FLUX AND WORKPIECE CURRENT DENSITY DISTRIBUTION IN LONGITUDINAL FLUX INDUCTION HEATERS

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Abstract This work investigates the distribution of flux density and current density on two types of rectangular workpiece, steel (magnetic) und aluminum (nonmagnetic). The workpiece were subjected to travelling fields, which come a longitudinal flux induction heater.

For the flux density measurements, search coils of 14 mm diameter were used small pins have been distributed on the surface the two workpiece to measure the current density Constantan wire was used with S.W.G-44.

1- INTRODUCTION

The longitudinal flux induction heater (L.F.I.H) is a single sided of the travelling wave induction heater [1]. It is used for heating rectangular workpiece from one side only, as the flux flows longitudinally along the workpiece and the normal component of the field may be negligible, inside the workpiece, in the analysis of such type of heaters [2].

The experimental work described in this paper studies the flux density and current density measurements on two types of workpiece, aluminum and steel, when they were heated by a 3-phase L.F.I.H moded at different current excitations and constant frequency (50 Hz).

The experimental model, the flux density and workpiece current density measurement are developed in the following sections.

2- THE EXPERIMENTAL MODEL

The experimental used is a L.F.I.H, which is a single sided a of the traveling wave induction heater, shown in figure (1a). It consists of a primary coil of 3- phase, fully filled, fully-pit-ched winding with dimensions of 400 mm length, 75 mm wide and 90 mm deep with 18 slots. The supply requirements are 380 volts line voltage at 50 Hz and 20 A line current. The heater contains two poles. The two workpieces are equal size 500 mm long, 100 mm wide and 10 mm thickness, as shown in figure (1b). The first workpiece is made of aluminum with $2.8*10^{-8}$ Ω.m resistivety.

The characteristics of the model with the presence of the two types of the workpiece and without workpiece are shown in figure (1.c). The figure indicates that at certain current the voltage drop with steel is higher than that aluminum workpiece or without workpiece. This is due to the reluctance of the heater being lower with aluminum, as the high permeability of steel, causing larger flux, larger heater inductance and larger voltage drop [3].

3- FLUX DENSITY MEASUREMENTS

The flux density measurements on the workpiece surface have been obtained using search coils, 14 mm diameter of a consistent wire gauge 44. For this purpose number of locations are fixed with equal distance along the center line of the workpiece and near the edge. The flux density has been measured in 3-dimension (X,Y,Z), when a 3-phase supply exacting the heater coil. Due to the symmetry, the flux density distribution at the upper edge of the workpiece is the same as that of the lower. For reason, the measurements were taken at the lower edge only, as well as at the centerline of the workpiece.

Figure (2) and (3) show the distribution of the 3- components of the flux density (normal component By longitudinal component Bx and transverse component Bz) along the workpiece surface, with 9 A excitation, at the center and near the edge respectively. The figures show that the flux density components have the same shape. They are maximum at the center and decrease toward the ends. It is noticed that the normal component by is higher than the other two components at the center while the transverse component Bz is higher than that others at the edge.

4- MEASUREMENT OF CURRENT DENSITY

The method of measuring the current density depends on the measurement of the voltage drop between two points on the surface of the workpiece, in x- and z- directions. For these purpose, small pins have been distributed uniformly with equal distance on the workpiece surface, in order to connect a fine wire on the surface. The first wire is kept as much as possible near the surface to reduce the effect of any stray field, and then closely twisted with the other wire.

The current density at the mid-point between the pins is [4-5]:

$$J=\sigma V/L \quad (1)$$

The value of J (A/mm) is an average current density between the two pins, therefore, if the current density various rapidly, the distance L between the probes should be made small. The value of voltage drop between the pins determines by a digital voltmeter.

Figures (4) shows the axial and transverse distributions of current density along the centerlines of aluminum and steel workpiece respectively, at 9A current excitation.

The transverse component Jz is maximum at the centerline and starts decreasing towards the ends. This is because the induced current due to the north pole is aiding the current due to the south pole, while the axial component Jx has minimum value at the center and nearly zero at the ends, due to the opposing effect of the induced current by the north pole that of the south pole.

Figures (5-6) show the axial and transverse current density distribution near the lower edge of the aluminum and steel workpiece respectively, 9A current excitation. The current density increases as the primary current increase. The current density at 9A excitation is three times greater than that of 3A at the centerline at the edge of the aluminum workpiece.

5- CONCLUTIONS

In this work, measurements have been made for flux density and workpiece current density distribution on the workpiece surface in a L.F.I.H for both magnetic and non-magnetic workpiece. Search coils were used to measure the flux density component in 3- dimension. The three- components of flux density have the same shape. The normal component is maximum at the center of the workpiece and minimum toward the ends, the transverse component is higher than the other component at the edge. The magnitude of flux density depends on the current excitation.

The magnetic flux cause induced current to flow on the workpiece surface in two directions, Axial and transverse. These components of current were testes experimentally on two samples, aluminum and steel workpiece, with current probe method, using small pins.

It was found that the concentration of transverse current density occurs at the center of the workpiece and approaches to zero at the ends, while the axial current density is minimum at the center and approaches to zero at the ends. The magnitude of the induced current depends upon the workpiece conductivity.

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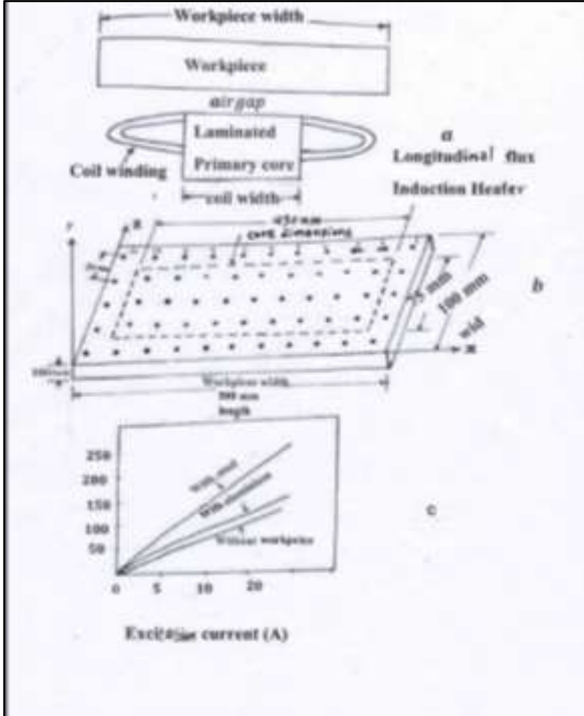

Fig .(1) The experimental model

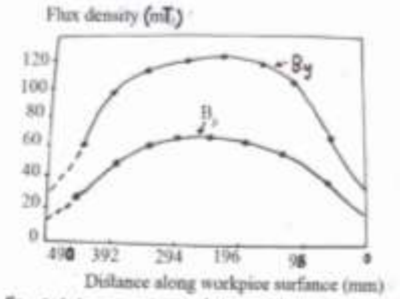

Fig (2) distribution of flux density components at the center of workpiece

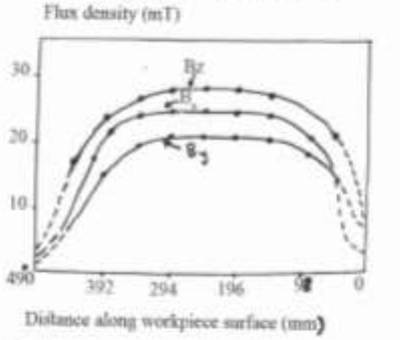

Fig (3) distribution of flux density components near the edge of workpiece

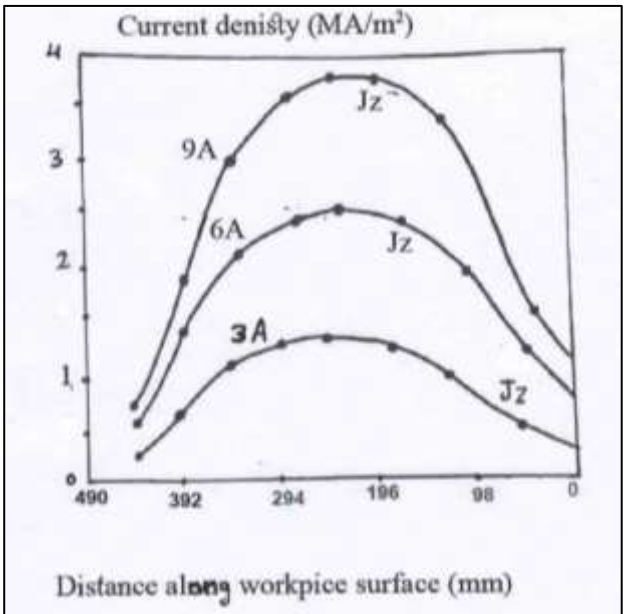

Fig (6) Variation of current density components with excitation current at the center of line workiece

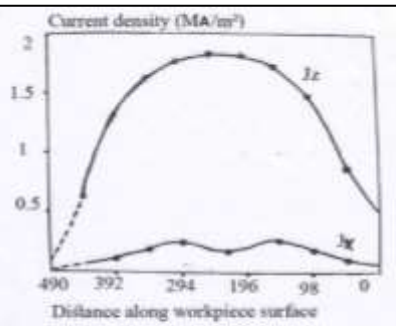

Fig (4) Distrbution of current density components along the center of workpiece

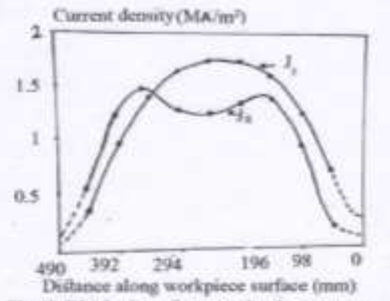

Fig (5) Distrbution of current density components near lower edge of workpiece