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Magnetic fluid between horizontal plates in the fields of horizontal conductors

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Abstract

The break-up and the creation of a magnetic fluid bridge between two horizontal plates in magnetic fields of a horizontal line conductor and a coil on the top plate are investigated theoretically.

Keywords: Magnetic fluid; Line conductor; Magnetic field

1. Introduction

A spasmodic change of the shape of the surface of a magnetic fluid (MF) can take place even a magnetic field changes slowly. In [1] a heavy MF under a line horizontal conductor was considered. In [2] the behavior of a MF bridge between two horizontal plates in a magnetic field was investigated experimentally, and the dependence of the maximum distance between the plates, when the bridge breaks up or appears, was measured for different values of a magnetic field gradient. In this paper calculations of the maximum distance, when the MF bridge between two horizontal plates breaks up into a few volumes or appears in the magnetic fields of a line conductor and a coil, are made for the magnetic fields of a line conductor and a coil.

2. Shape of the MF under a line horizontal conductor

Consider a heavy MF with a magnetic permeability μ_1 = const > 1 in a cylindrical vessel with a rectangular cross-section and a horizontal slideway. A line conductor with current I is along the slideway of the vessel and locates at the middle of the top horizontal plate (the point (0, 0) in the (x, z) plane), Fig. 1. Parameters of the MF and nonmagnetic fluid are denoted by subscripts 1 and 2, $\rho_1 > \rho_2$. The problem is solved in non-inductive approximation and neglecting the surface tension. Static surface of the MF $z = h(x)$ is described by the equation

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$$C + \Delta\rho g h + \frac{(\mu_2 - \mu_1) I^2}{2\pi c^2 (x^2 + h^2)} = 0.$$

Here $\Delta\rho = \rho_1 - \rho_2$, $C = \text{const}$.

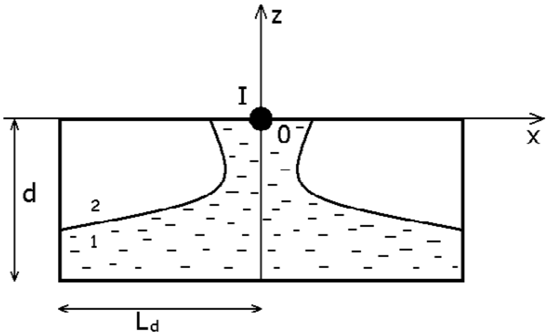

Figure 1: The MF bridge before break-up

Introducing the dimensionless parameters $x^* = x/\delta$, $h^* = h/\delta$, $\delta^3 = (\mu_2 - \mu_1) I^2 / (2\pi c^2 \Delta\rho g)$, $\alpha = -C/(\Delta\rho g \delta)$ the following dimensionless equation for h^* is obtained

$$x^* = \sqrt{\frac{1}{h^* + \alpha} - h^{*2}}. \qquad (1)$$

The parameter α is determined from condition$V_0 = 2\int_{-d}^{0} x dh$, here V_0 is a volume of the MF, per unit of length of the cylindrical vessel.

It is known that a surface shape of a MF chances spasmodically in a magnetic field of a liner conductor when parameter $\alpha = \alpha_c = (27/4)^{1/3}$ [1]. The MF bridge between two horizontal plates can break up in two cases: when $\alpha = \alpha_c = (27/4)^{1/3}$ (the MF volume consists of two intersecting at one point parts) and when $\alpha > \alpha_c$ and the bridge touches the bottom plane at one point [3]. The program for numerical calculations the maximum distance d_c when the MF bridge exists for fixed values of V_0 and I is written.

In general the value of d_c depends on the four dimension parameters: $(\mu_2 - \mu_1) I^2 / (2\pi c^2)$, V_0, L_d, $\Delta\rho g$. From Pi theorem follows equality is valid: $d_c/\sqrt{V_0} = f(\delta^2/V_0,\ L_d^2/V_0)$. When $L_d/\sqrt{V_0} \gg 1$ dependence on the second parameter disappears and $d_c/\sqrt{V_0} = f(\delta^2/V_0)$. For three values of V_0 the functions $f = f(y)$, (here $y = \delta^2/V_0$) are calculated and presented on Fig. 2.