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RELIABILITY EVALUATION FOR ROTARY MACHINE INSULATION

Takeo Kitoh
Hiroyuki Yamaguchi

I. INTRODUCTION

The increased capacity, higher voltage, and smaller size and lighter weight, rise of the thermal resistance classification, etc. has been noticeable in rotary machines. On the other hand, enlargements the life-time of machines, improvements toward maintenance-free machines and reliability evaluation technology by means of scientific techniques are being advanced. The insulation of a rotary machine is the heart of the machine, to put it into human terms, and since the end of its functioning is judged to be the life, evaluation of the insulation system is emphasized.

Our way of thinking about reliability evaluation of rotary machine insulation and the actual situation are introduced here.

II. RELIABILITY EVALUATION

1. Basic way of thinking

Since the purpose of reliability evaluation of rotary machine insulation is cooperation with the user's maintenance standards by life estimation and improvement of insulation, that is, development of new insulation, the following two points should be considered.

1) Problem of initial level due to scatter in materials and manufacturing techniques.

2) Quantitive grasping of deterioration factors and their effect in practical use.

However, since the combinations of these two problems is actually extremely diverse and reliability evaluation is performed by restricting certain patterns to typical combinations. Specifically, there is "A guide for the evaluation and identification of insulation system of electrical equipment[1]" from TC63 of IEC. The thermal factor (T), electrical factor (E), environmental factor (E), mechanical factor (M), and intended performance (P) or duty (D), etc. are coded and there is an international movement toward guaranteeing life by limiting the specific function by means of this combination. We also conform with this, but are currently stressing enviromental resistance.

2. Outline of test method for reliability evaluation

An outline of the test method for reliability evaluation shown by pattern is given in *Fig. 1*. When improving and developing insulation systems, we perform evaluation in accordance with the procedure shown in *Fig. 1* based on a company wide uniform way of thinking. This prevents the erroneous application of materials and manufacturing technique and serves to increase the reliability of the apparatus.

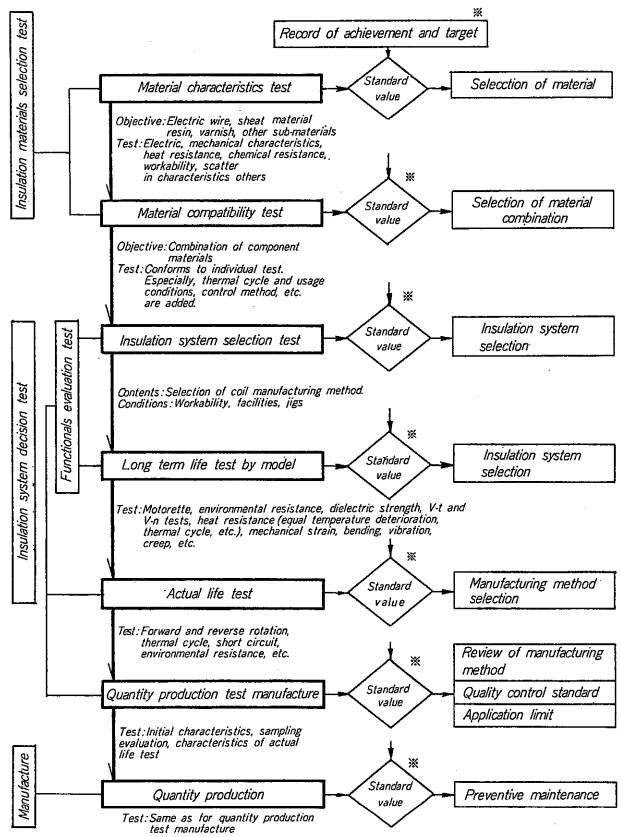

Fig. 1 Patterns of reliability evaluation for rotary machine insulation

3. Vital points of test method and evaluation

1) Material selection test

In additional to the electrical, thermal, mechanical, and

chemical characteristics generally tested, workability including resistivity to manufacturing, scatter in characteristics and cost studies become important judgement items. A study of quality assurance of enameled wire and other long materials, characteristics difference by conductor diameter and other dimensions, and resistivity to manufacturing, etc. are important items[2]. For example, we developed a test equipment which checks continuously for defects in several tens of meters of wire and a simulator test equipment to test resistivity to manufacturing jointly with a wire manufacturer.

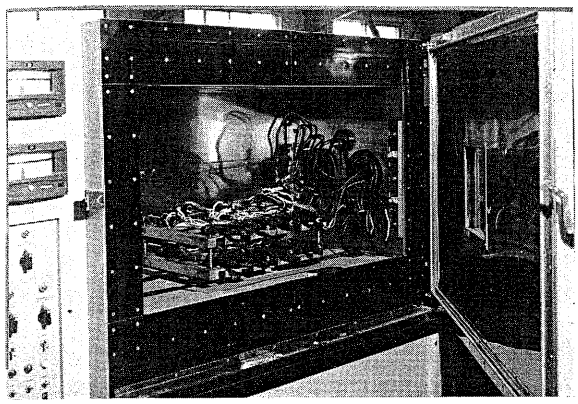

Fig. 2 Automatic motorettes test equipment

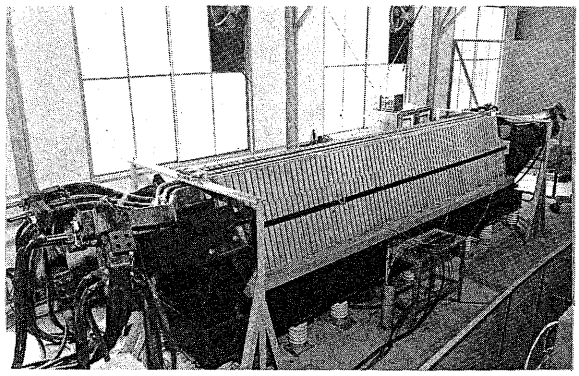

Fig. 3 Functional evaluation test equipment for large coil insulation systems

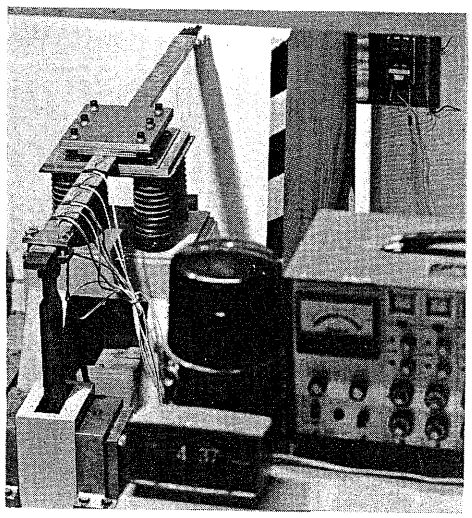

Fig. 4 Test equipment on insulation fatigue strength (cyclic bending test)

2) Functional evaluation test for insulation system

For insulation systems, various functional evaluation tests are conducted on a model or the actual machine for a long period of time and efforts are simultaneously made for the establishment of rational evaluation methods. The automatic Motorette test equipment shown in *Fig. 2*, thermal cycle test equipment for large coils shown in *Fig. 3*, and cyclic bending fatigue test equipment for coil insulation shown in *Fig. 4* are examples of functional tests. Since these functional evaluation tests are introduced in a separate article[3], envirorment resistance will be described here.

At the user's side the cases are rather rare, in which the environmental conditions based upon the IS code of the previously mentioned IEC (TC63) are grasped quantitatively, and therefore, consideration of the insulation specifications by coding the experience at the manufacturer's side is necessary. At this time, standardizing by raising the environment resistance level of the insulation is more rational than corresponding to the individual items having diverse specifications.

For this purpose unrelenting improvements are being made in improving material and processing techniques such as impregnating resin and its impregnating method. The basis of environment resistance is, of course, moisture resistance and water resistance, and the changes of the electrical characteristics when a model or the actual machine is moisturized or immersed in water are being studied under no voltage applied and voltage applied condi-

Fig. 5 Environment test equipment for motors

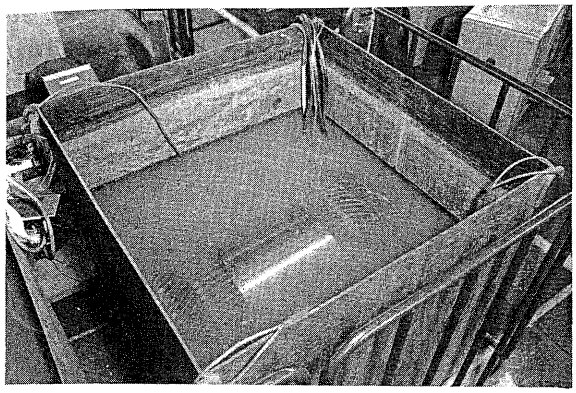

Fig. 6 Water-submerging test for stator coils

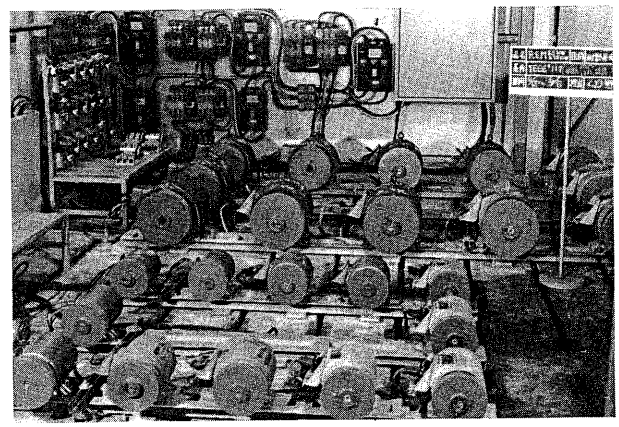

Fig. 7 Motor life tests

tions. Coil end insulation layer wear, local concentration of electric field, creeping flashing, etc. are generated by carbon, metal powder, cement, or sand, etc., and since the mutual action with the water component is large, the blowing in of these dusts and absorption of moisture and deterioration of the insulation characteristics is studied. The entry of carbon and other conductive powders in the gap of the insulation by the occurence of a kind of electrophoresis by the electric field is seen and voltage appliance becomes a necessary test condition. Chemical resistance tests, including coolant and cutting oil, are also performed at both no voltage applied and voltage applied, and so classification into chemical response deterioration and voltage applied deterioration is possible. The environment test equipment is shown in *Fig. 5* and the water-submerging test is shown in *Fig. 6*.

3) Actual machine life test

Since the life is governed by the machine output and the relationship, life $= K \cdot \frac{1}{(\text{machine size})^n}$ is considered when insulated with insulation of the same level [4], actual life test, including manufacturing conditions checks, will be necessary up to large machine. With general purpose or industrial motors, accelerated life tests are performed with the actual machine or with a model corresponding to the actual machine when unavoidable (*Fig. 7*). Actual machine operating tests of large generators, etc. are impossible at the manufacturer's side. But when requested by the customer assistance in securing reliability is provided by estimating the voltage endurance life from the remaining breakdown voltage of the winding of overhauled machines.

4) Reliability analysis

As previously described, the vital point of reliability evaluation is the judgement standards based on demanded quality, market quality, and recording of achievements. We establish a special committee for rotating machine insulation for adjustment from this standpoint between the related factories.

Moreover, in concrete data analysis, a faulty physical model is considered and life measurement is performed by statistical techniques using reliability engineering. For example, Weibull distribution is effective in proving the variation of the breakdown voltage after deterioration and life distribution at the voltage endurance characteristic can be analyzed by extended utilization of the Weibull distribution function. The results of these are feedback to design. The use of life estimate data, etc. is related to the supply of software to the user from the PM (Preventive Maintenance) committee.

III. CONCLUSION

An outline of our way of thinking about reliability evaluation and the actual situation in improving and developing rotary machine insulation systems has been given here. The activity of all regarding reliability has allowed used to cope with the trend toward increased capacity and smaller size and quality assurance and we wish to make efforts in securing reliability with the cooperation of our customers in the future.

References:

(1) IEC Pub 505 (1975), Guide for the evaluation of indentification of insulation systems of electrical equipment.
(2) Minami *et al.*: Recent insulation system for low voltage rotary machines, Fuji Elec. Rev. **25**, No. 1 (1979)
(3) Ohtaguro *et al.*: Mechanical properties and evaluation of coil insulation for high voltage Fuji Elec. Rev. **25**, No. 1 (1979)
(4) D.E. Crawford: 12th Electrical Insulation Conf. p. 126 (1975)