Ramp differential expansion measurements with the SKF Multilog On-line System DMx

By Marcel de Boer • SKF

As described in the differential expansion application note, publication number CM3073 EN, the SKF Multilog On-line System DMx is specifically designed to perform critical measurements which are used in the control of large steam turbine generator trains. One of the most important measurements is that of differential expansion.

Differential expansion monitoring measures the change in axial clearances between the machine rotor and stationary casing caused by thermal changes inherent in most machines. The primary purpose of a differential expansion monitor is to guard against axial rub between rotating and stationary parts, the consequences of which can be catastrophic.

There are many configurations for measuring differential expansion.

This application note discusses the common sensor configuration of ramp differential expansion (abbreviated to "RDE"). The sensor orientation is considered, together with the appropriate SKF Multilog DMx configuration example.

There could be a number of reasons for using ramp differential expansion instead of straight differential expansion (SDE):

- The desired working range of the non-contact Eddy Current Probe is not enough. A ramp provides "mechanical" advantage.
- Due to machine design, there is not enough space available to mount a probe of sufficient diameter versus required range for a straight measurement.



The SKF Multilog On-line System DMx.

• To keep the diversity of used probes to a minimum, often a standard Eddy Current Probe with a range of only 2 mm can be used with a ramp differential expansion measurement. By using the ramp, the amplification of the measuring range is enough in most cases.



How does ramp differential expansion work?

In **Figure 1** and **Figure 2**, the ramp differential expansion measurement uses two sensors viewing a concave or convex ramp integral to the rotor assembly. The amount of differential expansion capable of being measured is based upon the angle of the target ramp and the linear range of the sensor making the measurement.

Typical ramp angles found in today's machines range from 9.5° to 14.5°, although in rare cases 30° to 45° angles are found.

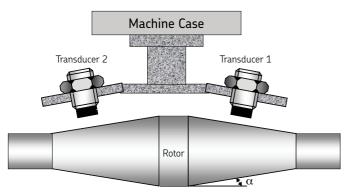


Figure 1

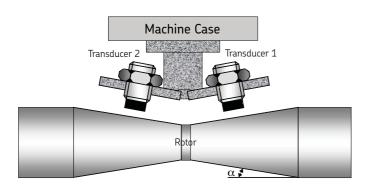


Figure 2

As the rotor thermally expands or contracts, the rotor target area moves at the sine of the ramp angle. This effect increases the sensor's maximum range as a large axial change in rotor position results in a much smaller relative perpendicular gap change. This increase in the sensor's maximum range effectively decreases the sensor's sensitivity in a proportional manner to axial direction movement.

Dual ramp differential expansion

Figure 1 and **Figure 2** represent what is called dual ramp differential expansion, which uses two transducers, both which measure radial and axial movement of the shaft.

Single ramp differential expansion

Figure 3 illustrates single ramp differential expansion, which uses two transducers. Transducer 1 measures the axial and radial movement of the rotor. Transducer 2 measures only the radial motion.

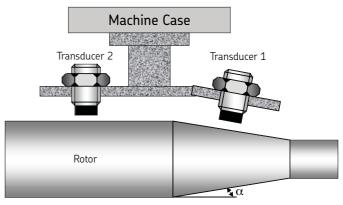


Figure 3

- Single ramp expansion performed by the SKF Multilog DMx needs transducer 1 facing the ramp.
- Transducer 1 is facing the ramp and the angle of the transducer has to be defined as α.
- Transducer 2 is facing the shaft and the angle of the transducer has to be defined as 0° (if the angle ≠ 0 dual ramp differential expansion is assumed!)
- To achieve standard active /inactive definitions, the programmed angles should be both positive with concave configurations, or both negative with convex configurations (Active is presented as a shaft movement to the right in Figures 1-3).

Note:

• As ramp expansion measurements are based on a dual channel input, the SKF Multilog DMx only accepts this kind of configuration if a channel pair is used. RDE should be set up for channel 1 and 2 or channel 3 and 4. Strictly speaking, we are only interested in the axial displacement of the rotor, but as an additional benefit, the radial displacement from the dual channel will also be calculated. This result is available for display, but should be used as information only. Normally there won't be any alarming for the radial displacement.

If all of the above rules have been applied, the axial displacement will be presented by the first measurement and the radial displacement is available from the second measurement (depending on the set up this could also be presented by channels 3 and 4 respectively).

How to set up the SKF Multilog DMx for RDE

The following example is how to set up the SKF Multilog DMx (model CMMA 9910) for dual ramp differential expansion. A real-world example is used, as shown in **Figure 4**. In this example, externally powered "probe sets" are used (comprised of a probe, extension cable and driver) as more care should be taken with this kind of setup. Where possible, direct ECP probes using the SKF Multilog DMx internal digital drivers are recommended, as they have a much higher accuracy and range, and so are more tolerant of user error.







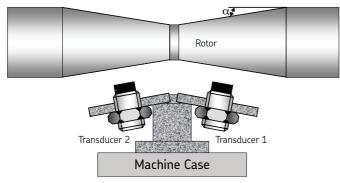


Figure 5

Probe: CMSS 68 Driver: CMSS 668-5 Usable range: 145 mils = 3.7 mm Sensitivity: 100 mV/mil ~ 3937 mV/mm

	Transducer 1	Transducer 2
Sensor sensitivity:	3 937 mV/mm	3 937 mV/mm
Measurement range:	15.2 mm	15.2 mm
Ramp angle:	14°	14°
Zero voltage:	-12.20 V	-4.71V

Danger rotor short: -5.8 mm Danger rotor long: +6.9 mm

SKF Multilog DMx configuration setup

Two "Config" channels will be configured like this:

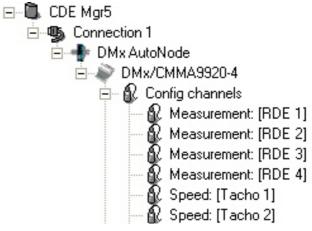


Figure 6

DMx measurement channel properties
General Transducer Transducer power Measurement Waveform/FFT Orders
 [®] RDE 1
Name
RDE 1
Transducer type Frequency Range (Hz) Displacement ▼ 2800 ▼ TSI application ECP type Ramp Diff Exp ▼ Probe system ▼
Upload Download Save/Dwnld Save to DB Done Help
Read OK



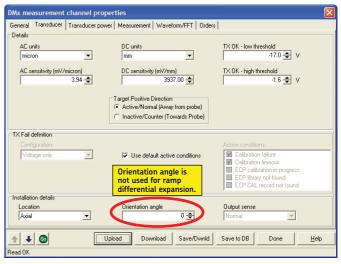
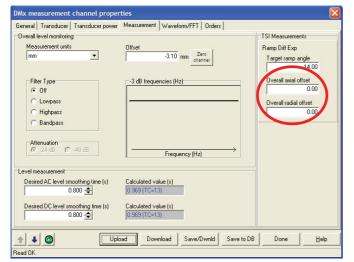


Figure 8

DMx measurement channel properties	
General Transducer Transducer power Measurement Waveform/FFT Orders	
Power supply Power output C Constant Current Mode C 20V/14 mA If Voltage Regulated Mode If OFF	
External ECP Offset Reference Vreg (V) 20.3 € □ Zero Depends if drivers are externally powered.	
Voltage regulation mode is active on a per channel pair basis. Therefore when measurement channel 1 is configured for Voltage regulation mode, associated channel 2 shall either be configured for Voltage Regulation or switched DFF. Voltage regulation mode, therefore, cannot be combined with constant current based sensor supply. When using Voltage regulation mode, combine 2se actemal divers on the applicable channel pair. When only requiring single extendiativers, which the power supply option DFF on the other channel. Current Regulation mode is active on a per channel basis and requires Voltage regulation to be disabled. Selection 0 3 ImA or 14mA constant current source can be freely selected for individual channels. In case on channel of a channel pair is using constant current source, then the other channels will use constant current source as well, whether used or not. There is no option to select OFF once constant current is used on a channel pair.	
Upload Download Save/Dwnld Save to DB Done H	эlp
Read OK	

Figure 9





In the measurement tab, an optional flied called "Overall axial and radial offset" provides extra flexibility for commissioning purposes. The programmed values will be added to the end result of the axial processed output and the radial processed output. This can be used after the mechanical zeroing of the rotor to set the final results to the desired value. The last two tabs in the measurement properties, the Waveform and the Order tabs should be disabled for optimized processing optimizing.

General Transducer Transdu	ucer power Measurement Way	/eform/FFT Orders	
FFT enabled			
Waveform setup			
Signal source	-		
Pre-filter			z)
Measurement units	0.0-2861.0	2.86	
mm	·		
Window function	Number of averag	es	
Hamming	• 1	-	
Band 1	Band 2	Band 3	Band 4
		1	
Start (Hz) Stop (Hz)	Start (Hz) (Hz)	Start (Hz) Stop (Hz)	Start (Hz) Stop (Hz)
10 🚖 🛛 250 🌩	20 🚔 🛛 🚭	10 🛨 100 🚖	10 🛫 200 🚖
8.6-246	17.2-54	8.6-97	8.6-197



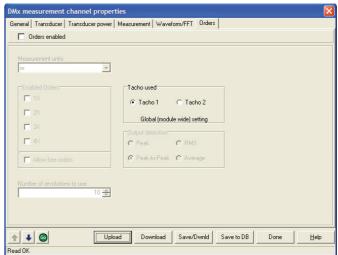


Figure 12

Mx measurement channel properties	K
General Transducer Transducer power Measurement Waveform/FFT Orders	
Name RDE 2 Transducer type Displacement	
TSI application ECP type Ramp Diff Exp Probe system Note: Paired application	
↑ ↓ Download Save/Dwnld Save to DB Done Help	
lead OK	

Figure 13

DMx measurement channel prope	rties	X
General Transducer Transducer power	Measurement Waveform/FFT Orders	
Details		
AC units	DC units	TX OK - low threshold -17.0 🜩 V
micron	mm 🗾	-17.0 💌 V
AC sensitivity (mV/micron)	DC sensitivity (mV/mm) 3937.00 🚖	TX OK - high threshold
	Target Positive Direction C Active/Normal (Away from probe) Inactive/Counter (Towards Probe)	
TX Fail definition		
Configuration Voltage only	☑ Use default active conditions	Active conditions Calibration failure Calibration timeout ECP calibration in progress ECP library not found ECP CAL record not found
Installation details		,
Location	Orientation angle	Output sense
Axial	0 🚖	Normal
	load Download Save/Dwnld	Save to DB Done <u>H</u> elp
Read OK		

Figure 14

DMx measurement channel prop	erties	
General Transducer Transducer powe	er Measurement Waveform/FFT Orders	
Overall level monitoring		TSI Measurements
Measurement units	Offset	Ramp Diff Exp
mm	-1.20 mm Zero channel	Target ramp angle
		14.00
Filter Type	-3 dB frequencies (Hz)	Overall axial offset
⊙ Off		1
C Lowpass C Highpass		Overall radial offset 0.00
C Bandpass		
, banapato		
Attenuation		
💿 -24 dB 🔿 -48 dB	Frequency (Hz)	
l evel measurement		
Desired AC level smoothing time (s)	Calculated value (s)	
0.800 🜩	0.969 (TC=13)	
Desired DC level smoothing time (s)	Calculated value (s)	
0.800	0.969 (TC=13)	
↑ ↓ 	pload Download Save/Dwnld Save to D	B Done <u>H</u> elp
Read OK		



Two "Process" channels will be configured like this:

Where RDE 1 will process the axial displacement of the rotor and RDE 2 processes the radial position of the rotor. The latter is not necessary for the RDE measurement but can be used for informational purposes.

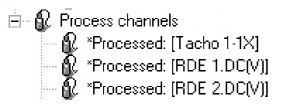


Figure 16

Process channel definition					
Enabled				10 (mm) ⁰ т	
Measurement source					
Ramp diff expansion	-	Get data from	1 DMx 4.	8-	
Measurement channel			1.	6 -	
1: RDE 1	•		-1.	e -	
Full scale 8.00 (mm)			-4.	8-	
(iiiii)			-8	.]	



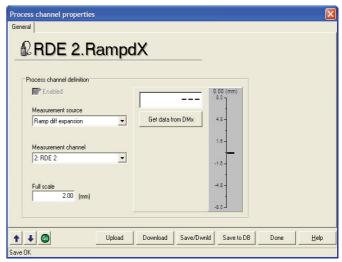


Figure 18

Alarms on this processed output are set accordingly as shown in **Figure 19** *and* **Figure 20**.

Narm name Ramp Expansi	on	Enable alarm	Advanced alarm setup	
eneral Normal	setup Advanced			
larm usage ``Alert	Alarm behaviour	Alarm action Delay time 0.30 (s)	Alarm multiplier Enabled On time	Global logic control
Danger	C Latching	Sustain time 0.00 (s)		

Figure 19

Alarm name					
Ramp Expans		M Enable	alarm 🔲 Advanced ala	rm setup	
eneral Norma	al setup Advanced				
Alarm type			Alarm gating		
C Normal	🔿 Non-fa	il safe	Parametric gating		
Fail safe	C Power	fail	Logic gating	×	
/oting scheme					
☞ 1001	C 1002		C 1003 C 2003 C 3003	C 1004	C 3004
1	Input 1				
Input 1	Channel	Alarm mode C Level C In window C Out window	Output RampdK Delay 0.00		level Hysteresis 6.90 (mm) 2 ♣ (% level Multiplier -5.80 (mm) 1.00

Figure 20

Ramp differential expansion: advantages and disadvantages

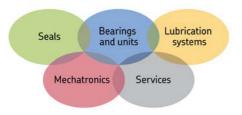
The significant advantage of using a ramp is that it increases the working range of the installed Eddy Probe.

However, there are some disadvantages with RDE when compared to SDE which one should be aware of:

- **Installation costs:** the installation of two transducers instead of one transducer for SDE will increase costs.
- **Machine design:** it will be very difficult, and maybe impossible, to rework an existing shaft to provide a ramp that can be used for measurements. Even if this can be done, problems often arise with mounting the brackets for the two transducers. Therefore, ramp expansion is almost always a feature in the original machine design.

• Accuracy of the measurement:

- Due to the increase of the working range, the sensitivity decreases.
- Because there are two transducers necessary for one axial measurement, problems will arise if the shaft bends. The radial motion measured by the second transducer may not be the same as the radial motion at the position where the first sensor is installed. This will lead to errors in the axial displacement. This problem also occurs if the transducers are mounted too far from each other. This possible error should also be considered during periods of high eccentricity measurements (e.g. at startup).
- Due to the fact that the ramp has an angle, the mounting of the transducer facing this ramp should be perpendicular. If the transducer is not mounted accurately, this will result in misleading results.
- **Calibration of the measurement:** the only reliable way to check a RDE measurement is to do this on the machine itself. This is not possible for ramp expansion because:
 - It is not possible to move the shaft in both directions to get close to, or even beyond, the danger values.
 - It is not possible to move the shaft accurately in an axial and a radial direction simultaneously.



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