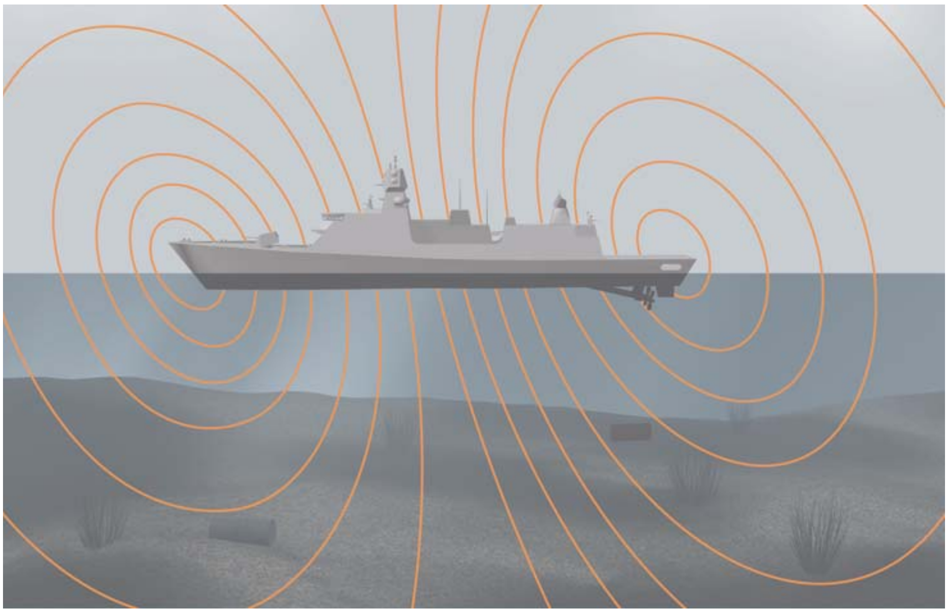
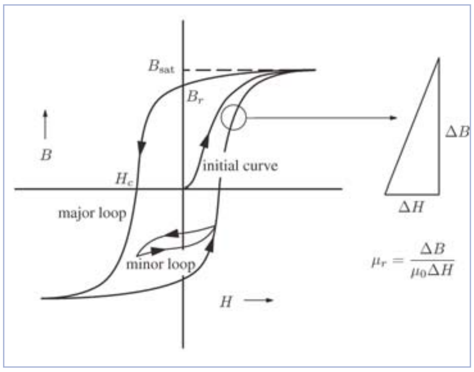
Magnetic signatures of ships

Ferromagnetic material in a ship significantly contributes to its static magnetic signature. The local disturbance of the earth magnetic field increases the detection chance as well as the threat of sea mines. It is therefore important to reduce magnetic signatures to acceptable levels.





Typical hysteresis loop

The threat

Electromagnetic signatures of naval ships need to be kept below safe levels. The main source of the static magnetic field of a ship is ferromagnetic material. If this magnetic signature is measurable in the local earth magnetic field, then several threats are present: detection and classification by *and* subsequent detonation of sea mines, detection and lacalisation of submarines out of the air. Because of increasing sensitivity of magnetic sensors and smart signal processing, signature reduction is topical as ever. Its goal is the decrease of the detection range by complying with the strict signature requirements.
To this end, identifying, understanding and modeling the underlying physical processes of magnetic signatures have been pursued. Our research helps to reduce the signature by a proper choice of materials or by the definition of optimised degaussing systems.

Moreover, our studies aim at predicting the ferromagnetic signature given the magnetic history (transit) of a ship. This is helpful in assessing the risk of a ship, either in an operational situation or at a design stage, and in determining the right moment for a deperm treatment.

Ferromagnetism

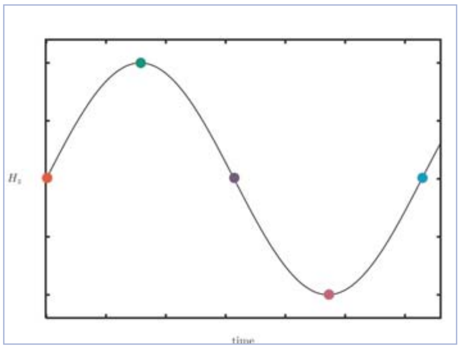
Due to an external magnetic field, ferromagnetic material gets magnetised. The relationship between the magnetic field and the magnetisation is described by the so-called hysteresis loop. Analogous loops are obtained for magnetic induction versus field. Due to this hysteretical behaviour, the momentaneous magnetisation depends not only on the present magnetic field, but also on the history of the field. In addition, stress and temperature influence the magnetisation. The hysteresis curve of ferromagnetic material can be obtained by measurements. One of the consequences of hysteresis is that after applying and removing an external magnetic field a net magnetisation remains. On a macroscopic scale this implies that after deperming, i.e., minimisation of the ship signature, the magnetisation of a steel ship gradually builds up.

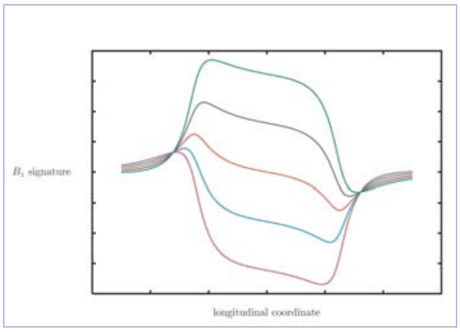
Mathematically, the complicated interrelationship between magnetic field, history, stress and magnetisation can be described by magnetomechanical models.

From magnetisation to hysteretic signature of a model ship

Not only does an external magnetic field lead to a magnetisation, a magnetised object also induces a magnetic field, which is measurable outside the object. In case of a ship, this field is the aforementioned magnetic signature. Given the magnetisation distribution of a ship, its signature can be calculated by means of magnetostatics. For simple geometries, for example block, cilinder and ellipsoid, and for simple magnetisation distributions the magnetic signature can be obtained analytically.

For the model of a ferromagnetic box, we can calculate the magnetic signature at each instant as the (internal) magnetic field varies with time. A typical result is given in the figure.

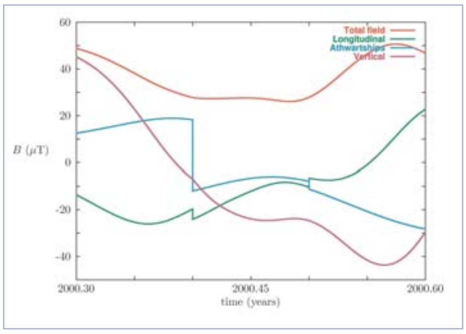


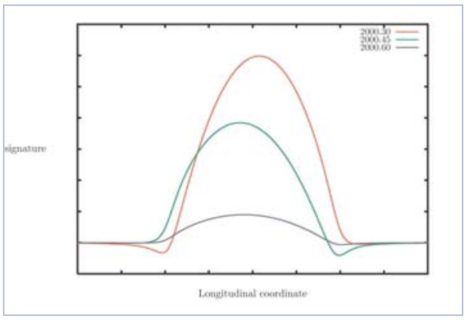


Variation of internal magnetic field (above) and corresponding magnetic signature for a ferromagnetic box (under) at five instances

Ship signature during transit

Time-dependent ship signatures have been studied by means of an ellipsoid as geometry. This model is exploited to calculate the signature during transit from Den Helder to Indonesia where a representative earth magnetic field and representative ship steel properties are used. The figure shows the sailed lane, the local earth magnetic field and the signature at three instances.





Lane from Den Helder to Indonesia (above), the corresponding magnetic field components during transit (middle) and magnetic signature at three instances for a ferromagnetic ellipsoid (under)

The way ahead

Using simple models, we have succeeded in simulating the magnetic signature of a steel ship during transit.
Refinements and extensions of these models are necessary to achieve realistic quantitative predictions. Exploiting this knowledge must eventually lead to further, i.e., unconventional recommendations for signature reduction

TNO Defence, Security and Safety

'TNO Defence, Security and Safety' is the title under which TNO operates as a strategic partner for the Dutch Ministry of Defence and makes innovative contributions to enhancing the security of the Netherlands both at home and abroad. We also use our accumulated knowledge for foreign governments and for defence-related industries.

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