FAST MODELLING OF ARMOUR LOSSES IN 3D VALIDATED BY MEASUREMENTS

Dag **WILLEN**, Carsten **THIDEMANN**; NKT Group A/S, (Denmark), dag.willen@nkt.com
Ola **THYRVIN**, NKT HV Cables AB, (Sweden), ola.thyrvin@nkt.com
Daniel **WINKEL**, Victor M. R. **ZERMENO**; NKT GmbH & Co. KG (Germany), daniel.winkel@nkt.com

ABSTRACT

The losses of armoured submarine cables were modelled using 3D Finite Elements. The FEM models used the measured magnetic properties of the armour material [1]. The use of a coarse mesh shortened the calculation time. The hysteresis losses were evaluated as a function of the local magnetic flux density. The modelled total losses and screen currents were validated against measurements performed on ~50-60 m long cable samples [2, 3]. The modelled values corresponded better to measurements than the values calculated according to the current standard, IEC 60287.

KEYWORDS

Submarine power cables, armour losses, non-linear magnetic steel, hysteresis losses, eddy currents, AC resistance, IEC 60287

INTRODUCTION

It is a computational challenge to accurately calculate the losses in magnetic steel armour due to the interactions between the eddy-currents in the armour and its non-linear permeability. The many small features in an armoured cable, including narrow gaps between armour wires, result in large meshes with long solution times and large memory requirements [4]. Here, we therefore explore approaches with relatively coarse meshes to enable practical engineering calculations in the daily work of tendering and project engineering.

It will be shown that a very coarse mesh can give a good representation of the full cable losses, and it will also be shown that the complicated non-linear magnetic behavior of the steel material can be represented with good accuracy by a fixed permeability, μ, by selecting an appropriate operation point on a measured μ(H) curve.

MAGNETIC FIELDS IN ARMOURED CABLES

A simple 3D model, Fig. 1, was constructed to determine the most basic features of the electro-magnetic system of a submarine cable: The paths and directions of the magnetic fields and the orientations of the eddy-currents. The field geometries and orientations on a large scale are illustrated in Fig. 2 a) and b). The magnetic field crosses essentially perpendicularly across the cable main air gap, even with an exaggerated pitch angle as in this model.

Figures 3 a)-c) show more detailed views of the orientation of eddy-currents in the armour, and thereby also the magnetic flux direction. The z-direction eddy currents, Fig. 3 a), that will dominate in a 2D simulation [5-9], are less than 1/5 in amplitude compared to the in-plane eddy currents shown in Fig. 3 b), circulating around the perimeter of the steel wires. Figure 3 c) shows the B-field amplitude, and a plot of the B_z component gives the same picture. This shows that most of the magnetic flux flows along the length of the steel wires [10], until it jumps out of the wires and is forced to cross the main air gap in the center of the cable due to the three-phase operation of the currents. These fields rotate inside of the cable, similarly to a multi-phase electric motor. The armour corresponds to a magnetic shell [7], short-circuiting the magnetic flux along the length of the steel wires, with only a small fraction of the magnetizing field potential driving the flux in the steel wires. The main part of the total magnetizing field potential is absorbed across the main air gap. Figure 4 shows the B-field profiles a) across a wire and b) along the length of a wire.

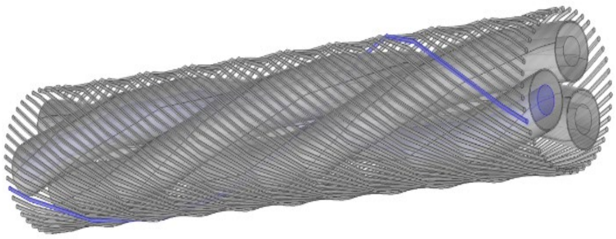
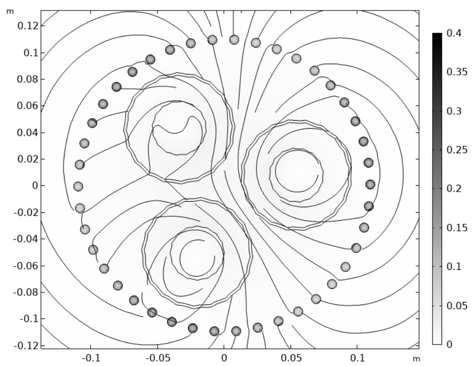
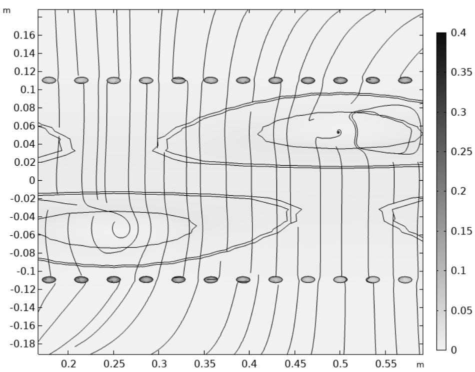


Fig. 1: A 3D cable model used to explore the modelling approach



a)



b)

Fig. 2: Geometry of the 3D magnetic flux in the air gap between the conductors, a) x-y cut; b) x-z cut