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Qualifying canned motor pumps

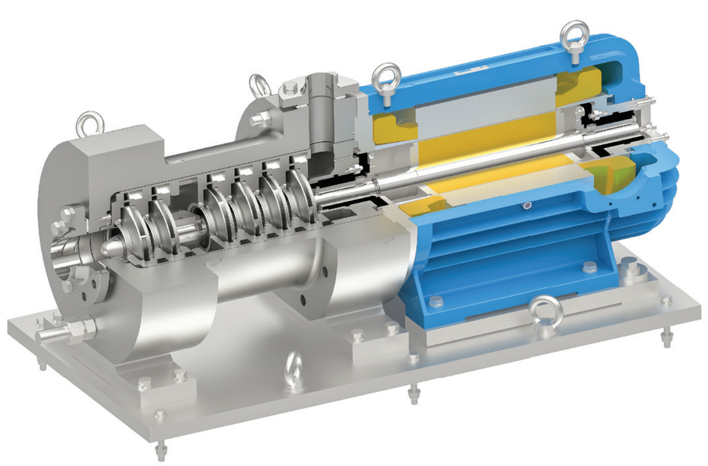
A multidisciplinary study focusing on nuclear qualification, electrical-thermal modelling and testing has been carried out in order to increase the service life of canned motors and to improve electrical and thermal performance while fulfilling safety functions. **Rémy Schmidt, Virgile Bissardon** and **Dr Amadou Tinni** report

IN RECENT YEARS, WE HAVE seen an increase in the operating life of nuclear power plants. In France, for instance, we have gone from an initial service life of 40 years up to one of 60 years. This increase in service life has repercussions on the service life of all the components that operate in nuclear power plants. We are interested in the life time analysis for centrifugal pumps, especially canned motor pump technology.

In addition to the increase in service life, most European standards require that the motors manufactured today have a higher efficiency, while also fulfilling safety functions. Compliance with these constraints therefore requires a multidisciplinary approach that takes into account both the increase in the service life of canned motors and their electrical and thermal performance.

Canned motor technology *(Figure 1)* is used mainly in the auxiliary and secondary circuits, but also to a lesser extent in the primary circuit. The canned motor pump is a compact unit integrating a hydraulic part and an induction motor with a common shaft. The special feature of the motor is that two non-magnetic cylindrical tubes, called "the can", are inserted into the gap to seal the rotor from the stator windings. The pumped fluid flows through the gap to cool the motor and lubricatethe hydrodynamic bearings.

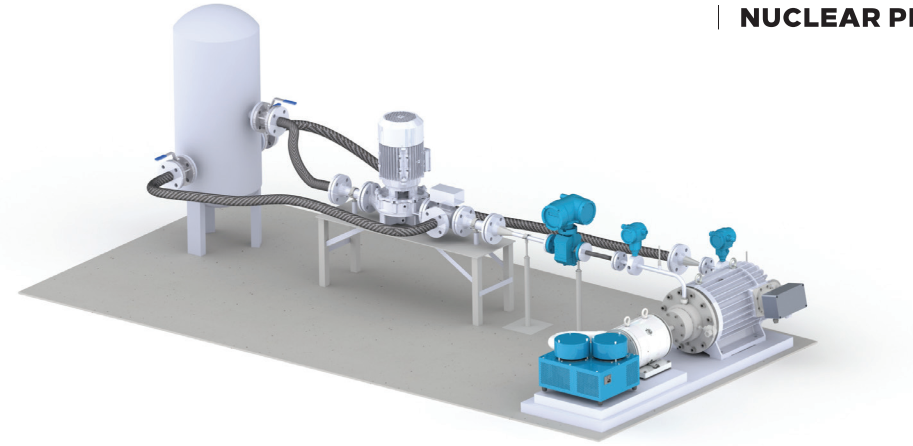
Below, figure 1:
Multi-stage canned motor pump
(Source Rütschi design)



Multidisciplinary approach

The canned motor is a zero-leakage technology. Safety is enhanced by a double barrier, which is primarily formed by the stator can and the motor casing. Deployment in nuclear power plants requires the use of materials able to withstand a certain dose of irradiation. The qualification of the motor for nuclear use is therefore the first step in analyzing the performance of the technology.

In addition to irradiation and seismic considerations, the qualification programme allows the determination of the service life of non-metallic components, particularly the insulation system of the motor, through accelerated thermal ageing tests based on Arrhenius' law. Through these aging tests it is possible to determine the lifetime of the insulation system of the motor as a function of the temperature towhich the stator is subjected.



Left, figure 2:
The instrumented test bench and the instrumented canned motor for electrical and thermal performance analysis
(Source Rütschi design)

Arrhenius' law equation[1]:

$$L_f = D.e^{\left(-\frac{E}{R_{gas.}T}\right)}$$

L_f: specific reaction rate

D: frequency factor

E: activation energy of the reaction

T: temperature in °K

R_{gas}: gas constant = 8.314 $J.K^{-1}mol^{-1}$

An effective way of determining the temperature distribution in the motor is by using a model-based design approach combining the electrical and thermal parts of the motor to determine its characteristics and performance.

As the "multiphysics" model uses different physical parameters, it requires calibration, hence the setting up of an instrumented test bench to validate the model on one hand and on the other hand to measure the evolution of the parameters experimentally.

The various points mentioned above have been the subject of work that has enabled us to carry out predictive maintenance and to improve the electrical and thermal characteristics of our canned motor while guaranteeing the safety of the pumps.

Qualification of the canned motor

The qualification can be divided into three parts: resistance to irradiation; seismic resistance; and ageing.

The resistance to irradiation and ageing qualifications are carried out on all non-metallic components. For the motor insulation system, nuclear standards allow the possibility of perform these tests on reduced windings, called "motorettes", in order to prove the conformity of the components.

These reduced windings must be of the same materials and should have undergone the same manufacturing processes as the stator.

The lifetime of the insulation system is determined by linear regression via Arrhenius' law[1]. In our study, we have performed tests on 45 motorettes in order to evaluate the influence of irradiation on our insulation system and to determine its lifetime for given operating conditions.

Model based design for electrical and thermal performance determination

The developed model consists of two sub-models interacting with each other: an electrical one; and a thermal one. The electrical sub-model allows us to determine electrical characteristics that are of interest to the user, and the thermal sub-model gives us the temperature distribution in different components of the canned motor.

The model takes as inputs geometrical data, the physical properties of the materials, and the operating point of the motor.

For the thermal sub-model, ambient temperature and recirculation fluid temperature are considered as well as the recirculation flow rate

Instrumented test bench

To validate the developed electrical and thermal models, different canned motor prototypes were designed and equipped with temperature sensors in the stator coil heads, in the slots, on the motor housing and at the rear bearing in order to map the temperature distribution.

An instrumented test bench has also been designed. It is composed of the motor to be tested, a tank containing the medium that cools the motor and lubricates the bearings, temperature sensors, manometers, a flowmeter, a valve and a recirculation pump, as shown in Figure 2.

Benefits to the user

Among the benefits of the multidisciplinary study outlined here are the following: better co-ordination of canned motor pump realisation with the design phase and better responsiveness to design phase activities; better matching to customer needs; development of a clear vision for preventive maintenance requirements; and longer pump service life. ■

For more information contact Gruppe Rütschi: contact1@grupperutschi.com

Further reading

1 **A. Tinni, D. Knittel, M. Nouari, G. Sturtzer,** *"Electrical-thermal modeling of a double canned induction motor for electrical performance analysis and motor lifetime determination,"* Electrical Engineering Springer (2020)

2 **A. Tinni, G. Sturtzer, D. Knittel, M. Nouari, J. Renaud,** *"Improved electrical modeling of a double canned induction motor with squirrel cage for performance analysis,"* IECON 2019 – 45th Annual Conference of the IEEE Industrial Electronics Society, Lisbon, Portugal, 2019, pp 1114-1119

3 **A.Tinni,** *"Mutiphysics modeling, redesign and optimization of canned motor pump,"* PhD Thesis, University of Lorraine