

# Fracture Analysis of Cast Steel Sling

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**Abstract:** The fracture reasons of ZG270-500 cast steel sling are analyzed through such means as macroscopic morphology analysis, chemical composition analysis, and microscopic metallography analysis. Results: coarse Widmanstatten structure and casting defects occurring in casting and subsequent heat treatment process reduce the strength, plasticity and toughness of the steel, which is the main reason of brittle fracture of the sling during work, and corresponding improvement suggestions are proposed herein.

Brittle fracture is one of the main failure modes of metal structures; in particular, materials with relatively large brittleness are more likely to produce brittle fracture. ZG270-500 cast steel has a good comprehensive mechanical properties, widely used in a variety of important structural parts, especially those working under alternating load connecting rods, hooks, bolts, gears and shafts and so on. One of the rings is a kind of spreader commonly used in hoisting machinery. However, if the manufacturing process is improper or the processing quality is not good, it may cause brittle fracture of the rings to cause the hanging material to fall and bring serious consequences.

A sudden fracture occurred when the clamping ring made of ZG270-500 cast steel by a mechanical company during use, which caused hoisting workpiece damages, impacted the safety of personnel and equipment, and caused loss of production. Broken rings is shown in Fig. 1. Coarse morphology, chemical composition, and microscopic metallography are analyzed for the fracture site in order to find out the cause of the sling fracture and prevent fracture.

## 1. Macroscopic Morphology Analysis

The rings are broken into two parts, some of which remain on the base. The fracture site of clamping sling ring is shown in Fig 2. The component integrally fractures; the fracture surface is relatively large; the macroscopic morphology shows that the fracture is a brittle fracture, the grains of the fracture surface are obviously coarse, and the crack originates from the interior of the material.





**Fig 1.** Broken rings



**Fig 2.** Macroscopic Morphology of Fracture

## 2. Chemical Composition Analysis

The chemical composition of the failure sample is analyzed with a spectrometer and the results are shown in Table 1. Table 1 shows that the chemical composition of the material conforms to the provisions of ZG270-500 in the Carbon Steel Castings for General Engineering Purposes (GB11352-89) and the analysis of chemical composition also shows that the design requirements are met.

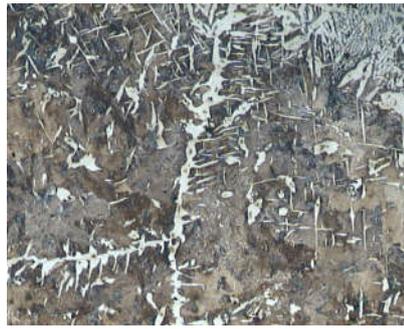
**Table 1.** Chemical Composition of Cast Steel (Mass Fraction)

元素 Element	C	Si	Mn	P	S
含量 Content	0.38	0.32	0.65	0.030	0.028

## 3. Metallography Analysis

In the hanging ring on the back of the longitudinal section of the specimen, polished after observation under the optical microscope, as shown in Fig. 3. Fig. 3 shows that the structure of the material is the typical Widmannstatten structure, namely free ferrites precipitate along grain boundaries, some ferrites extend to the grain interior from grain boundaries, and some ferrites precipitate independently in the grain interior. The metallography result also shows that obviously coarse grains appear in the material interior but it is hard to find a complete grain under 50x optical microscope. According to GB13299-1991, the level of Widmannstatten structure is Level 3-4.

The Widmannstatten structure has coarse grains and reduces all the strength, plasticity and toughness of the steel, especially toughness. Therefore, Widmannstatten structure is generally not allowed in important products.

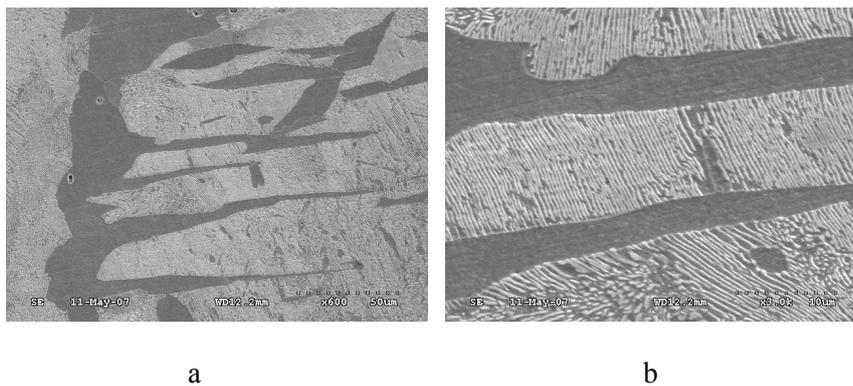


**Fig 3.** Metallurgical Structure of Failure Sample

#### 4. SEM Analysis

##### 4.1 Microstructure

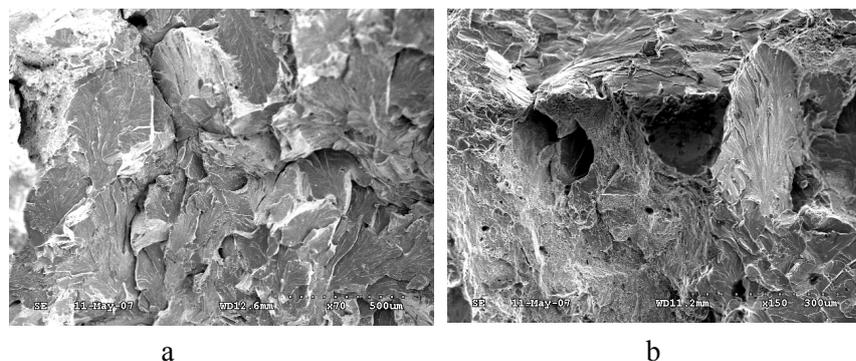
Will ring broken with acetone repeated ultrasonic cleaning, the microstructure of sample fracture is examined with a SEM and the sample microstructure is shown in Fig.4. Fig. 4 shows that massive pearlite exist among ferrite chips in the Widmanstatten structure.



**Fig 4.** Microstructure of Sample Fracture under SEM

##### 4.2 Morphology of Sample Fracture

The morphology of the sample fracture is shown in Fig. 5. Fig. 5 shows that the fracture is an obvious brittle transgranular fracture and the characteristics of radial stripes can be observed. There are a lot of secondary cracks on the fracture surface and there are a large number of casting defects (pore) in the fracture surface material.



**Fig 5.** Fracture of Failure Sample under SEM

## 5. Conclusions and Suggestions

From the above analysis we can see that the chemical composition of the ring meet the standard requirements, but the microstructure shows the material was overheated.

The main reasons of sling fracture are improper casting and subsequent heat treatment process which caused obvious Widmanstatten structure and coarse grains in the material.

As the service status of the rings for the dynamic load, often by the tensile load and the impact of the repeated impact of the load, The Widmanstatten structure reduces the strength, plasticity and toughness of the steel; in particular, the reduction of toughness reduces the capacity of the cast steel sling to withstand the impact load and brittle fracture occurs during work. In addition, many micropore defects during sling casting are also a factor causing its brittle fracture.

The method for preventing brittle fracture is mainly to prevent the generation of Widmanstatten structure and normal normalizing process can be utilized to eliminate the Widmanstatten structure. As for this product, it can be treated with two normalizing processes; relatively high normalizing temperature is adopted in the first time and relatively low normalizing temperature in the second time, which can not only eliminate the Widmanstatten structure but also can refine grains.

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