QUALITY ENGINEERING

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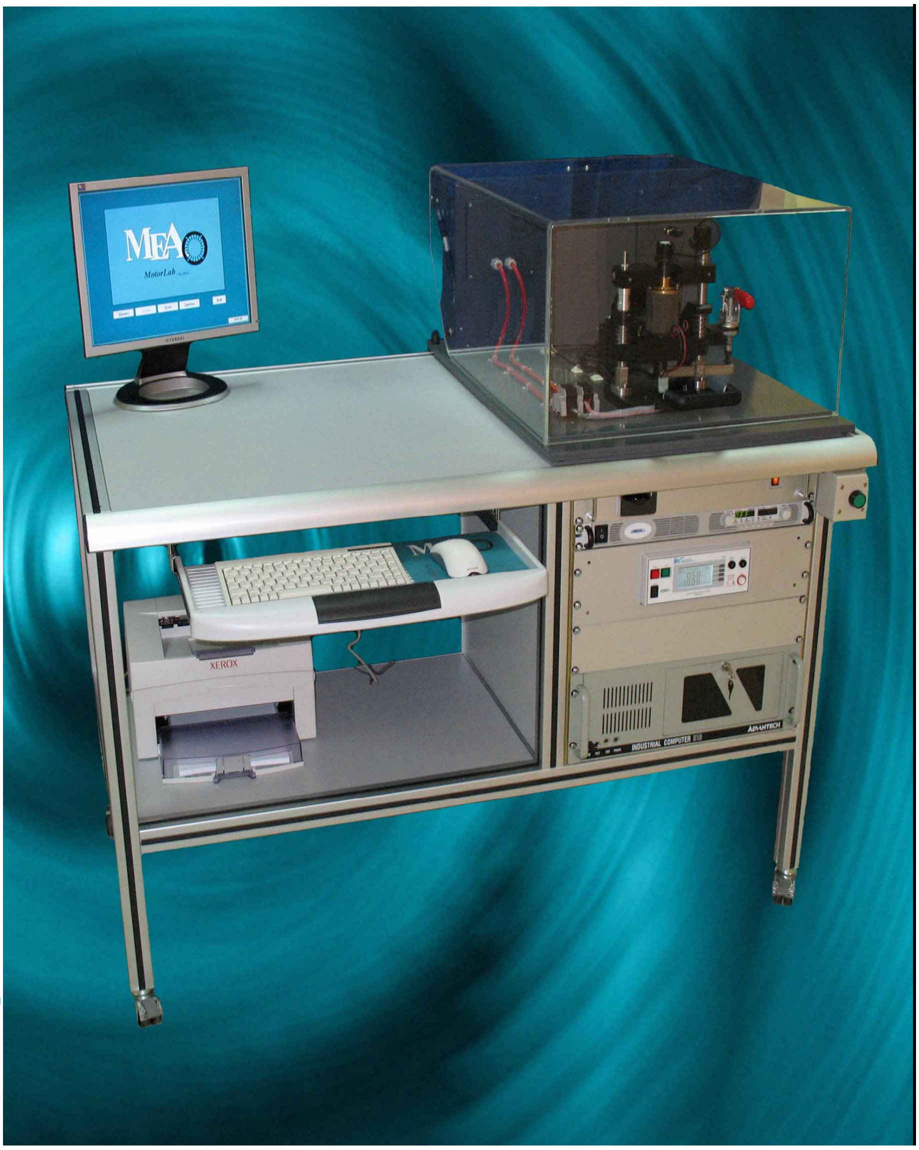

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MEDIENGRUPPE

Production Control of Electrical Drives by the M.E.A. Testing Method

The M.E.A. Test System

The M.E.A. System for the testing of electrical drives [1], [2], [3], [4], [5] permits to asses in seconds the complete static and dynamic characteristic of an electromotor.

Using this method a motor is accelerated from 0 to the no load speed. The load is only its own rotor's moment of inertia. In micro second intervals current, voltage and speed over time are measured. The speed measurement is either done by an external M.E.A. speed sensor or by a motor internal encoder, which supplies the speed signals. A very user friendly software calculates from the measured values the data listed in Tab. 1 shows them in graphs and tables and saves them for evaluation, comparison, quality assurance etc.

The method may be used in research and development and also for production end control of motors, gear motors and electrical brakes, also drives of multi axis machines.

The M.E.A. test procedure for quality assurance differs from the usual methods of today's practice. Conventionally some few parameters like winding resistance, quality of insulation at elevated voltage, reaching of maximum speed and similar criteria will be checked. If those parameters are found satisfactory it is assumed that the motor will reach its design characteristic. With the M.E.A. System a different top-down approach is followed. One determines the complete motor characteristic. Deviations from the design values indicate faults. Since every fault type has a typical fingerprint faults can be easily identified by the measuring results. This way more faults - be it electrical or mechanical - are detected than with conventional test methods ensuring that the desired motor characteristic and quality will be obtained in all parameters. Very important are the dynamic tests since many defects can only be found this way.

The faults detectable by the M.E.A. testing system are listed in Tab. 2.

In a study executed for a customer the capability of finding also minute mechanical faults of a motor without delaying the line throughput in mass production was proven.

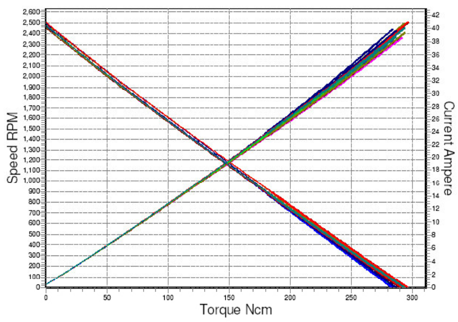

Fig. 1: Repeatability of the measurements of torque and current as a function of speed. The 4 motors (#13, 21, 23, 24) were measured 10 times each.

Static Characteristics	Dynamic Characteristics
Power input – speed	Speed – time during acceleration
Power output – speed	Torque– time during acceleration
Efficiency – speed	Unbalance at rotational frequency
Torque – speed	Torque- and speed- oscillations
Friction torque – speed	Spectrum analysis of the speed oscillations
Voltage – speed	Spectrum analysis of the torque oscillations
Current – speed	Integral of the oscillation amplitudes
Current – torque	Spectrum analysis of the friction torque
Back EMF during deceleration	Cogging level
Sense of rotation	
Stator temperature	
Power output and torque at different motor temperatures	
Determination of moment of inertia	
Determination of load curves	

Tab. 1: Evaluation of measurements of electrical motors by the M.E.A. Testing System.

THE AUTHOR

Dipl.-Eng. Alfred K. Wunsch
EC ENERGOCONSULT,
CH-5400 Baden/Switzerland

Efficacy of the M.E.A. system in fault detection

A motor manufacturer provided 5 good (#13, 21, 22, 23, 24) and 4 motors having mechanical defects. The motors were DC motors with permanent magnets and a no load speed of 2'500 R.P.M. They give operated at 24 V a power output of 200 W. The 5 good motors served as basis for comparison in order to recognise the standard deviation from significant deviations of the faulty motors.

The defect motors had:

- Roller bearing damage shaftside # 1
- Brush fault # 4
- Unbalance #5
- Roller bearing damage brushside #8

After having run for 1 minute as a warm-up, the 5 good motors were measured 10 times each in order to determine the average values and the scatter. The M.E.A. MotorLab software was used to determine:

- Torque
- Current drawn
- Power input
- Efficiency and
- Friction torque

All as a function of speed and also:

- Friction torque as a function of the rotation angle and
- Speed as a function of time

It was found that the so-called good motor 22 also had a defect.

The repeatability when measuring the faultless motors was good as shown in Fig. 1.

Based on the result of the 4 good motors an acceptance range of 6 Sigma +/- 4% was established by

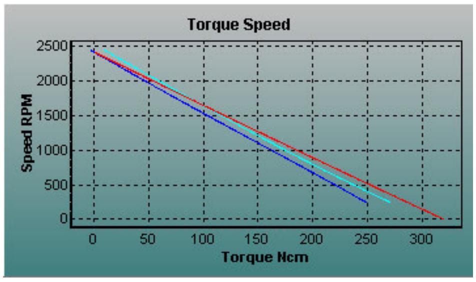

Fig. 2: Torque deviation from the tolerance area of motor #5 (red) with unbalance and vibration.

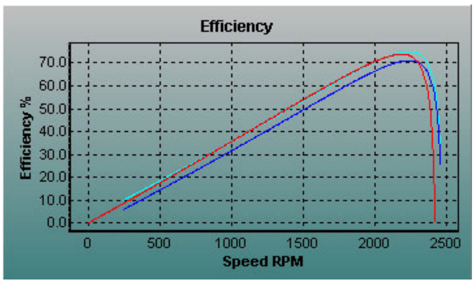

Fig. 3: Efficiency deviation from the given tolerance field of motor #5 because of unbalance and vibrations.

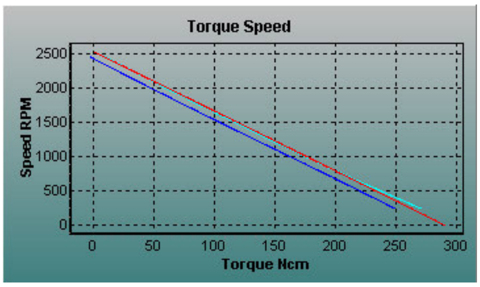

Fig. 4: Torque deviation of motor #1 (red) with a slight bearing problem on he shaft side. The failure is not clearly recognisable even though the software shows a defect.

Fault indication	
Deviation from design in:	
- Current	- Flash fails
- Voltage	- Deviation in back EMF
- Power input	- Brush problems
- Power output	- Bearing damage in the motor
- Torque	- Increased friction of the motor
- Efficiency	- Vibrations and oscillations
- Cogging level	- Noise of motor
Find:	- Unbalance
- Magnetic problems	- Bad alignment
- Broken wires or cage bars	- Gear noise
- Insulation faults	- Increased friction of gear
- Electric asymmetry of the rotor	- Bearing damage
- Bad soldering of the rotor winding connection	- Faulty electronic motor control

Tab. 2: Faults, which the M.E.A. System will find, when testing an electric drive.

the aid of the M.E.A. Go/No Go software. In the following graphs the lower border of the tolerance range is the dark blue line, the upper border is the light blue line.

The motors with defects had also a 1-minute run-in before measuring them.

The measurement results of the motors operated at a nominal voltage of 24 V are shown in Tab. 3. A plus sign **+** means the measured values were within the tolerance range, a minus sign **-** , however, indicates that the measured values fell outside the tolerance range.

All the measurements indicate the motor performances from 0 [rpm] up to its maximum No Load Speed.

While all the motors without defects also in case of repeated measurement were clearly within the tolerance range the faulty motors showed partly even very significant deviations from the tolerance range with its light and dark blue limitations. Fig. 2 for example shows the deviation of motor #5 with unbalance and vibrations (red line), which clearly is outside of the tolerance field for the torque. Equally clear was the deviation of the efficiency (Fig. 3) and the friction torque.

In some cases, however, the deviation didn't have great significance, e.g. in the case of the very slight bearing damage of motor #1 (Fig.4).

Also the motor #8 with a slight damage on the brush side failed only in one criterion, the efficiency. In such cases uncertainty exists. On the other side it proves the advantage of considering a larger numbers of criteria in the test process as this guarantees that all defects can be detected during testing.

Measurement **Motor**	**Power input** vs. Speed	**Current** vs. Speed	**Power output** vs. Speed	**Efficiency** vs. Speed	**Torque** vs. Speed	**Friction** vs. Speed
#13, 21, 23, 24 Good motors	+	+	+	+	+	+
#22 So called "good" motor	+	+	-	-	-	-
# 1 Bearing damage shaft side	-	-	-	-	-	+
#4 Brush damage	+	+	-	-	-	-
#5 Unbalance	-	-	-	-	-	-
#8 Bearing damage brush side	+	+	+	-	+	+

Tab. 3: Overview of all the results of the tested motors.

Refining of the M.E.A. testing procedure

Cogging torque

As further test criterion the cogging level was added. It shows that the so-called "good motor" #22, which obviously had a electro mechanical defect, had a cogging level five times as high as the good ones, which were all very close together. The motors with the mechanical defects on the other side showed a clearly lower cogging level than the good motors.

Operation with reduced voltage

The M.E.A. System further offers the possibility to increase the sensitivity of

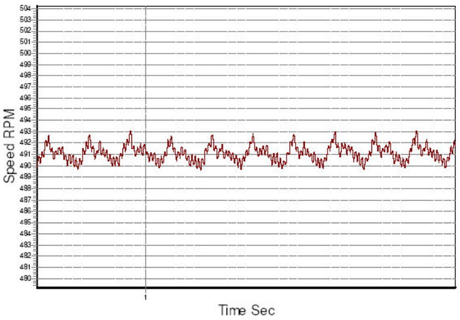

Fig. 5: Speed oscillations during stationary operation of the good motor #24 as a function of time remain relatively small and regular.

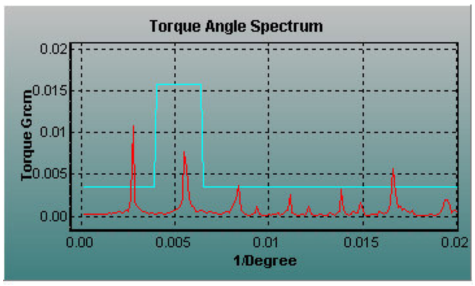

Fig 8: Friction torque oscillations of the motor #1 with a bearing problem as a function of the inverse angle of rotation. The amplitudes exceed the given tolerance limits.

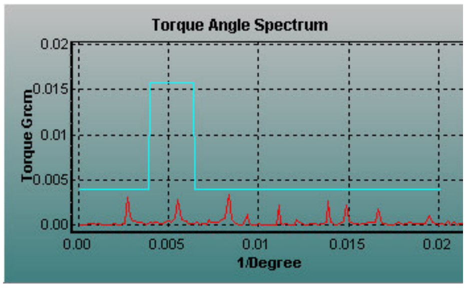

Fig 7: Friction torque oscillations of the good motor #24 as a function of the inverse angle of rotation remain within tolerance limit.

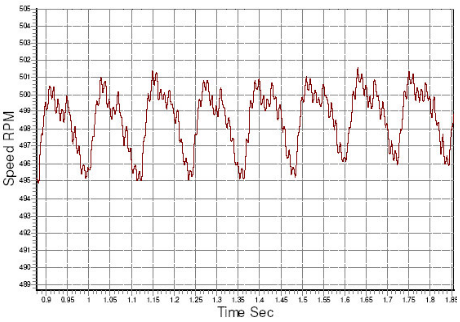

Fig. 6: Speed oscillations during stationary operation of the motor #1 with a bearing problem as a function of time become larger. Difference to Fig. 5 is clearly visible.

the tests to eliminate all doubts. While measuring the motors with nominal voltage relatively high electromagnetic as well as mechanical forces act on the motor thus creating disturbances. The influence of the mechanical disturbances can be better recognised if the motor is operated with reduced voltage. Electromagnetic disturbances are reduced and mechanical noise can be better distinguished and recognized.
In addition to the nominal voltage of 24 V all motors were also dynamically measured with 5 V in stationary state, this means the oscillations at no load speed were determined. See Tab. 4 and Figs. 5 and 6.
Also the oscillations caused by the motor friction torque were determined as shown in Figure 7 and 8. All faults were clearly indicated.

Air gap problems

Another motor manufacturer wanted to be sure that also bad alignment of rotor and stator will be recognised by the M.E.A. method. Five good motors were measured and - in the same way as described above - a statistical average was obtained and a tolerance fields were set for all parameters.

Motor	Cogging torque	Dynamic measurements (stationary state) with reduced voltage of 5 V	Friction torque spectrum
#13, 21, 23, 24 Good motors	+	+	+
#22 so-called "good" motor	-	-	-
# 1 bearing damage shaftside	-	-	-
#4 brush damage	-	-	-
#5 Unbalance	-	-	-
#8 Bearing damage Brush side	-	-	-

Tab. 4: Additionally refined measurements with the M.E.A. System in order to recognise little mechanical defects: Cogging torque as criterion, dynamic measurement of speed oscillations in the no load point and friction torque spectrum show motor faults.

Also in this case a faulty motor slipped among the " good" ones. In 5 further motors with air gap problems all defects were found due to increased speed and torque oscillations.
The static values of the faulty motors as usually measured by a brake were in order and did not indicate the bad alignment.

Conclusions

All mechanical and electrical defects which may occur in an electromotor can be found in the production end control by the M.E.A. System. The present study was limited to the detection of mechanical defects, which are relatively difficult to find. The M.E.A. System was capable of finding them all. At the first glance the large number of criterions having been used may appear very complicated. One has, however, to consider that all these measurements were made with one instrument in one or maximum two measuring steps and the time used for all these readings, evaluations and display of the results requires only seconds. Even the test with reduced voltage, which can be done fully automatically, needs only very little additional time. This M.E.A. method is superior to conventional test methods and offers highest security that production faults cannot pass through without being detected. The test reports delivered by the software are also a perfect quality assurance document of the tested product.

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energoconsult@hispeed.ch