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The Application of NISA II FEM Package in Seismic Qualification of Small Class 1E Electric Motors

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Abstract

According to the IEEE standards 323/1974 and 344/1975, [1] and [2], seismic qualification of class 1E equipment is appropriate combination of test and analysis methods. Complex equipment and assemblies are usually tested through seismic testing. The analysis is recommended for simple equipment that can be easily modeled to correctly predict its response. This article deals with the application of NISA II FEM package in 3D FE modeling and mode shape calculations of small power low voltage electric motors.

Introduction

IEEE has developed Std. 344-1975 for seismic qualification of class 1E equipment for nuclear power generating stations, as the supplement of IEEE Std.323-1974. Both standards cover basic requirements and procedures (recommended practices) for seismic qualification of class 1E electric equipment. As one can see, [1] and [2], seismic qualification of class 1E equipment is appropriate combination of test and analysis methods. It should demonstrate that the structural integrity of the equipment is maintained during the appropriate number of Operating Basis Earthquakes (OBE). Additionally, the equipment's ability to perform the required Class 1E function must not fail during and after the time it is subjected to the forces resulting from Safe Shutdown Earthquake (SSE). The analysis method is recommended for simple equipment that can be easily modeled to correctly predict its response. If structural integrity alone can assure the design-intended equipment function, analysis without testing may be acceptable. Testing is proposed for complex equipment and assemblies that can't be analyzed relatively simple, or can't be adequately analyzed at all (that is a majority of all cases).

The Design of L-shaped Motor Carrier and Seismic Tests of Small Electric Motors

As a part of long-term project dealing with the 1E qualification of small electric motors, finite element method (FEM) application possibilities have been analyzed. NISA II / Display III general purpose FEM program package has been used as a support of analysis, [3]. FE method has been successfully used as a tool for the design of rigid mechanical L-shaped motor carrier for connecting the small low-voltage electric motor to the vertically vibrated surface of the vibration shaker table. As **fig. 1** shows, 30 millimeters thick L-shaped mechanical construction (410 x 300 x 330 mm, steel) keeps the first resonant frequency above 300 Hz, so it can be used as motor carrier in seismic tests.

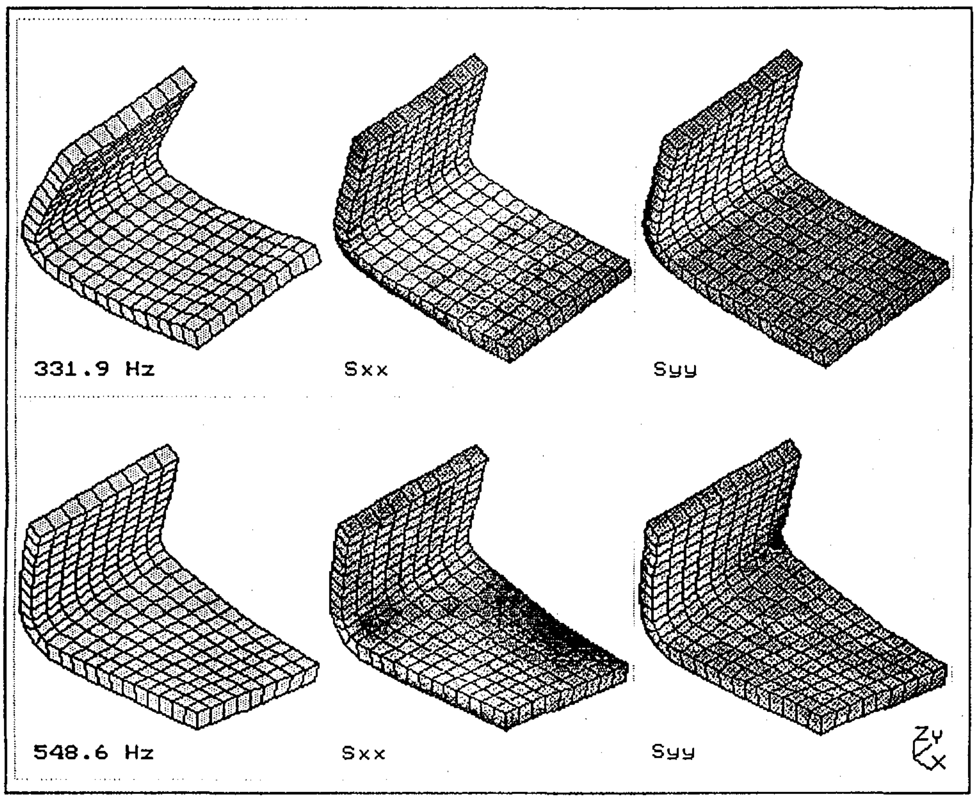

Figure 1. The first two resonant frequencies, mode shapes and modal Sxx and Syy stresses of L-shaped electric motor carrier (253 3D-finite elements).

Seismic tests usually contain visual examinations and insulation resistance checks, voltage, current, temperature and speed measurements, exploratory vibration resonance (natural - fundamental frequency) tests (search), and "OBE" and "SSE" seismic excitation tests.

Seismic tests of small electric motors were prepared for low-voltage 1.2 kW motor. For this motor only an exploratory monoaxial resonance search was conducted to determine the dynamic characteristics of the motor. Vibration test was performed by the application of sinusoidal input motion with maximum acceleration of 1.0g and with the frequency sweeping from 5 to 300 Hz at a rate of 2 octaves/min. No resonance was found in this frequency interval..

3D Modeling and Mode Shape Calculations

NISA II / Display III program was used for 3D finite elements modeling of all motor parts, **fig. 2**: 1728 linear (8-nodes) 3D-solid elements (264 elements for the shaft, 1128 elements for the casing and the front and back lid, 144 elements for rotor coil and 192 elements for stator coil) and 6 3-D general spring elements (for two bearings) was defined (created), mainly with the rotation of 2D plane elements (from the meridional z-r plane) around the (z) axis of rotation.

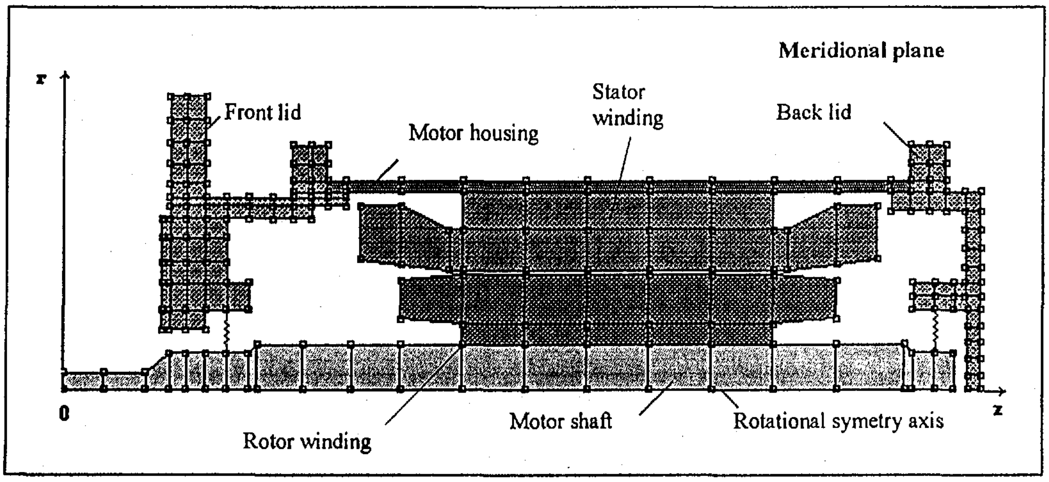

Figure 2. 3D Modeling of small low voltage electric motor

The calculation of resonant frequencies and structural mode shapes of the motor, with NISA II / Linear dynamic program, shows no resonant frequencies of the casing, coils and shaft below 330 Hz. The results of mode shape calculations (performed FEM analysis, **fig. 3**) indicate that this small commercial grade motor is built with an inherently rugged design. It has the high resonant frequencies whose values have to be proved by high-frequency testing. It has to be mentioned that adequate 3D bearing modeling (with 3D-spring finite elements, or with a group of adequately connected and shaped numerous 3D elements) is still under development. Vibration resonant frequency tests, together with OBE and SSE seismic tests can be used in verification of our calculations.

The results of FEM calculations presented on the figure 3 at left show typical "S" bending of front and back lid that happens at 332.4 Hz, double "S" bending of front lid at 1135 Hz, bending of lids caused by bending of the shaft at 1002 Hz, the torsion of the casing at 1241 Hz. The results at the right side show four rotor's (shaft + coils) bending modes at 1054, 3067, 8262 and 10710 Hz. At 5394 Hz the front part of the rotor bends over front bearing. At 6484 and 8753 Hz there are two rotor's torsion modes, and at 9890 Hz rotor's radial and axial stretching mode.

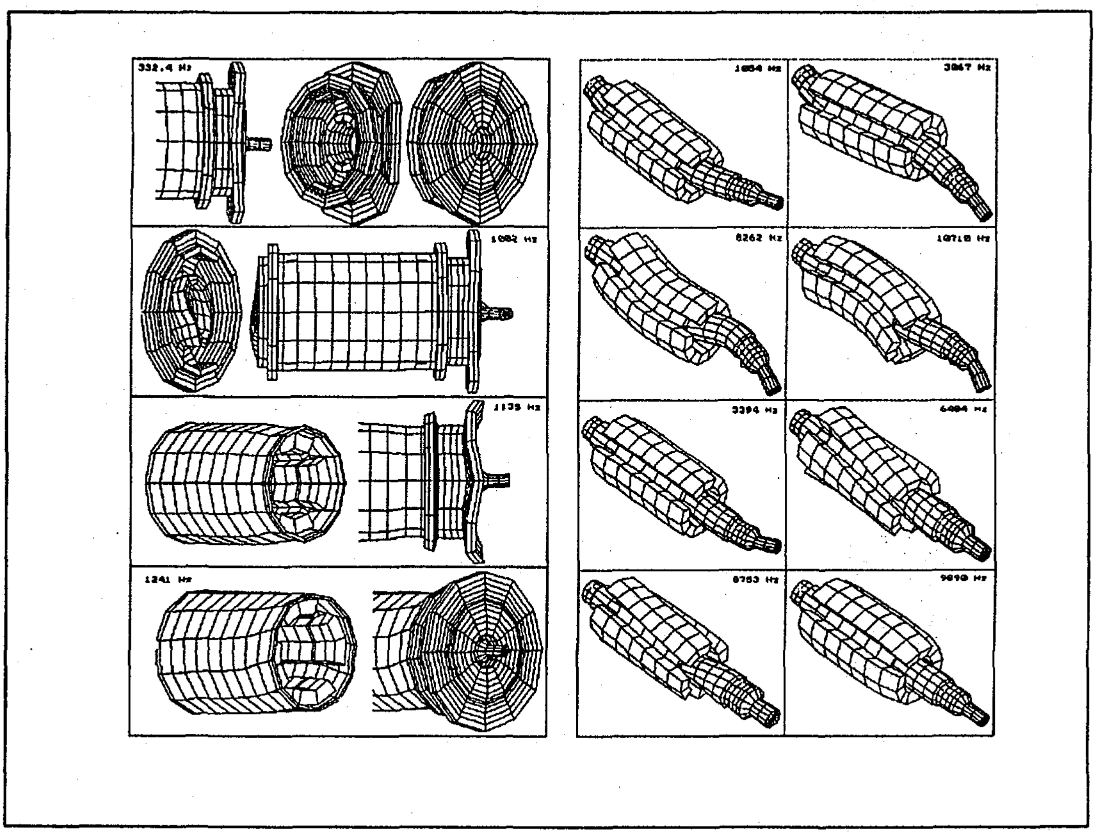

Figure 3. a) The first four mode shapes of the casing: 332/1002/1135/1241 Hz.
b) The first eight mode shapes of the rotor: 1054/3067/5394/6484,/8262 /8753/9890/10710 Hz.

Conclusions

The 3D finite element modeling of a small electric motor has been performed. It shows that all rotational symmetrical parts of the motor (casing, coils, shaft) can be easily modeled by the rotation of 2D elements (from the meridional plane of a motor) into 3D space. Calculated frequencies and mode shapes of the casing and shaft seem realistic, with the exception of missing mode shapes that are caused by the (dynamic) behavior of bearings. Further investigations are needed (both theoretical-3D modeling and practical-testing), and the results will be analyzed, reported and discussed.

References

[1] IEEE Std 323-1974: "Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations", The Institute of Electrical and Electronics Engineers Inc, USA, 1974.

[2] ANSI/IEEE Std 344-1975: "IEEE Recommended Practices for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations", IEEE, Inc., USA, 1975,

[3] EMRC: "NISA II User's Manual for PC, Mini, Supermini, Mainframe and Super Computers", Center for Engineering and Computer Technology, Version '93, Troy, Michigan, USA, April 1993.