TEST CASE DOCUMENTATION
AND TESTING RESULTS

TEST CASE ID EM-VER-1.1

Magnetic field Diffusion

Tested with LS-DYNA® v980 Revision Beta

Friday 1st June, 2012

Document Information	
Confidentiality	**external use**
Document Identifier	LSTC-QA-LS-DYNA-EM-VER-1.1-1
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Number of pages	7
Date created	Friday 1st June, 2012
Distribution	External

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1 Introduction

1.1 Purpose of this Document

This document specifies the test case EM-VER-1.1. It provides general test case information like name and ID as well as information to the confidentiality, status, and classification of the test case.

A detailed description of the test case is given, the purpose of the test case is defined, and the tested features are named. Results and observations are stated and discussed. Testing results are provided in section 4.1 for the therein mentioned LS-DYNA® version and platforms.

2 Test Case Information

Test Case Summary	
Confidentiality	external use
Test Case Name	Diffusion: Magnetic field diffusion in a resistive circuit
Test Case ID	EM-VER-1.1
Test Case Status	Under consideration
Test Case Classification	Verification
Metadata	INDUSTRIAL/ACADEMIC TEST CASE

Table 1: Test Case Summary

3 Test Case Specification

3.1 Test Case Purpose

The purpose of this test case is to study the magnetic field's diffusion due to Eddy currents through a non-moving linear circuit where the current is imposed and constant.

3.2 Test Case Description

In a resistive circuit where the current is imposed, the magnetic field follows Fick's second law that predicts how diffusion causes the concentration to change with time :

$$\overrightarrow{\nabla} \wedge \overrightarrow{\nabla} \wedge \overrightarrow{B} = -\mu_0 \sigma \frac{\partial \overrightarrow{B}}{\partial t} \tag{1}$$

where B is the magnetic field,μ_0 is the permeability of free space and σ the circuit's conductivity.

For a simple case of diffusion, the quantity diffused with time t in one dimension (taken as the x-axis) from a boundary located at position x=0, where the concentration is maintained at a value $n(0)$ is :

$$n(x,t) = n(0)erfc(\frac{x}{2\sqrt{Dt}}) \tag{2}$$

where $erfc$ is the complementary error function and n the magnetic field in this case. The length $2\sqrt{Dt}$ is called the diffusion length and provides a measure of how far the concentration has propagated in the x-direction by diffusion in time t. In the case studied here, n corresponds to the magnetic field and the diffusion coefficient D to :

$$D = \frac{1}{\mu_0 \sigma} \tag{3}$$

The test case's objective is to study the behavior of the magnetic flow and to compare the results with the calculated analytical solutions. The target elements will be chosen far from the BEM boundaries and close to the center of the circuit. Indeed, the imposition of the current value rather then the magnetic field at the boundaries implies expected differences between numerical and analytical solutions for elements too close to the circuit's boundaries thus making their study unfit for verification purposes (the analytical results are for a Heavyside B field at the boundaries). Figure 1 offers a sketch of the problem and the expected effects.

3.3 Model Description

The description of the model's geometry and a view of the mesh are shown in figure 2 . Table 2 offers some information on the mesh while Table 3 gives the physical parameters used.

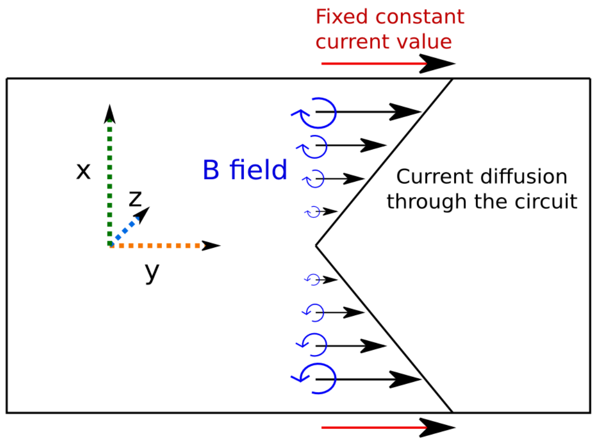

Figure 1: Test case sketch

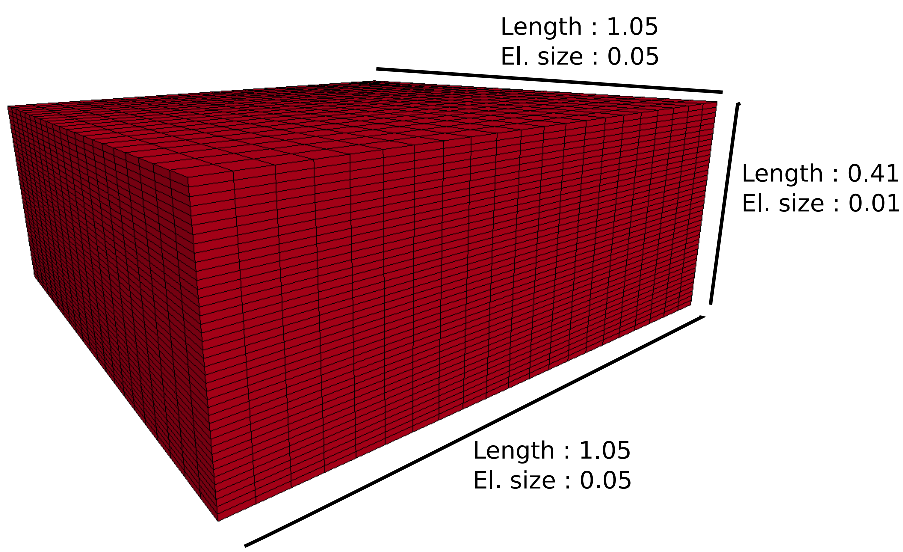

Figure 2: Test case Geometry and Mesh

Model information	
Nodes	20328
Solid elements	18081
Parts	1

Table 2: Test Case Mesh information

Model physical parameters	
Conductivity	1e6
Imposed current value	1

Table 3: Test Case Parameters

4 Test Case Results

4.1 Test Case observations

The magnetic field at a cross-section for this test case can be observed in figure 3 . As expected, the magnetic field vectors are oriented at 90 degrees compared to the direction of the current ($\bigtriangledown \times \mathbf{B} = \mu_0 \mathbf{J}$). Figure 4 shows a cut plane where the current's diffusive behavior through the circuit can also be clearly identified. Figure 5 shows the good agreement between the numerical and analytical results.

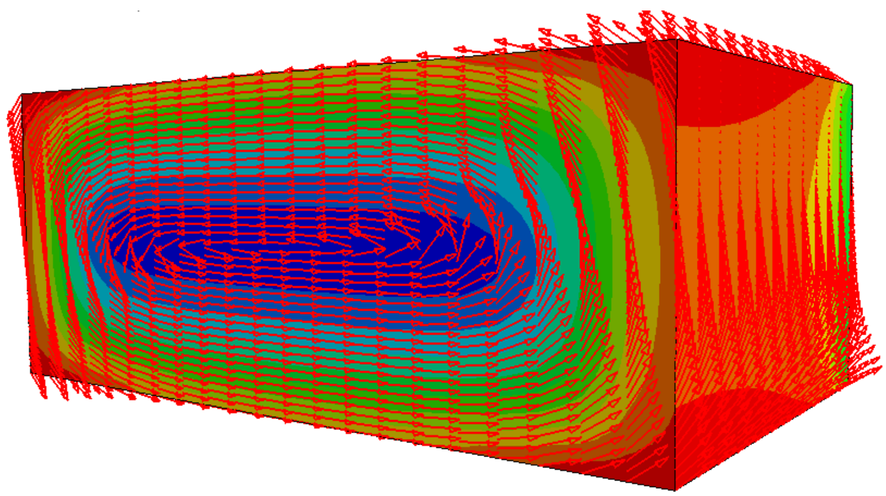

Figure 3: Test Case Magnetic field

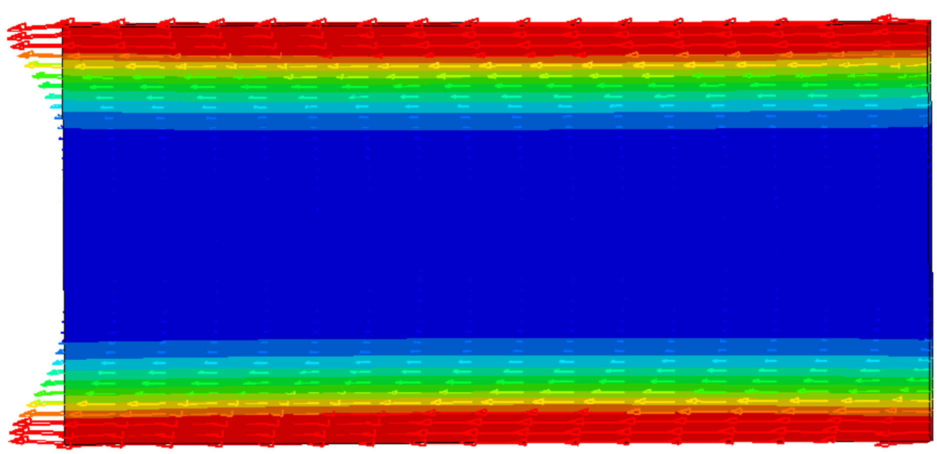

Figure 4: Test Case Current Density profile

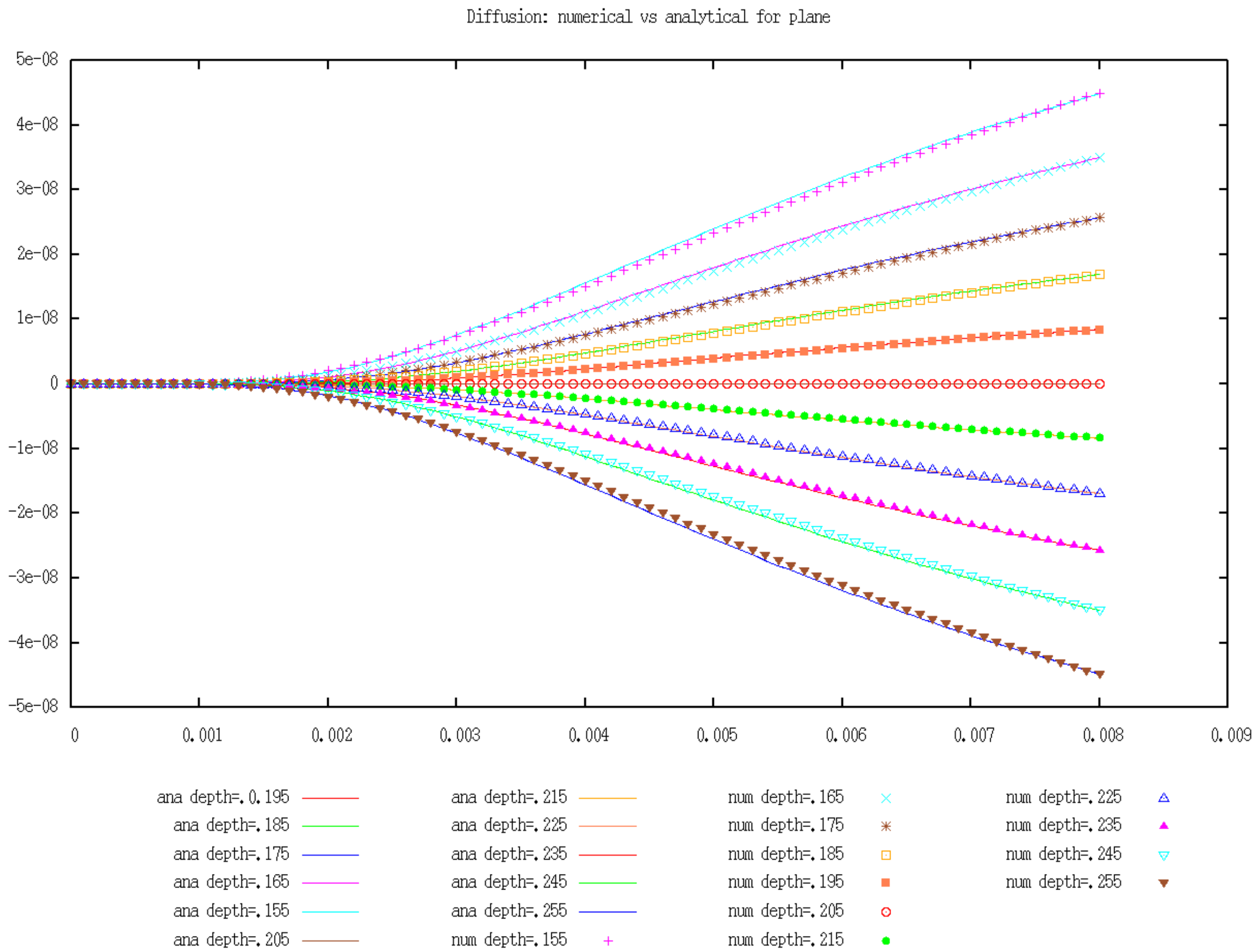

Figure 5: Comparison for the Magnetic field between numerical and analytical results at different depths