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

**Han-lin LI [1], Yi-dong HE [2], Jun-ming LIN [2], Zhen-xiong CAI [1]**

**1 Jimei University Marine Engineering Institute，Xiamen，Fujian 361021**

**2 Eddysun (Xiamen) Electronic CO., LTD., Xiamen，Fujian 361004**

## 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

Several kinds of steel structure and different specifications of the plate are widely used in the shipbuilding industry. According to building Criterion of Classification Societies (CCS), steel of hull structure in shipbuilding generally includes ship plate profiled bar. In order to ensure safety of the ship, a series of demands for the hull structure include smelting method, chemical composition, mechanical properties and technical capability [1]. 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 contain low sulfur 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 accident, the regular test is need to marine steel in service or before service, and so workmen repair or replace defective components in time [2]. 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 methods for marine steel plate testing are 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. Eddy current testing detects mainly the steel plate surface defects and can not detect the underside of the plate and internal defects. Ray Testing operation is more complicated and difficult to detect the floor plate. Infiltration of coloring and magnetic testing need impose coloring agent and powders, those methods are low efficiency to Marine steel plate testing.

Compared to over several methods, magnetic flux leakage testing does not require coupling agent, is not polluted by surface oil and non-magnetic impurity, is tested quickly, high sensitivity and reliability, and 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 [3].

### 2.2 Magnetic Leakage Testing Technology Principle

Principle of magnetic flux leakage (MFL) is plate material defect (such as cracks, corrosion) magneto conductivity rate is very smaller than ferromagnet when the plate is magnetized by the external magnetic field, local magnetic reluctance increase to bend magnetic lines, some of magnetic lines leak to the material surface, thereby, produce proliferation magnetic leakage field. It can gained defect feature information, using that magnetic sensitive element detect magnetic leakage field [4].

## 3 Finite Element Analysis of Marine Pate Magnetic Flux Leakage Testing

Marine plate volume is hugeness, its magnetized method can only be used local magnetic testing and this method could achieve comprehensive testing by scanning repetitiously. Therefore, the excitation devices and magnetic components in testing sensor system are important parts in design.

### 3.1 The Basic Structure of sensors

The plate leakage magnetic testing sensors contain mainly excitation device, magnetic components and driver etc.

Excitation device contains adjusting bolts, gag bit and permanent magnet. The main magnetic circuit which magnetic plate is constituted by permanent magnet, gag bit and the plate detected. For enhancing excitation magnetic circuit permanent, we choice NdFeB and rare earth that is high residual magnetism and coercivity as permanent magnetic materials [6]. 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. The current coil and hall devices are used commonly as magnetic components.

### 3.2 Simulation Specimen

To detect the system testing performance and defect calibration, process and produce a standard specimen (as shown in Fig. 3). The specimen is made by ordinary low- carbon of 10 mm thickness plate, the plate process 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.

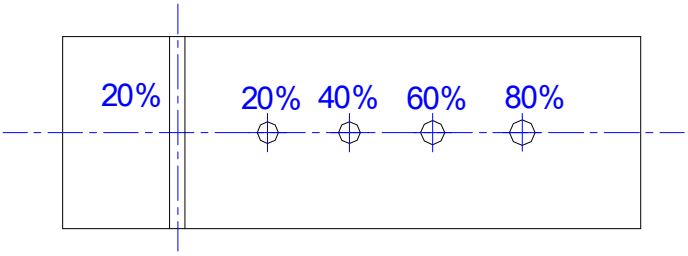
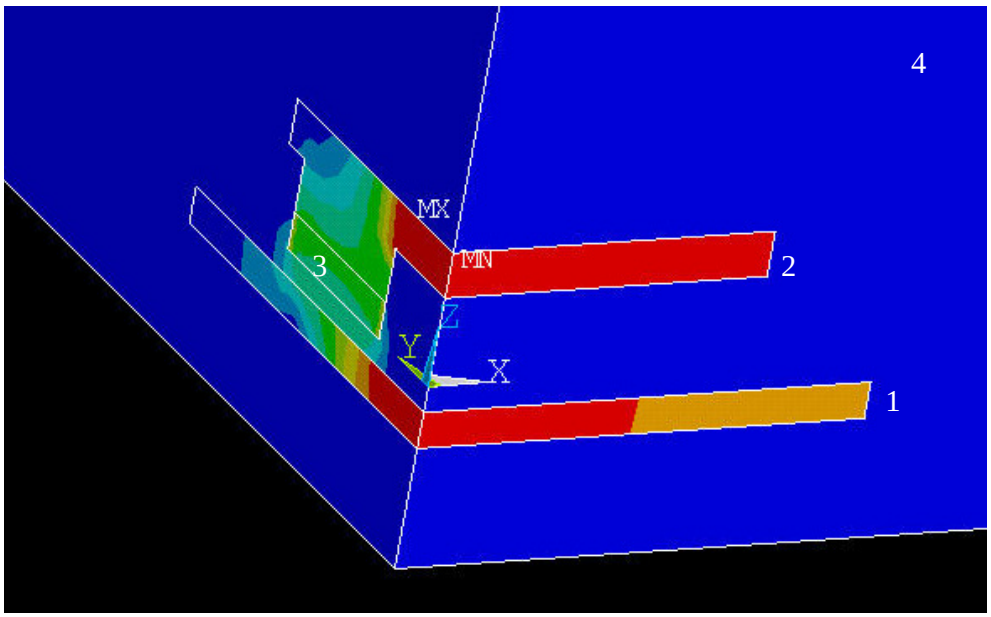



Figure 1 plate magnetic flux leakage test specimen

### 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 [7], so we take 1/4 model as description. Fig 4 shows the air layer which is used as surrounding the model for the cuboid space, 1 shows 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 contains NdFeB, the face which gets together with bracket 2 is N pole and the face which gets together with detected plate is S pole in figure. The magnetic circuit is made up of permanent magnet, detected plate and steel bracket 2, the circuit magnetize plate to detect 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 figure 2. The overall plate and unit used in cube are mapped mesh, because of modal symmetry, impose symmetric boundary conditions; the air layer is free mapped by tetrahedral unit and impose far-field boundary conditions in the air boundary.

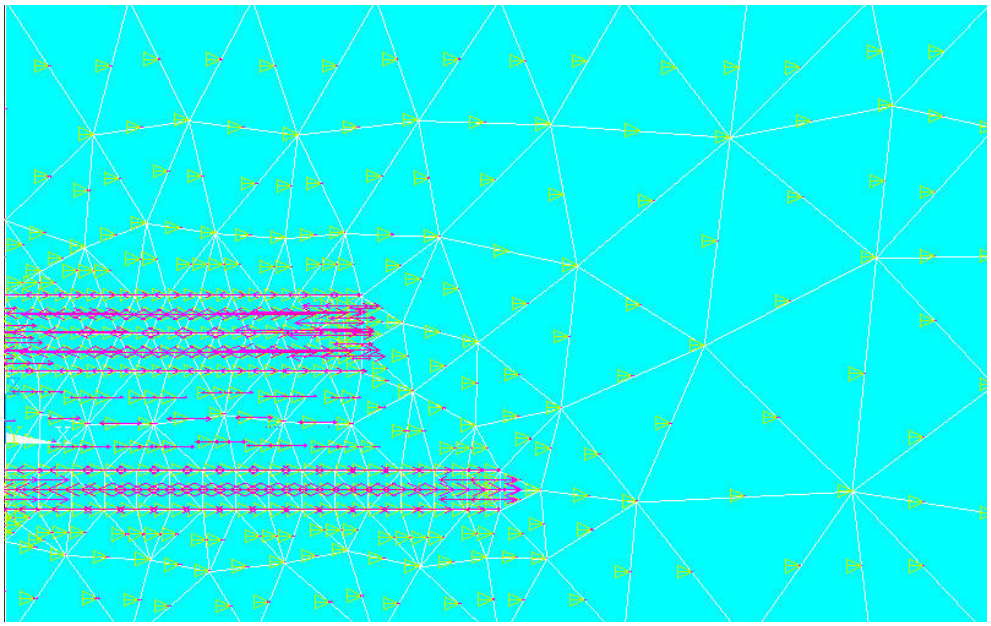


Fig 3 sensor system finite element mesh model

**3.4 Finite Element Analysis**

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

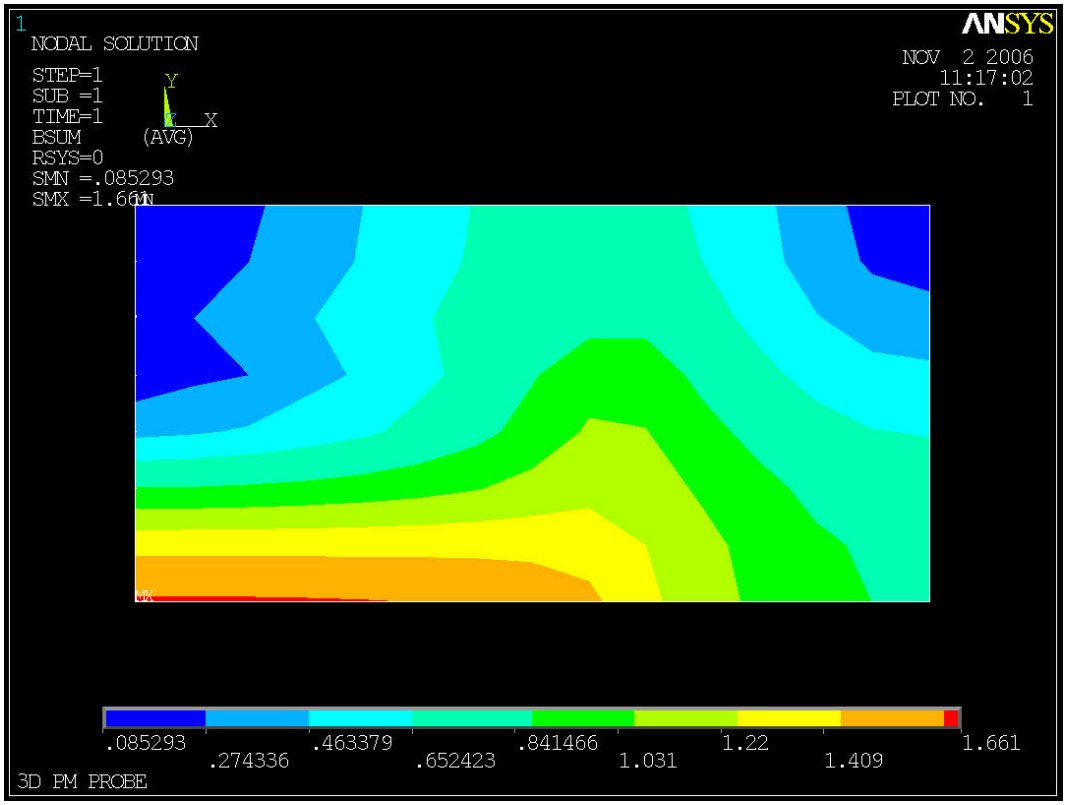



Fig 4 magnetic flux density distribution in plate

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 Conclusions

Volume of marine plate is big and the quality is high. Magnetic flux leakage testing method is a major damage testing method; its advantage contains quick 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.

## References


[1] Wu Quan-Xing. Small marine materials and prospects(Ⅱ)[J]. Rare Metal Express, 2003, (8):23-24.

[2] Ministry of Communications. The Aviso about three ships of the communications testing including Jin-fu Star 18 [J]. China Maritime Affairs, 2005,(2):35.

[3] Chen Jia-Xing, Chen Yong, Deng Yun-Feng. Application of MFL technology in the steel storage tank corrosion testing [J]. Storage and transportation of oil and gas. 2005(2):56-58.

[4]Guo Tai- Feng, Jin Qi, Dou Xin-Hua. Surface Cracks Analysis on MFL testing [J]. Construction and File. 2005(2):134-135.

[5] Keng Yi-Hua, Wu Xin-Jun,Yang Shu-Zi. Nondestructive Testing Technologies in the Magnetic Signal Measurement Technology [J]. NDT. 1999(8):340-343.

[6] Zhong Wei-Chang. Surface Trench Depth on the Impact of the Magnetic Field Leakage [J]. NDT. 1997,(11):304~307.

[7] Huang Zuo-Ying, Que Pei-Wen. Computer Simulation Apply in the Pipeline Leak Testing of Magnetic [J]. Computer Simulation. 2004(l0):174-177.