Study on Mechanical Behavior of High Pressure Heater Tubesheet 20MnMoNb

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Abstract. 20MnMoNb alloy steel is a structural steel for forgings with good mechanical properties, which is typically used in the manufacture of pressure vessel tube sheets. The mechanical properties of 20MnMoNb at different temperatures were systematically studied. It is shown that the 20MnMoNb material has the good high temperature resistance. With the increase of temperature, the yield strength and tensile strength of the material have little difference. The tensile strength is nearly 800MPa at high temperature, and the yield strength is about 643MPa, which could meet the complex working environment of the high pressure heaters. It is helpful to improve the accuracy of analytical design results and provide a data base for the revision of subsequent material standards.

1. Introduction

20MnMoNb alloy steel is a structural steel for forgings, which has good mechanical properties and is not normally used as quenched and tempered steel[¹⁻³]. In the case of quenching, the metallographic structure is lath martensite, and after tempering it is bainite. The quenching and tempering treatment is tempered sorbite, which has been included in NB/T 47008-2017 "carbon steel and alloy steel forgings for pressure equipment". In recent years, with the continuous improvement of design parameters, the temperature of the tube sheet has got larger and larger, and the wall thickness of the tube sheet design got bigger and bigger. It is urgent to carry out research on analysis and design methods to reduce the wall thickness. It is necessary to fully understand Mechanical properties of the material at the different temperatures. Therefore, the mechanical properties of 20MnMoNb at different temperatures are studied systematically by perfecting the analysis method of container steel with superior performance. It is useful to further improve the accuracy of analytical design and provide a basis for the revision of China's material standards.
2. Test

2.1. Purpose of the test
The purpose of the experiment is to obtain the stress-strain curve and tensile strength of the material. The influence of temperature on the tensile mechanical properties of 20MnMoNb at high temperature was analyzed to further judge the static performance and safety of 13MnNiMoR material at high temperature based on the experimental results.

2.2. Process of the test
The high temperature furnace is used to raise the temperature to the specified temperature according to the designed heating rate (20°C/min), and the temperature is maintained for 30 minutes. The temperature and the heat preservation process test load are 0, which allow the specimen to expand naturally. Secondly, the loading method of the test piece in the steady state test is the same as the loading method of the tensile test piece at normal temperature during the first stage refer to the requirements of GB/T 228.2-2015 "Metal material tensile test part 2: high temperature test method". The loading rate is 0.1 mm/min until the specimen strain is 2.0 mm; the second phase loading rate is 1.0 mm/min until the specimen is broken. The constant temperature is always constant during the loading process. The test temperatures were 100 °C, 150 °C, 200 °C, 250 °C, 300 °C and 350 °C. Since the constant temperature time at each temperature point is short. The influence of creep is not fully considered.

2.3. Equipment of the test
The instrument used in the high temperature tensile test is the INSTRON 8801. The measuring device is a high temperature extensometer UTM5305 for measuring the tensile strain. The sampling frequency is 5 Hz and the measuring range is 50 mm.

2.4. Specimen of the test
The dimensions of the test piece are in accordance with GB/T 228.1-2010 "Metal material tensile test part 1: Room temperature test method" and GB/T 228.2-2015 "Metal material tensile test part 2: High temperature test method". The design is carried out, and the specific dimensions are shown in Fig. 1. In order to avoid the influence of stress concentration and surface roughness on the test results as much as possible, the gauge length of the tensile specimen was polished and polished with 5000# German Warrior sandpaper before the experiment.

![Figure 1 The size of specimen](image)

3. Results
The tensile curves of the materials at different temperatures are shown in Figure 2.
The mechanical properties of the material are shown in Table 1:

| Temperature, °C | Serial Number | Tensile Strength, MPa | Yield Strength, MPa |
|----------------|---------------|-----------------------|--------------------|
| 100            | A-1           | 815                   | 670                |
|                | A-2           | 811                   | 670                |
|                | A-3           | 819                   | 671                |
|                | average       | 815                   | 670.3333           |
| 150            | B-1           | 811                   | 671                |
|                | B-2           | 793                   | 653                |
|                | B-3           | 802                   | 653                |
|                | Average       | 802                   | 659                |
| 200            | C-1           | 802                   | 653                |

Figure 2. Tensile Curves of Materials at Different Temperatures
| Temperature, °C | Serial Number | Tensile Strength, MPa | Yield Strength, MPa |
|-----------------|---------------|-----------------------|--------------------|
|                 |               |                       |                    |
|                 | C-2           | 802                   | 662                |
|                 | C-3           | 802                   | 662                |
| Average         |               | 802                   | 662                |
|                 | D-1           | 793                   | 635                |
|                 | D-2           | 793                   | 627                |
|                 | D-3           | 776                   | 618                |
| Average         |               | 787.3333              | 626.6667           |
|                 | E-1           | 802                   | 640                |
|                 | E-2           | 789                   | 618                |
|                 | E-3           | 797                   | 609                |
| Average         |               | 796                   | 622.3333           |
|                 | F-1           | 806                   | 622                |
|                 | F-2           | 815                   | 627                |
|                 | F-3           | 824                   | 627                |
| Average         |               | 815                   | 625.3333           |

4. Discussion
From Table 1, it could be clearly seen that the 20MnMoNb material has good high temperature resistance. The tensile strength at high temperature is about 800MPa, and the yield strength is about 643MPa. The mechanical properties are good, and the tensile strength of the material is basically increased with the increase of temperature. The yield strength is slightly reduced, and the material could be effectively applied to the complex working environment of the high pressure heater.

5. Conclusion
The mechanical properties of 20MnMoNb at different temperatures were systematically analyzed. It is shown that the 20MnMoNb material has good high temperature resistance. With the increase of temperature, the yield strength and tensile strength of the material have little difference with temperature increasing. The tensile strength of 800MPa at high temperature, and the yield strength of about 643MPa, which could meet the complex working environment of high-pressure heaters. It could be useful to improve the accuracy of analytical design results and provide a data base for the revision of subsequent material standards.
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