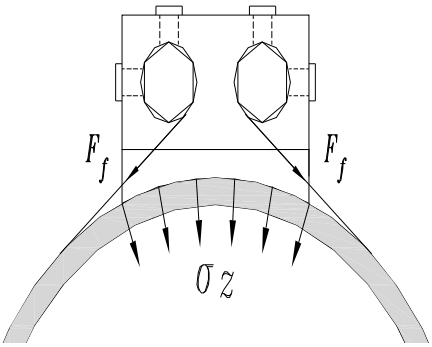

Fig. 1 The working principle of the anchorage

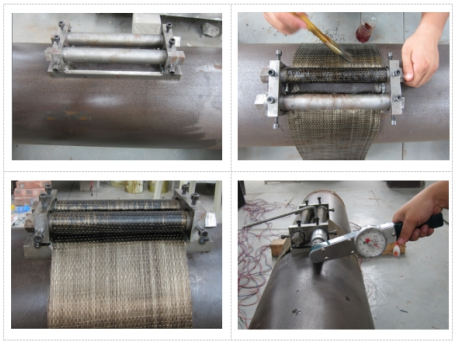

Fig. 2 The construction operating procedure

The construction technology of the anchorage applying prestress

The construction operating procedure of the anchorage applying prestress are as follow, as shown in Fig. 2.

(1) Polish and clean the surface of mental pipeline to be strengthened with alcohol, and fix the anchorage in a reinforced area.

(2) Cut the BFRP sheet with corresponding length.

(3) Configure glue separately with epoxy resin AB group.

(4) Wrap BFRP around the mental pipeline to be reinforced, and paste the ends of BFRP with the glue to the anchor rod.

(5) Fix one end of the anchor rod and rotate the other end when the glue is solidified.

(6) When prestress reaches the preset value, promptly tighten the bolt to lock the anchor rod.

Experimental study on prestressed BFRP reinforced mental pipelines with anchorage

Test Overview

Test materials and equipment

The specimen is made of Q235B low carbon steel pipes with a dimension of 273 mm x 1.92 mm x 1500 mm, the elastic modulus is 200 GPa, the yield strength is 240 MPa, and the ultimate strength is 445 MPa. The tensile strength of BFRP is 2002 MPa, and the elastic modulus is 105 GPa. The glue uses CH-1A resin-impregnated with a shear strength of 24.6 MPa.

The test equipment adopts the static strain tester of DH3818-3 produced by Donghua Corporation and the ACD and TG300 torque wrench produced by Zhejiang Shengzhou Moment Tool Manufacturing Co., LTD.

Loading method

According to the operating procedure of the anchorage applying prestress, and the arrangement of strain gauge is shown in Fig. 3. The torque is applied to the anchor rod by using graded step-by-step loading method with the torque wrench.

Test results and analysis

The validity of stretching and anchoring integral anchorage

When the torque is applied to 160 N·m, the change of BFRP strain in 2h is shown in Fig. 4. BFRP is tensile strain by stretching, and the loss of strain after anchorage locked is reduced, but the strain attains balance after 2h, and remains in the initial value of 95.54%. It indicates that the stretching and anchoring integral anchorage is effective and feasible.

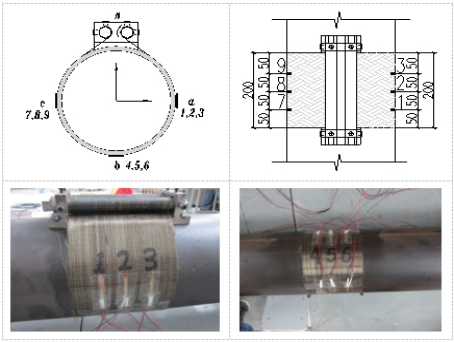

Fig. 3 Arrangement of measuring points

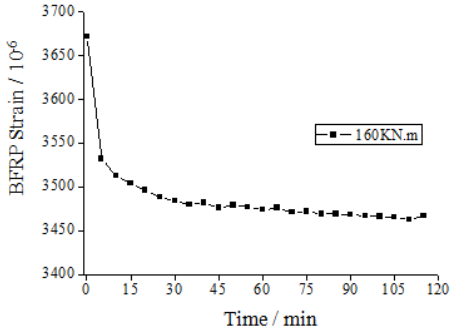

Fig. 4 The change curve of strain and time

The strain distribution of prestressed BFRP

According to the prestressing steps, the loading ranges from 0 to 120 N·m, and the test is carried out by using the torque wrench, and the strain distribution of prestressed BFRP has the following rules.

(1) The BFRP strain value is not evenly distributed on the axial section.

Under the same torque, the BFRP strain values of different axial positions on the same circumference are different, as shown in Table 1. The reason is that BFRP sheet is different from the general homogeneous material, which is made of many root filaments, and it is difficult to achieve the same length in weaving process. The filaments of BFRP without brushing glue are independent of each other, and they cannot be coordinated as a whole. Therefore, it is very difficult for the BFRP to be uniformly prestressed when the tension of the anchorage is not equal to that of each fiber.

Table 1 The strain measured results of measuring points

Torque /N.m	1	2	3	4	5	6	7	8	9
					/10^{-6}				
0	6	9	15	2	19	0	0	9	0
5	324	264	304	158	144	121	164	160	166
10	517	422	434	235	205	176	250	243	292
15	693	576	584	308	318	257	366	310	333
20	884	767	828	340	426	372	562	436	402
25	1021	884	933	411	496	424	660	522	474
30	1115	982	1047	443	548	471	712	567	531
35	1182	1060	1120	483	609	533	756	597	569
40	1171	1028	1103	446	592	541	766	551	466
45	1384	1178	1298	534	692	613	918	774	687
50	1391	1292	1401	566	784	682	943	850	758
55	1416	1279	1395	571	801	720	984	878	789
60	1512	1393	1491	586	839	734	1035	916	820
70	1532	1231	1229	725	1059	1067	1377	1257	1081
80	2048	1805	1789	978	1307	1239	1704	1519	1347
90	2159	1929	1928	973	1317	1212	1708	1532	1379
100	2541	2260	2183	1218	1482	1294	1883	1677	1566
110	2655	2278	2153	1249	1561	1371	1986	1766	1682
120	2732	2459	2385	1449	1728	1547	2181	1921	1813

(2) The strain value is not evenly distributed in the circular direction.
In order to reduce the influence of strain on axial cross section distribution, it is assumed that the average axial cross-sectional strain is the strain of the BFRP section. Under the same torque action, the strain value of BFRP in the distance from the anchorage is smaller, as shown in Fig. 5. This is because there is the friction between BFRP and the contact surface of the hardened specimen, and with the gradual tension of BFRP, the friction force is increasing.

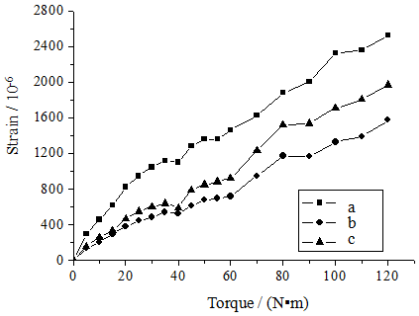

Fig. 5 The torque and strain curve of different measuring position

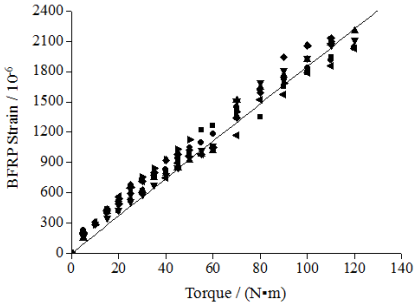

Fig. 6 The curve of torque and the average BFRP strain

(3) The average strain is linearly r elated to the torque value.
The average strain of BFRP increases with the increased torque, and the distribution between them is close to the obvious linear relationship,as shown in Fig. 6.

Conclusion

Based on the working mechanism of BFRP reinforced metal pipelines, BFRP applying prestress is proposed by using stretching and anchoring integral anchorage. The paper expounds the working principle and the construction technology applying prestress of the anchorage, and establishes the BFRP strain distribution law after applying prestress and analyzes the causes. It provides an important reference for the further study on the technical method of prestressed BFRP reinforced metal pipelines.

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