Bearing impedance and bearing damage due to bearing currents in inverter-fed electrical machines

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Field of activity: Reliability of Electric Machines, Standards

Main Focus: Bearing Model based on Statistical Evaluated Measurements

Inverter:
- Switching Frequency
- Modulation process
- Voltage (dv/dt)

Filter:
- Passive Filter
- Active Filter

Cable:
- Length
- Shielded Cable
- Not Shielded Cable

Machine Design:
- Stator Winding Design
- Stator Lamination and Frame

Bearing Design:
- Dimensions
- Material Properties
- Cage

Lubricant:
- Viscosity
- Volumic mass
- Threshold Voltage
- Conductivity
- Permittivity

Operation parameter:
- Speed
- Axial Bearing Load
- Radial Bearing Load
- Bearing Temperature

Figure 1: Influence on bearing currents

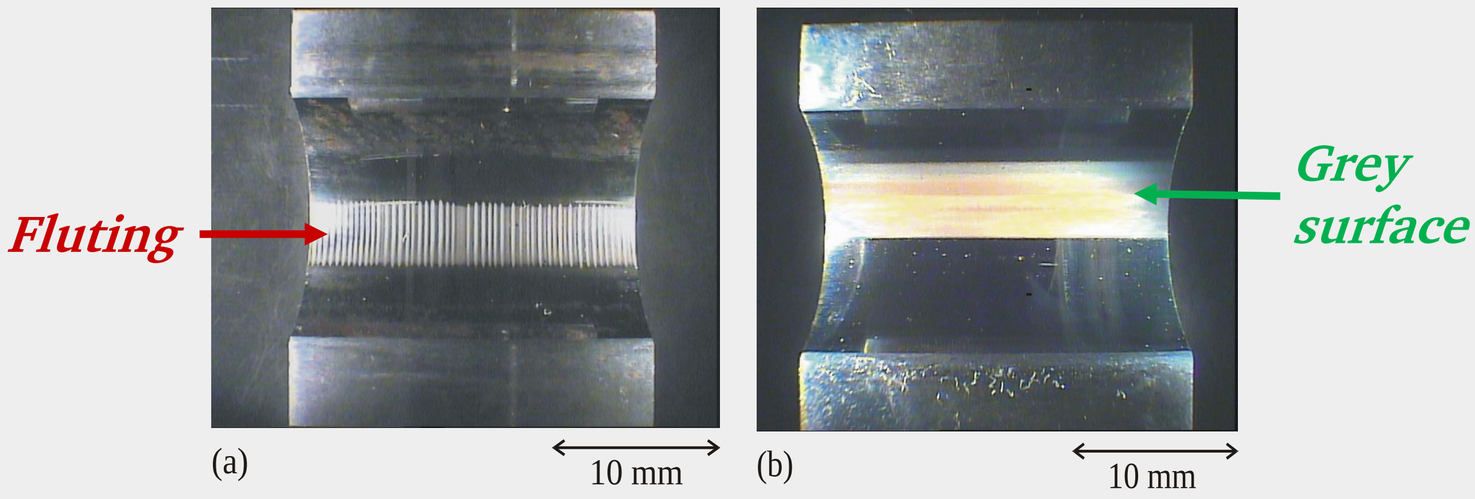

Figure 2: Bearing Damage Inner race of a ball bearing type 6309 C3 (Siemens) 11 kW - induction motor, 10 kHz - inverter switching frequency, 1275 operating hours, 1500/min, no-load

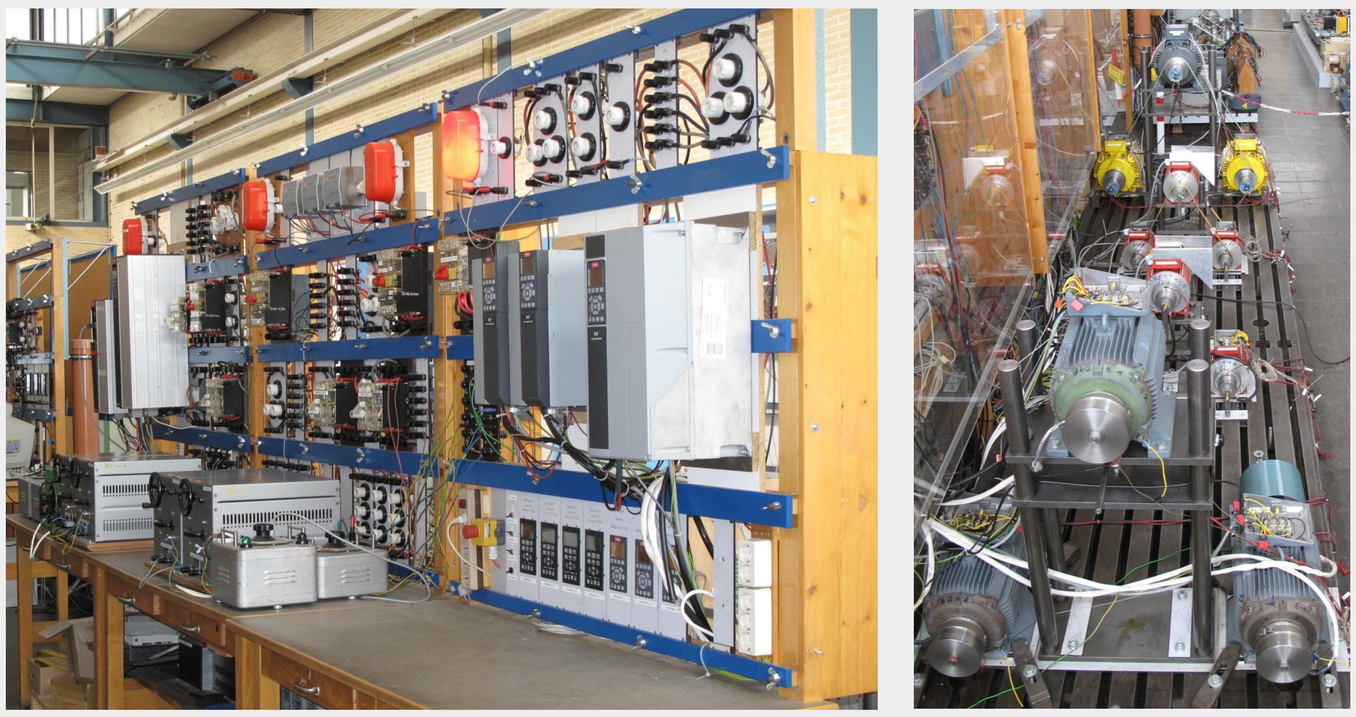

Figure 3: Bearing Test Rigs (1.5 kW and 11 kW)

Scientific Background:

Fast switching inverters cause common mode voltages at the motor terminals with high *dv/dt*, which may cause a common mode (CM) bearing voltage between inner and outer bearing ring. This may lead to a punch-through of the lubricating and insulating oil film between the roller elements and the bearing race. Hence we get discharge bearing currents, which acts like an erosion or machining. The inverter switching CM voltage causes also a HF ground current, which at a low rotor grounding impedance, results also in a rotor ground current, which passes via the bearings. The stator and rotor ground current excite also a circular CM HF flux, which induces a shaft voltage. This voltage causes a circular HF bearing current especially in bigger machines above 100 kW rated power, which will also cause a damage of the bearings. The damage of the bearings can be “Fluting” or a “Grey Surface” of the bearing race. Bearing with “Grey Surface” allow further stable operations. Bearings with “Fluting” are destroyed completely and are able ,if not detected, to destroy the electrical machine (Figure 2).

Aims:

During this research project a sufficient number of 600 roller ball bearings as test specimen for motors, with a power rating of 1.5 kW, 11 kW and 110 kW shall be used to investigate the evolution of bearing damages experimentally. The state of the bearing: „grey trace – stable bearing operation“ versus „fluting – unstable bearing operation“ is to determine, to get a answer on the question: What are safe operating conditions?

Methodology:

The research work is experimental and theoretical. Seven special bearing test rigs (Figure 3), with in sum 17 machines, based on standard cage induction motors, allow a defined adjustment of several operating parameters:
- Axial bearing force (via springs)
- Radial bearing force (via belt)
- Speed (via inverter control)
- Bearing temperature (via heating devices)

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