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# Experimental and Computational Support of Strength Assessment of Shrink Ring of Asynchronous Motors

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**Abstract:** The paper describes used approach to strength assessment of shrink ring of asynchronous motors. Computer simulations were used for the strength assessment. The problem of the measurement at rotation, in a strong electromagnetic field and at higher temperature was solved. The first performed measurement influenced methodology of calculations. The results are discussed.

**Keywords:** Asynchronous Motor; Strength assessment; Stress measurement; Shrink ring

## 1. Introduction

A common requirement of customers is the assessment of the strength of critical structural parts of the purchased equipment. It includes the strength assessment of the shrink ring of the short circuit-ring for high power asynchronous motors. The function of the shrink ring is to prevent creep of massive short circuit-ring due to rotation and elevated temperature. Short circuit-ring is made of copper and soldered to the copper rotor bars that are inserted into slots of rotor laminations packet. Soldering process causes degradation of mechanical properties of the short circuit-ring. Mechanical properties of copper are also affected by temperature achieved during operation of the electric motor. Temperature distribution in the motor is determined by hysteresis loss and forced ventilation cooling. Due to centrifugal forces the short circuit-ring is stressed in tangential direction. This can cause creep and therefore also irreversible expansion of the short circuit-ring. The shrink ring shall be designed for the permanent strength to hold this load.

## 2. FEM calculation

The strength assessment of the shrink ring was based only on the FEM calculations of stress by rotating and pressing on the short circuit-ring. Thermal stresses were neglected regarding the lack of information about the temperature field of the rotor at that time. These uncertainties have been included in the conservative approach to the modelling and strength assessment with required value of the endurance safety factor.

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*2.1. FEM model*

FEM model was created as a volume model and was composed of the hexagonal elements of the SOLID type. Calculations were performed using the FEM COSMOS/M program. Only segment of the circle, which lay between the centre of the rotor bar and the centre of the adjacent space, was calculated. Boundary conditions were defined as symmetrical cylindrical coordinates in planes of cut. The stiffness in the contact of rotor bars and slots of rotor laminations is unknown. The rotor bars are caulked into slots of rotor laminations. Due to irregular laminations the rotor bars are not in contact with all rotor laminations in the rotor slots. Due to large forces during operation a shift of rotor bars in the slots occurs on the margin of the packet rotor laminations. The FEM model therefore included a marginal part of the rotor laminations packet. Contact of rotor bars and rotor laminations was considered without friction. The model was created for the smallest and largest interference of shrink ring pressed on short circuit-ring. The interference is modelled through contact elements.

## 3. Strength assessment

Strength assessment of shrink ring was performed using the FEMFAT program. The program allows processing of the calculations results in all nodes of the FEM mesh see Fig. 1.

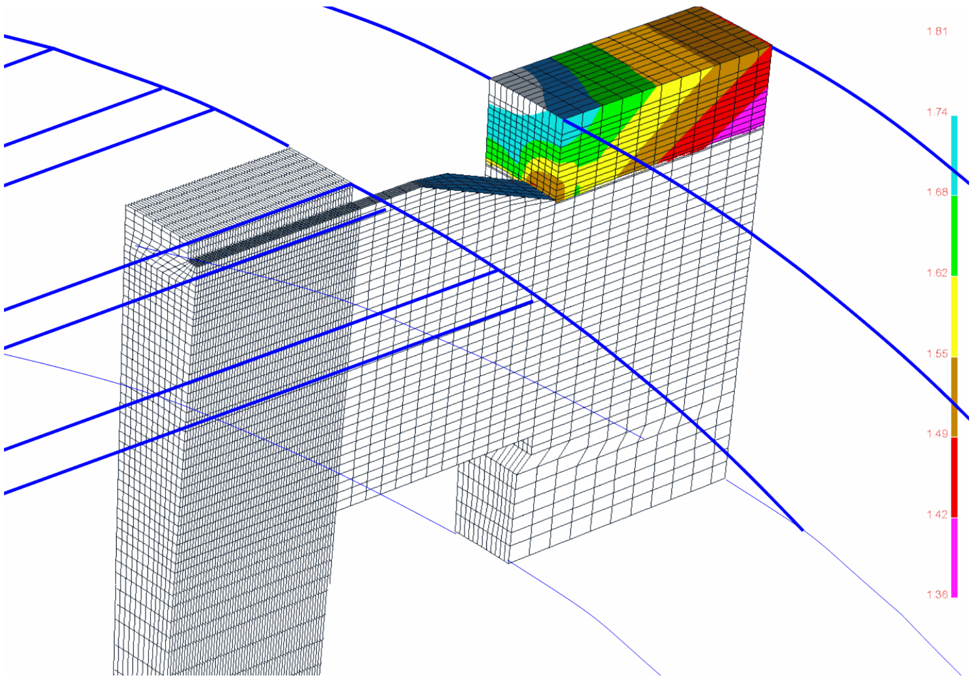


**Fig. 1.** Example of results of the strength assessment calculated by program FEMFAT

The stress amplitude is given by the stress at zero rotation speed and maximum rotation speed in operation. There are two limits for a successful design of the shrink ring. The first limit is the possible creep of the short circuit-ring made of cuprum. Calculation is focused on this phenomenon mainly in the case of the smallest interference. The second limit of the design is the strength of the shrink ring, mainly in the case of the largest interference. It is necessary to consider material properties corresponding to real temperature in operation, see [1].

## 4. Experiment

It is evident that measuring the shrink ring during the motor running is a difficult task. The problem is in the measurement at rotation, in a strong electromagnetic field and the temperature higher than 100 °C. The preparation of the test measurement requires the correct procedure to install strain gauges, choose the suitable sensors and components, compensate temperature of strain gauges and the way of signal transmission from the revolving rotor. The first measurement like that was performed within solving the project No. 2A-2TP1/139 of the Ministry of Industry and Trade of the Czech Republic. The measuring chain is shown in Fig 2.

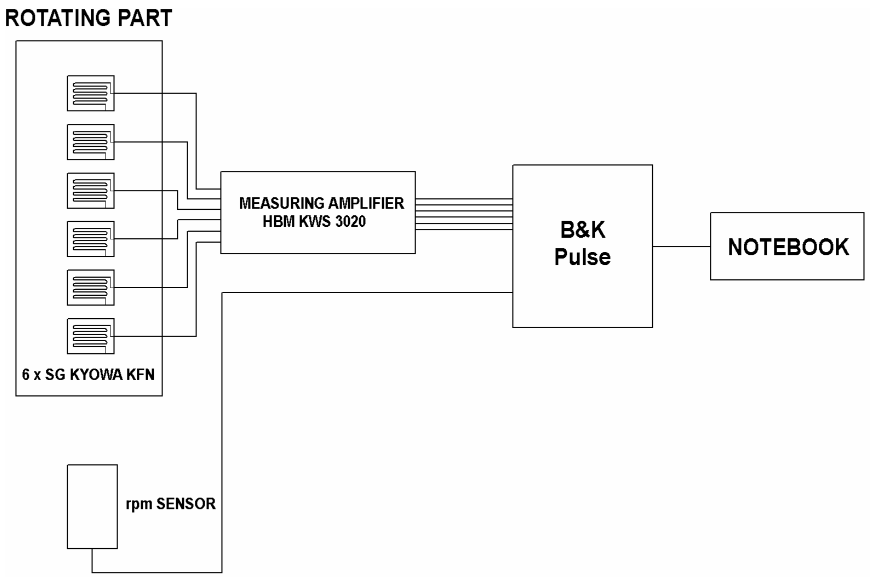


**Fig. 2.** The measuring chain

Strain gauges made by KYOWA ELECTRONIC INSTRUMENT CO., Ltd. were used due to the temperature and electromagnetic field. Compensation of the temperatures was performed by calibration measurement and determination of the appropriate compensation equation for strain gauges. The measurement was carried out in the testing laboratory of motors of the producer. It ensured better security of the measurement thanks to the specially built test pit. Equipment that enables the motor to operate on the desired revolution speed, load, temperature, etc. is also available in the producer’s testing laboratory. Measurement during operation is practically impossible considering the necessary motor adjustments, such as the holes in the rotor or complicated installation of sensors. Installation of strain gauges on the shrink ring and short circuit-ring motor is shown in Fig 3.

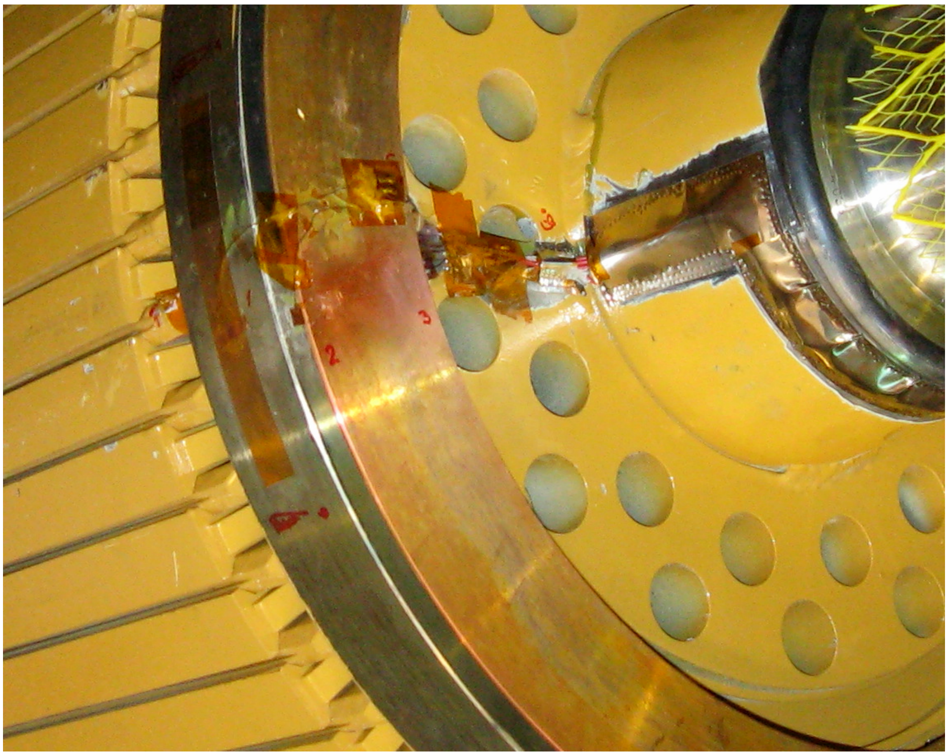

**Fig. 3.** Installation of strain gauges on the shrink ring and short circuit-ring motor

The goal of the experimental work was to monitor other places or phenomena. This article deals with part of the measurement connected with the shrink ring and the short circuit-ring. Monitored variables were measured during increasing revolutions up to test revolutions at a cold motor, motor braking, heating the motor up to the operational temperature and repeated measuring at test revolutions and motor braking.

Note: The producer tests the motors at test revolutions before delivering to a customer. These revolutions are higher than the maximum revolutions in operation.

## 5. Discussion of the measured results

The measurements showed that the temperature influences the loading of the shrink ring. Growth of the temperature causes decreasing of stress in the shrink ring. Plastic deformation appeared after measuring at test revolutions and motor braking both for the cold motor and the motor at the operation temperature.

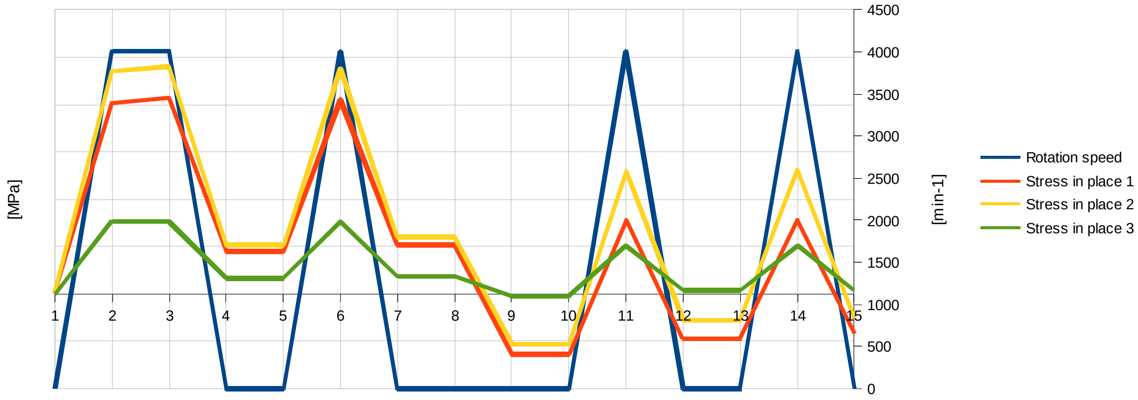


**Fig. 4.** Measured stresses in dependence on rotation speed, measurements 1 to 8 at ambient temperature and measurements 9 to 15 at higher temperature

The electric motor operates at lower revolutions than were revolutions during the experiment and thus the plastic deformation may not occur during operation. However, it is necessary to modify the design of the short circuit-ring and shrink ring to prevent such an event. Another possibility is to design the safe shrink ring in such a way that it could stand the increased stress.

Stress range is given by stress at zero revolutions and stress at measured revolutions. Stress range was similar at the measurement on both the cold motor and the motor at operating temperature.

## 6. Comparison of experiment and calculation

Measurements showed that the chosen approach to modelling gives higher calculated values of stress at the shrink ring than are the values of the measured stress. On the basis of this measurement it was possible to modify the boundary conditions in the FEM model for them to correspond with the actual behaviour.

If the shrink ring is well designed the creep does not occur.

In the case that the effect of temperature is included in the calculation the used methodology is applicable to assessing the shrink ring strength.

## 7. Conclusion

To assess the strength of the shrink ring of heavy asynchronous motors first only FEM calculations using conservative approach to modelling were performed. The first measurement of stress at shrink ring and short circuit-ring at running motor was performed. The problem of the measurement at rotation, in a strong electromagnetic field and at the temperature higher than 100 °C was solved. The measurement enabled to correct the approach to FEM modelling and the strength assessment.

## 8. Acknowledgements

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## References

[1] Hejman M., "Fatigue Life Assessment using FEMFAT Program (In Czech)" in *Proceedings of conference Únava a lomová mechanika 2008*, Žinkovy, Škoda Výzkum s.r.o., Plzeň, 2008, on CD ROM. ISBN 978-80-7043-679-0

[2] Václavík J., Measurement of Stress at the Shrink Ring of the Electric Motor (In Czech), (VZÚ Plzeň s.r.o., 2010) Test rpt No: VYZ-1054-0067-01N.

[3] Hejman M., Assessment of the Shrik Ring (In Czech), (VZÚ Plzeň s.r.o., 2010) Rpt No: VYZ 1183/2009

[4] FEMFAT 4.8 Basic user manual

[5] COSMOSM user manual