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DEVELOPMENT OF A MULTISECTION EDDY-CURRENT PROBE FOR TESTING OF TUBULAR OBJECTS

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ABSTRACT

The paper describes a new approach to the inspection of nuclear fuel rods on the production stage. Research was conducted by means of finite element modeling in 2D and 3D. Modeling results were compared later with experimental data acquired during laboratory testing. An encircling coil and surface eddy current probes are analysed in this research.

Index Terms – Eddy-current testing, nuclear fuel rods, encircling coil, surface probe, finite element modeling

1. INTRODUCTION

Nuclear reactor fuel production technology requires thorough testing of the final product. Specifications of measuring equipment must be of utmost precision due to the extreme risks in the nuclear sector. Fuel rods are currently used in most of the reactors all over the world.

Nuclear fuel testing directly after the production is an integral part of the manufacturing process. This paper describes the research of new testing methods to upgrade the measuring quality.

2. NUCLEAR FUEL ROD TESTING APPROACHES

The range of non-destructive testing (NDT) methods for such objects spreads nowadays from optical [1] to ultrasonic [2], but the eddy-current testing (ECT) method proves to be the most efficient, taking advantage of the fuel rods' conductive cladding and inner structure.

Optical method is based on fuel rod outer housing inspection by means of special endoscopic systems with high resolution digital cameras. The main disadvantages of this method are:

- low resolution
- inability to detect subsurface and interior flaws
- necessity to apply special means for flaw measuring

Although ultrasonic method is intended for the detection of interior flaws, it doesn't allow measuring the isolated flaws with required precision.

3. ENCIRCLING COIL ECT PROBE

Conventional way for the fastest and simplest ECT of a cylindrical object is to place an encircling coil(s) to excite and measure the electromagnetic field, e.g. [3]. It allows to analyze the response from the whole volume of the object and to detect possible flaws (nonconducting impurities inside the conductive material).

The described research is based on the results of finite element modeling (FEM) of ECT. Modeling was conducted in both 2D and 3D frequency domain calculation. 2-dimensional axisymmetric FEM provides better element-resolution along with shorter CPU-time especially in the case of encircling coil. The first goal of this research was to reach a solid equivalence between FEM-results and corresponding experimental measurements conducted on precisely machined reference standards for the existing nuclear fuel testing equipment. Meshing parameters acquired from this comparison were further used for the estimation of the multisection eddy-current probe characteristic.

Although encircling-coil method proves to be efficient for overall flaw detection, it has no capability to determine the parameters of the flaw, such as size, depth, angular location with respect to the tubular axis and it shows no difference between a large flaw and multiple small ones. To obtain such diversity of parameters surface-type probes are widely used for various ECT applications and recently for nuclear fuel testing [4].

4. SURFACE ECT PROBE

3D modeling of surface eddy-current probe provided wide range of possibilities for the research of the proposed ECT arrangement. The probe is based on a standard differential measuring circuit with two coils on ferrite cores. During finite element modeling the acquired results were compared with the data from specially constructed differential surface probe and available set of standard samples. Real probe also allowed extrapolating the most efficient operation frequency for future research. The relation of signal voltage to frequency is represented on Fig. 1.

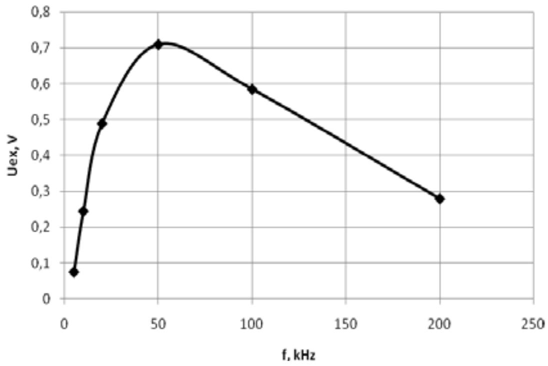

Figure 1 Frequency selection

Computer modeling allowed to acquire the necessary calibration curves for further measurement and also to confirm the dependence of signal phase from flaw depth.

Surface ECT probe was optimized according to FEM results. The optimization parameter was the base of the differential probe (Fig. 2) – distance between the centers of two measuring coils situated above the fuel rod.

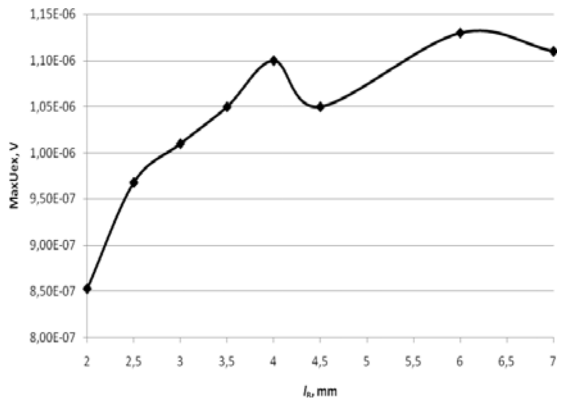

Figure 2 Base selection

Influence of the gap between the probe and the test object surface was also taken into account.

5. CONCLUSION

The main result of the conducted research is the unambiguous conclusion that the surface ECT probe provides definite advantages in comparison with the encircling coil ECT probe during nuclear fuel rod control.

Further research should be dedicated to consideration, modeling and implementation of a measuring arrangement with at least three differential surface probes placed evenly around the circumference of the test object. This way not only the size but also depth of the flaw will be precisely measured in the entire volume of the fuel rod.

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