

# **3D Finite Element Analysis of Marine Steel Plate Magnetic Leakage Testing**

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## **Abstract**

Several types of different disfigurements of marine steel plate were studied and magnetic leakage testing method for inspection was put forward. Based on finite element analysis software ANSYS, 3D models of testing sensor system, magnetizing equipment and steel plate disfigurement were established, and the magnetic field distribution of the model was numerically simulated in its electromagnetic field module. Experiment proved that result of finite element analysis was reliable and could be used to guide design of testing sensor system.

**Keywords:** marine steel plate; magnetic leakage testing; finite element analysis

## **1. Introduction**

All kinds of steel structure and different specifications of the plate are widely used in the shipbuilding industry. Steel of shipbuilding which is made of hull structure according to building criterion of Classification societies generally include Ship Plate Profiled Bar. In order to ensure the safety and life of the ship, a series of demands to the hull structure are need including the method of smelting, chemical composition, mechanical properties and technical capability<sup>[1]</sup>. Marine steel whose requirements are high to material is produced on the basis of requirements of hull structure and its chemical composition and mechanical properties (tensile strength, yield point, elongation, toughness, etc.) which are different from ordinary steel. Marine steel contains low sulphur and phosphorous, high-volume manganese, and high toughness.

The existence of plate defects will seriously affect the operation of the ship stable, in order to ensure the safety of ship and prevent such accidents, the regular test is need to marine steel in-service and service, so that workmen repair or replace timely defective components<sup>[2]</sup>. Therefore, Marine steel plate defect testing method is of great practical value and academic significance.

## **2 Marine Steel Testing Method**

### **2.1 Ordinary Testing Method**

At present testing methods of marine steel plate mainly have Ultrasonic Testing, Eddy Current Testing, Ray Testing, Infiltration of Coloring, Magnetic Testing and Magnetic Flux Leakage Testing. Ultrasonic Testing has high precision to detect

thickness, however, the method efficiency is low because it needs slick steel plate to impose coupling agent and often occur leakage detection. Eddy Current Testing mainly detects the steel plate surface defects but can not detect the defects which are underside and internal of the plate. The operation of Ray Testing is more complicated and it is difficult to detect the floor plate. Infiltration of Coloring and Magnetic Testing need impose coloring agent and powders, they are low efficiency to marine steel plate testing.

Different from the several methods, Magnetic Flux Leakage Testing does not require coupling agent, and not influence by polluted surface oil and non-magnetic impurity, and is with high rate, high sensitivity and reliability, and the results can provide metal surface corrosion defects and crack information. So Magnetic Flux Leakage Testing has been gradually applied in ferromagnetic materials in the NDT <sup>[3]</sup>.

### **2.2 Magnetic Leakage Testing Technology Principle**

The principle of Magnetic Flux Leakage (MFL) is plate material defect (such as cracks, corrosion) magnetoconductivity rate is very smaller than ferromagnet when the plate is magnetized by the external magnetic field, and local magnetic reluctance increases to bend magnetic lines. Some of magnetic lines leak to the material surface which produce proliferation magnetic leakage field. It can gain defect feature information by using Magnetic sensitive element detect magnetic leakage field <sup>[4]</sup>.

### **3 Finite Element Analysis of Marine Plate Magnetic Flux Leakage Testing**

The volume of Marine Plate is hugeness and its magnetized method can only be used local magnetic testing. Comprehensive testing for the whole plate can be achieved by scanning repetitiously. Therefore, the excitation devices and magnetic components in testing sensor system are important parts in design <sup>[5]</sup>.

#### **3.1 The Basic Structure of sensors**

The plate leakage magnetic testing sensors mainly contain excitation devices, magnetic components and drivers, etc.

Excitation devices contain adjusting bolts, gag bit and permanent magnet. The main magnetic circuit which magnetizes plate is constituted by permanent magnet, gag bit and the detected plate. For enhancing excitation magnetic circuit permanent, Nd, Fe, B and rare earth with high residual magnetism and coercivity as permanent magnetic materials are selected <sup>[6]</sup>. Gag bit in excitation magnetic circuit is used to change the direction of magnetic force lines, reduce the magnetic-reluctance of magnetic loop system, and increase magnetic flux density of the key parts. In a magnetic circuit design of constant magnetic field, gag bit material chooses induction pure iron and low-carbon steel, magnetic induction intensity of plate measured generally is larger than 1.4 T to ensure high accuracy rate.

Magnetic components which include coil, Hall devices, magnetic diodes, magnetic resistance, giant magnetic-reluctance sensor, and so on achieve magnetic-electricity conversion. Coil and Hall devices are used commonly as Magnetic Components.

#### **3.2 Simulation Specimen**

For testing the system testing performance and defect calibration, producing a standard specimen to test (as shown in Fig.1). The specimen is made by ordinary low-carbon of 10 mm thickness plate. The plate processes five standard damages which are

20% deep, 8mm wide long-tank and 20%, 40%, 60%, 80% of the spherical deep depression. The standard damages of the specimen have good representations and these damages are similar to corrosion and cracks of steel floor of the large package. The defect face of standard specimen is under the place, at the same time testing system is placed on board to detect several damages.

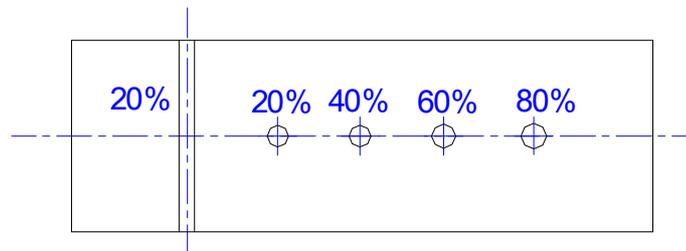
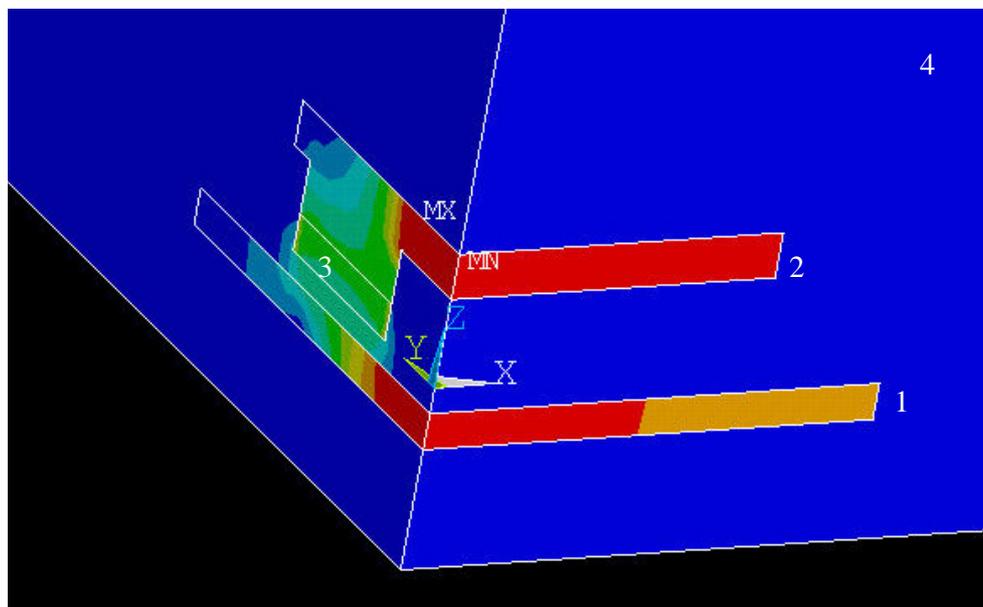


Figure 1 The plate magnetic flux leakage test specimen

### 3.3 Finite Element Model

The simplified model of the sensing system is shown in Figure 2. The model is symmetric about the X-axis and Y-axis<sup>[7]</sup>, so we take 1/4 model as description. In the figure, the 4 stands for the air layer which is used as surrounding the model for the cuboid space, 1 means a plate which is placed below the sensor system, 3 shows permanent magnet, it constitute a magnetic device with the steel bracket. Permanent magnet material contain Nd, Fe, B, the face which get together with bracket 2 is N pole and the face which get together with testing plate is S pole. The magnetic circuit is made up of permanent magnet, detected plate and steel cradle which can magnetize plate to test requirements.



1-plate detected 2- steel bracket 3- Permanent magnet 4-the air layer

Figure 2 Sensing system simplified model

Finite element mesh of marine plate is shown in Fig. 3, the figure is corresponding with X-Y face in Fig. 2. The overall plate and unit used in cube are mapped mesh.

Because of modal symmetry, boundary conditions are imposed symmetry. And the air layer is free mapped by tetrahedral unit and Far-field boundary conditions are imposed in the air boundary.

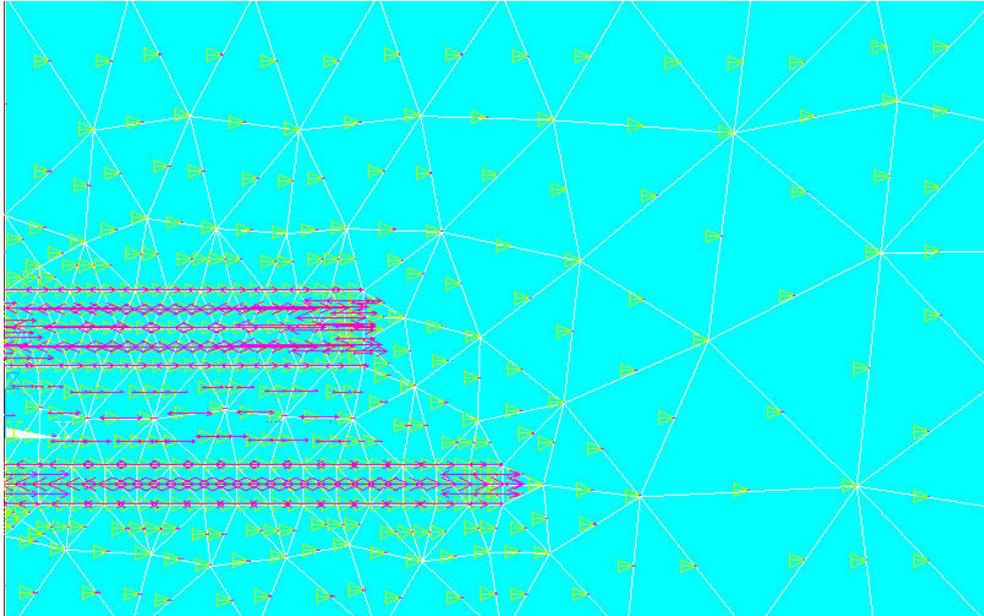


Figure 3 Sensor system finite element mesh model

### 3.4 Finite Element Analysis

We impose the appropriate boundary conditions and carry through static analysis to Sensor System. We can receive magnetic lines distribution and magnetic flux density, as shown in Fig.4.

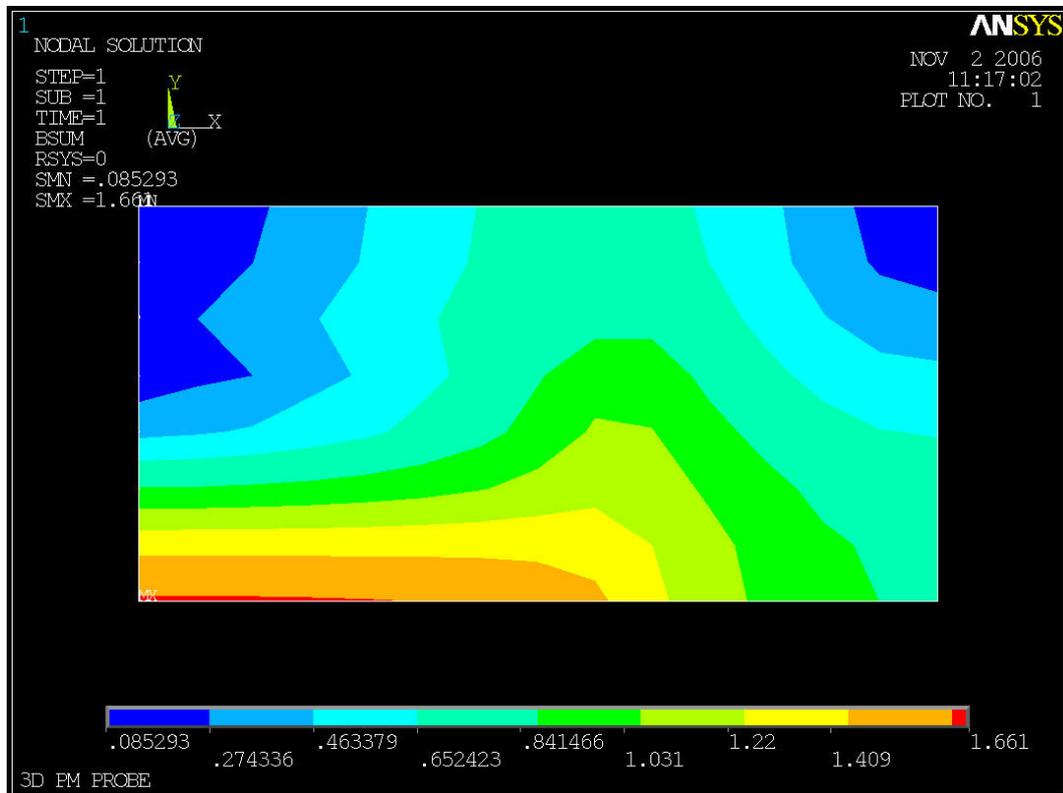


Figure 3 The magnetic lines and magnetic flux density distribution

The figure shows that magnetic flux density can reach 1.4 T in the middle of steel parts, it meets the requirements of Magnetic Flux Leakage Testing. The magnetic field of the middle part of the plate distribute uniformly, the field is similar to the constant magnetic state, if there are damages in the plate, the part of magnetic lines are passed by air, therefore, the sensor is detected to magnetic field changes in the air to determine whether there are damage.

#### **4 Conclusion**

The volume of marine plate is big and the quality is high. Magnetic Flux Leakage Testing Method is the major damage testing. Its advantage contains fast speed, high sensitivity and good reliability. Magnetic Flux Leakage Testing of the marine plate is received three-dimensional finite element analysis by ANSYS software, we can found quickly and accurately the relationship between damage and distribution of the magnetic field, according to magnetic induction intensity, we may make an accurate judgment to the existing form, location, and severity of damage. As the Magnetic Flux Leakage Testing System application and promotion, it will contribute to the plate safety for ship.

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