Demagnetization Scheme for Avoiding Magnetic Mines Under the Exposure of Earth Magnetic Field

Sang Hyeon Im[1], Ho Yeong Lee[1], Hyun Ju Chung[2], Gwan Soo Park[1]
[1]School of Electrical and Computer Engineering, Pusan National University, Busan 46241, South Korea gspark@pusan.ac.kr
[2]The 6th Research and Development Institute-3, Agency for Defense Development, Changwon 51678, South Korea

Demagnetization of warship is needed to reduce residual magnetization to avoid the detection of magnetic mines. However, after a warship was demagnetized, it may be magnetized again by the earth magnetic field during the operation. Conventional deperming protocol does not consider to magnetize again by earth magnetic field after demagnetization. To develop a robust deperming protocol to the influence of earth magnetic field, this paper proposes a protocol that demagnetization finished in a region where the interaction field is large on the Priesach plane. It was found to be more effective by analyzing the trace on the Preisach model and it is proved by experiment. Therefore, it is expected to prevent to magnetize again by earth magnetic field when applying proposed protocol.

***Index Terms*— Demagnetization, earth magnetic field, interaction field, Preisach model, deperming protocol.**

I. Introduction

Demagnetization is to reduce the residual magnetization in magnetic materials. It is used in various industries such as HDD and VFD to record and erase data. Especially, in national defense, it is very important since there are fatal hazards such as magnetic mines if warship has high magnetic flux inside it [1]-[2].

Before warship voyaged to operation region, permanent magnetic fields in it was reduced by demagnetization process to avoid the detection of magnetic mines. However, it may be magnetized again by earth magnetic field when it goes out to operation region and then it will suffer damage by magnetic mines. Conventional deperming protocol is not considered about this, so it is needed to develop a protocol considering on the effect of earth magnetic field after demagnetization.

In this paper, Preisach model was used to analyze deperming protocol. On the Preisach plane, magnetic domains with various size of coercive and interaction force are distributed to represent magnetic properties. And the trace was drawn by the applied magnetic fields on the plane, then the total magnetization was obtained by integrating the two areas [3]. When the conventional protocol was applied, the trace finished in a region with high density and small interaction field on the plane, so it is greatly affected by the earth magnetic fields. Therefore, in order to minimize the effect of the earth magnetic field after demagnetization, it is necessary to finish demagnetization process in the region with large interaction fields.

This paper focused on the deperming protocol considering the effect of the earth magnetic fields after demagnetization by using Preisach model. The proposed protocol not only sufficiently reduces the residual magnetic field, but also minimized the effect of the earth magnetic fields after demagnetization. To validate the proposed one, a specimen of SM45C was tested in a scale-down MTF test room and simulation results are compared with measured ones.

II. Conventional Demagnetization

Demagnetization is usually used for silencing warship to avoid the detection of magnetic mines. In order to demagnetize it, alternating and decreasing magnetic fields are applied through an external coil surrounding the warship as shown in Fig. 1 [3].

Fig.1 Demagnetization of the warship

In order to analyze the deperming protocol, Preisach model was used in this paper. The trace was drawn according to the applied magnetic fields on the Preisach plane, and then the magnetization was obtained by integrating the area due to the trace by (1). When total magnetization was close zero, it is said that the demagnetization is sufficient [4].

$$Magnetization = \iint_{S+} p(a,b)dadb - \iint_{S-} p(a,b)dadb \quad (1)$$

Fig. 2(a) shows a schematic of the conventional deperming protocol and the trace is drawn on the Preisach plane as shown in Fig. 2(b). The final magnetization approaches to zero since the sum of the two areas due to the trace.

However, there could be other way to satisfy in demagnetized state. This is reason that the warship can be sufficiently demagnetized, if the protocol that makes the sum of the two regions of the Preisach plane to zero.

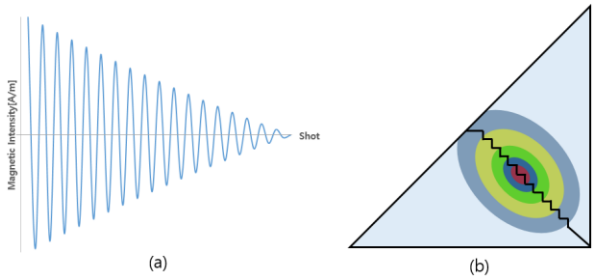

Fig.2 Schematic of conventional protocol and the trace on the Preisach plane. (a) Conventional protocol. (b) Trace on Preisach plane

III. Variation of Magnetization by Earth Magnetic Fields

After demagnetization, the warship goes out to the operation area and then it is magnetized again by the earth magnetic fields. If the earth magnetic fields was applied to it, the trace was redrawn and the change in the area represents the variation of total magnetization as shown in Fig. 3(b). Since there are many domains with small interaction field in this region, it was greatly affected by earth magnetic fields and the warship can be damaged by mines. Therefore it is necessary to develop a protocol considering earth magnetic field effects.

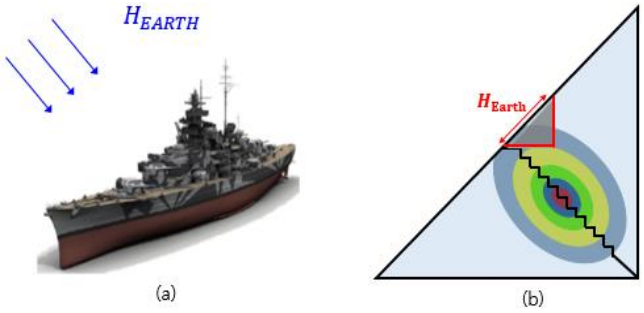

Fig.3 The effect of earth magnetic field after demagnetization. (a) Earth magnetic field. (b) Trace on Preisach plane.

IV. Proposed Deperming Protocol

The magnetic domains in magnetic materials was affected by interactions between different domains. If there are no interactions, they are located at P1. However, some are shifted from P1 to P2 since it is affected by each other. There are many domains near P1 while domains near P2 are less. It means that magnetic domains with small interaction field was mainly distributed, so it is easy to magnetize again by earth magnetic

The proposed deperming protocol was developed by using the interaction fields. Since the density is low in the region with high interaction fields, if the demagnetization process ends in the region, the change in magnetization due to the earth magnetic field after demagnetization was less than when applied conventional protocol as shown in Fig. 4. Also, even if the demagnetization is complete in a region where the interaction fields is large, the sum of the areas according to the trace is close to 0, so that the warship was sufficiently demagnetized by proposed deperming protocol.

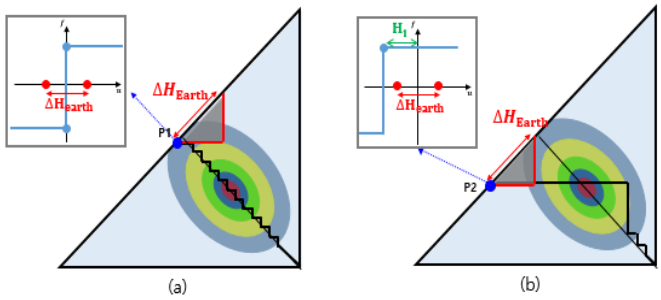

Fig.4 Traces applying two protocols and earth magnetic field. (a) Conventional protocol. (b) Proposed protocol.

V. Simulation and Experiment Result

In order to verify the proposed protocol, the SM45C specimen was used as a warship equivalent model as shown in Fig. 5. Hollow cylindrical specimen were used to simplify the structure of a complex warship. Deperming protocols was applied by a solenoid type coil outside of it as shown in Fig. 5(b).

In order to analyze the proposed protocol, Preisach modelling and finite element method were used for the demangeitzation in this paper. After applying two protocols, the magnetiude of the magnetic field was simulated under the vertical direction of the specimen. Then, the external magnetic field was applied and the results at the same position were compared and analyzed. Finally, the simulated results and experimented results agreed well.

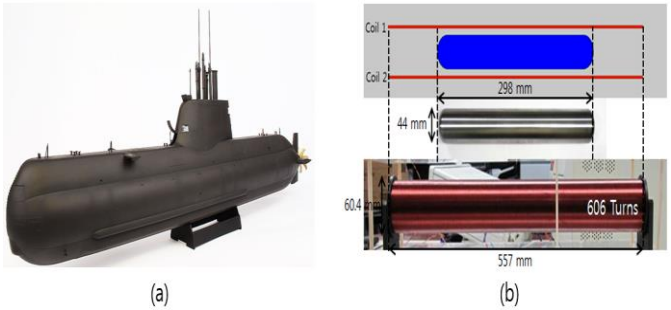

Fig 5. Experiment specimen and device. (a) Warship. (b) Specimen, solenoid coil and simulation model.

VI. Conclusion

This paper proposes an efficient deperming protocol to reduce the effect of earth magnetic field. It was analyzed by simulation using Preisach model and proved through experiments. By completing final applying magnetic field in large interaction field region of the Preisach plane, an efficient deperming protocol can be made.

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