# Residual stress determination on U-sheet pile using stress free method

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**Keywords:** U-sheet pile; Residual stress; Strip sectioning method; Full release method; X-ray diffraction method.

**Abstract.** The Influence of the residual stress on the entire quality of U-sheet pile is introduced. The sectioning method and full release method are used to detect the surface residual stresses on quarter and half length place of the U-sheet pile. The testing principle of stress free method, experimental equipment and testing process are introduced in detail. The stress distribution on U-sheet pile is obtained. X-ray diffraction (XRD) method is used to validate the residual stresses on the same positions. The difference between the two testing methods is compared. Result shows that the stress gradient on the bottom sternum is comparatively larger. On the left side plate, longitudinal compression stress and transverse tensile stress are detected at half length positions, and opposite results are found at quarter length positions. On the right side plate, the stress states are coincident. Transverse stress presents difference between sectioning and full release method, because of the unreleased stress on transverse direction of sectioning method.

## Introduction

The groin has been widely applied as a conventional hydraulic structure for beach protection and accretion promotion. The traditional rock-fill groin is subject to destruction and the cost of maintenance is rather high. As an improvement of traditional rock-fill groin, the sheet-pile groin, which is composed of piles arranged in parallel and connected with a beam at the top, is increasingly used for the purpose of preventing scour and reducing the cost of maintenance. However, the residual stress induced by mechanical assembly processes and heat treatments will influence the entire quality of sheet pile. In the working temperature, the residual stresses can reduce the strength of the product or the components, or even bring some defective workmanship such as cracking and deforming in the manufacturing process. On the other hand, after products are manufactured, the stress releasing process will change the size of the components or reduce their fatigue strength, stress corrosion and other mechanical performance [1-2]. The size change may even make the sheet pile can not be locked together. Therefore, residual stress research is all-important to ensure product quality or safety and reliability of sheet pile products.

The stress release method is an appropriate way to determine the residual stress for the steel sheet pile with large size. The stress release method is founded a century ago. In 1888, Kalakoutsky from Russia firstly report the strip slitting method to test the longitudinal residual stress. American Treuting develops this method and calls it sectioning method in early 1950s. Nowadays, the stress release method has been widely used in research institutes, universities and manufacturing enterprises, covers iron and steel, utilities, aluminum, power and other domain [3].

In order to study the residual stress distribution condition of the U-shaped steel sheet pile and provide the product design reference, the sectioning method and full release method are used to detect the surface residual stresses on quarter and half length place of the U-sheet pile. First of all, the test principle of stress release method is introduced linked with rail residual stress determination. In the section two, experimental equipment and testing process are introduced in detail. Finally, the X-ray diffraction method is used to validate the residual stresses on the same positions.

## The test principle of stress release method

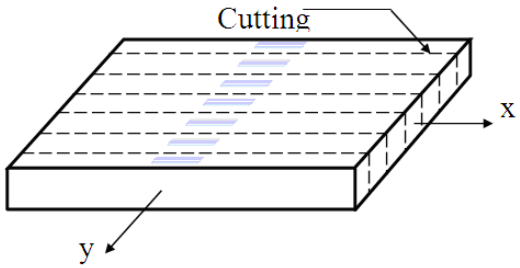


Fig. 1 A schematic illustration of stress release method

The cutting stress release method includes strip sectioning method and full release method. A schematic illustration of stress release method is shown in figure 1. For strip sectioning method, the test piece is only cut into strips to be separated along the X direction. For full release method, the test piece should also be separated along Y direction to release the stress in X direction. The strain increment can be measured near the separating surface. Then the original residual stresses can be determined according to Hooke's law.

The most typical application example of stress release method is residual stress determination of rail. The destructive rail waist sawing method and cross-cutting method are the most popular ways to test the residual stress of rail. One meter rail sample should be cut from the finished long rail. Paste the strain gauge on the central position at the rail bottom, then sawing 20 mm wide central specimen. The strain values before and after cutting can be measured. Then the residual stress at the central position can be calculated. The rail can not be accepted when the residual stress at the rail bottom is greater than 250Mpa. And the cross-section cutting method is recommended in Chinese iron standard [4].

In order to get comprehensive understanding of the residual stress distribution on U sheet pile, more stain gauges are set compared with the residual stress test in rail. Beside the multiple test points set on the sternum, measuring points on the corners and side panels are added. In addition, in order to examine the residual stress change in the length direction, the residual stress distribution on both half and quarter length locations are inspected.

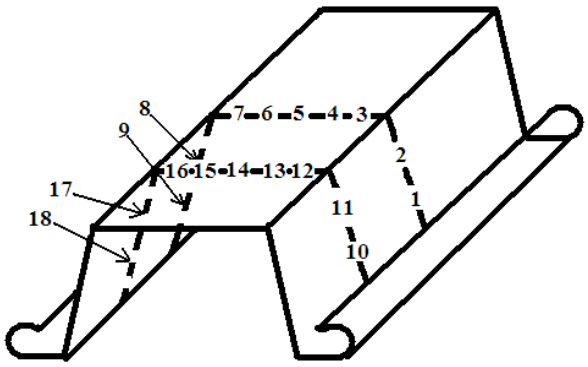


Fig. 2 Schematic diagram of testing position on U-sheet pile

## Residual stress test using stress free method

Sectioning method and full release method recommended in TB/T 2344-2003 [5] are used to detect the surface residual stresses distribution of WBZ500 steel sheet pile.

**Test Equipment.** The static resistance strain gauge tester BZ2206 is used to measure the strain value. The substrate size 6×6mm bi-directional strain gauge BA120-1BA (11)-ZKY is used in the test.

**Sample specification and test position.** The sample size specification: length 1.2m, width 0.4m, height of 0.17m, the thickness of 15.5mm. The test methods refer to the heavy rail residual stress

measurement. The sectioning method and full release method are used to detect the surface residual stresses on quarter and half length place of the U-sheet pile. The test positions are shown in Figure 2.

Fig. 3 Small samples after full stress release

**Test process.** Firstly, polish the test positions with a cloth wheel on the 1.2m long steel sheet pile surface. Then use 200# sandpaper to do refine polish and clean up with alcohol. Use 502# glue to paste the strain gauge on the corresponding measuring point. Record the initial strain readings after the strain piece get dry. Cut the test sample into pieces according to TB / T 2344-2003. For full release method test, the test sample should be then cut into 10 x 10mm size one, shown in Figure 3. After the strain increment is obtained, the original residual stresses can be determined according to Hooke's law.

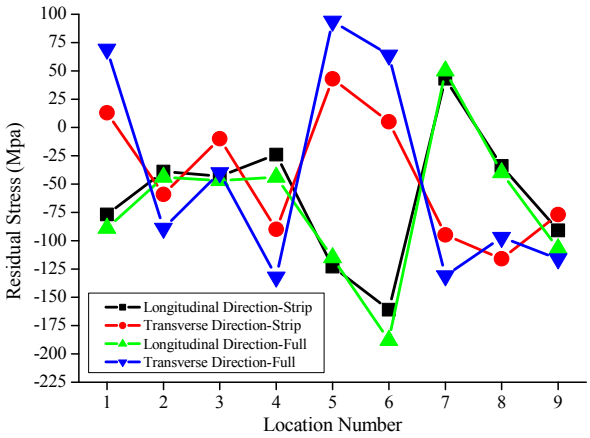


Fig. 4 Half length residual stress distribution

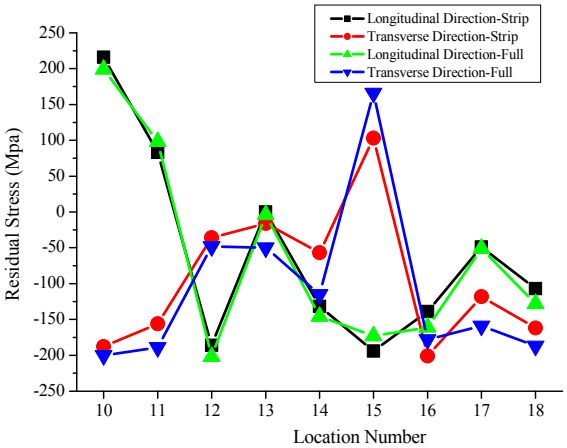


Fig. 5 Quarter length residual stress distribution

**Test results.** Figure 4 and 5 show the residual stress distribution at half and quarter length position using strip sectioning and full release method respectively. Result shows that the stress gradient on the bottom sternum is comparatively larger. On the left side plate, longitudinal compression stress and transverse tensile stress are detected at half length positions, and opposite results are found at quarter length positions. On the right side plate, the stress states are coincident. Transverse stress presents difference between sectioning and full release method, because of the unreleased stress on transverse direction of sectioning method.

For U-sheet pile this kind of stress distribution is suitable for engineering application. The sample residual stress on side plate will help the product to get a better size control and lock performance. In addition, the compressive stress on the sternum plate will enhance the fatigue performance.

## Validate test by XRD method

IXRD X-ray residual stress tester made by Proto is used to do validate test along length direction. The residual stress test process using X-ray method is according to national laboratory standards GB/T7704-2008 [6]. In this experiment, the round φ2mm collimator is employed. As the sheet pile is ferritic steels, CγKα radiation and vanadium foil filters is used. Diffraction crystal face is (211) with the stress constant K =-318MPa / (°).

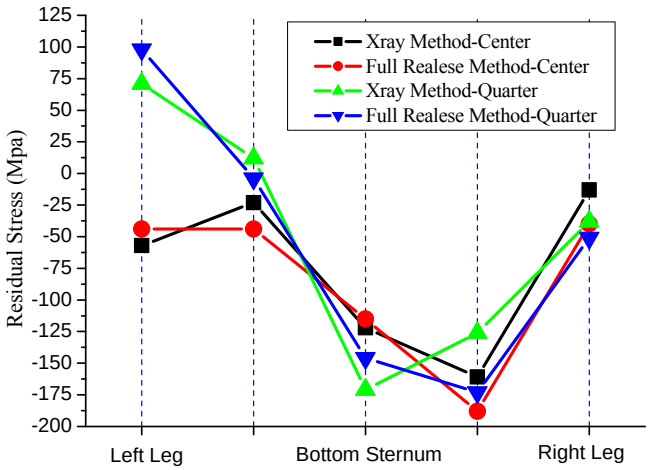


Fig. 6 Test comparison of full release method and XRD method.

Figure 6 shows that release method and X-ray test results are in agreement. It is worth noting that the residual stress value test by X-ray method is slightly larger than the stress release method at quarter length position. It is because that the 1/4 length place can not provide enough stress release space.

## Conclusions

1. Because the strict size requirement of the U-sheet pile, the residual stress will influence its entire product quality.

2. The sectioning method and full release method are used to detect the surface residual stresses on quarter and half length place of the U-sheet pile. The stress distribution on U-sheet pile is obtained. X-ray diffraction (XRD) method is used to validate the residual stresses on the same positions.

3. The stress gradient on the bottom sternum is comparatively larger. On the left side plate, longitudinal compression stress and transverse tensile stress are detected at half length positions, and opposite results are found at quarter length positions. On the right side plate, the stress states are coincident.

4. Transverse stress presents difference between sectioning and full release method, because of the unreleased stress on transverse direction of sectioning method.

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