Date : 21.12.2018
Company :
Branch :
Plant :
Unit : GTE-160 st. No. 2
Factory No:

Conclusion No. 02.1-R

On the impact of repairs / adjustment works on the technical condition of the unit

Date of shutdown for repairs	Repair / adjustment finish date	Repair duration, days	Reason for repairs
15.09.2018	24.10.2018	39	Conduct of a large scheduled inspection of GT after 33,000 equivalent hours of operation.

Change in the MTBF indicators after the repairs and startup

Parameter	Before	After	Difference
Number of start-ups	137	149	+ 12
Total equivalent hours, hour	35,939	36,129	+ 190
Dynamic MTBF, hours	2,841.8	2,846.9	+ 5.1
Operation with a frequency of <47.5 or >51.5 Hz, s	2,584.9	2,585.7	+ 0.8

1. Start-up after repairs

Event	Date	Time	Value	MU
Outlet to shaft-turning gear	27.10.2018	07:44:42	88.2	rpm
No-load operation	27.10.2018	09:02:27	3,006.1	rpm
Low load mode (>20 MW)	27.10.2018	15:27:00	25.0	MW
Average load mode (>60 MW)	27.10.2018	16:49:45	60.0	MW
Rated load mode (>140 MW)	27.10.2018	19:06:20	140.0	MW

Fig.1 GTU indicators after repairs (within 72 hours).

2. Evaluation of fuel-air duct parameters, combustion properties, CC operation parameters

Parameter / Mode	Average value before / after repairs / deviation, MU								
	No-load operation			Average 80 MW			Nominal 165 MW		
10MBL10CP003 Mist Separator, Pa	34.6	34.0	**-0.6**	34.3	35.8	**1.5**	34.2	37.2	**3**
10MBL10CP004 Coarse Filter, Pa	167.3	112.3	**-55**	163.8	107.7	**-56.1**	301.9	168.4	**-133.5**
10MBL10CP005 Fine Filter, Pa	126.2	99.4	**-26.8**	122.7	100.6	**-22.1**	190.5	158.4	**-32.1**
10MBL10CP010 Filter Unit DP 0-2000, Pa	329.4	231.1	**-98.3**	318.0	232.0	**-86**	592.8	407.5	**-185.3**
10MBA12FP100ZQ03 Pressure at the K Outlet (FP100), bar	6.1	5.9	**0.2**	7.83	7.84	**0.01**	12.1	11.8	**0.3**
Compressor Pressure Ratio	6.1	5.8	-0.2	7.8	7.7	0.01	12.1	11.8	-0.3
10MBM11CP102XQ01 Pulsation in the Left CC, mbar	3.9	4.1	0	4.3	4.3	0	7.3	6.9	0
10MBM21CP102XQ01 Pulsation in the Right CC, mbar	3.6	3.9	-0.3	3.9	3.9	-0.1	6.9	6.5	-0.3
10MBM11CP103XQ01 Pressure Difference at the Left CC, mbar	154.7	156.5	0.2	142.2	148.4	0	215.1	224.2	-0.4
10MBM21CP103XQ01 Pressure Difference at the Right CC, mbar	151.0	153.9	0.3	138.3	142.6	0	211.6	215.6	-0.4
10MBA22CT102BXQ02 Temperature at GT Exhaust (102B), °C	253.6	248.6	1.8	477.2	520.0	6.2	567.1	573.6	9.1
10MBA22CT103BXQ02 Temperature at GT Exhaust (103B), °C	248.6	251.6	2.9	539.0	532.3	4.3	558.8	560.5	4
10MBA22CT104BXQ02 Temperature at GT Exhaust (104B), °C	245.5	247.2	-5	584.0	581.4	42.8	556.6	536.3	6.5
10MBA22CT106BXQ02 Temperature at GT Exhaust (106B), °C	247.5	257.0	3	445.9	433.8	-6.7	535.1	495.7	1.7
10MBA22CT107BXQ02 Temperature at GT Exhaust (107B), °C	262.7	258.6	1.7	529.4	508.7	-2.6	504.2	502.2	20.3
10MBA22CT108BXQ02 Temperature at GT Exhaust (108B), °C	267.5	252.6	**9.5**	506.3	262.9	**-12.1**	555.1	262.9	**-39.4**

Parameters deviations: In line with performed operations.
Changes in pressure difference at AIS sections are associated with the replacement of filter element during large inspection.
Changes in pressure at the outlet of the compressor and compressor pressure ratio respectively, can be associated with control instrumentation calibration. Deviations in temperature at the GT (108B) exhaust are associated with a malfunction of thermocouple / contact weakening during start-up.

Associated events:
- replacement of fuel rods;
- replacement of heat resistant tiles in the CC;
- installation of new working blades of GT st. 1, 2, 3;
- cleaning of IGV guide blades and compressor blades;
- AIS elements inspection;
- Control instrumentation measuring channels calibration.

3. *Evaluation of Lubrication System and HS AGS Parameters*

Parameter / Mode	Average value before / after repairs / deviation, MU								
	No-load operation			Average 80 MW			Nominal 165 MW		
10MBV10CL101OUT Oil Level in the Oil Tank, mm	423.3	386.3	**-37**	422.9	388.3	**-34.6**	422.4	386.6	**-35.8**
10MBV26CP101XQ01 Oil Pressure Upstream of Bearings, bar	2.4	2.3	-0.1	2.4	2.4	0	2.4	2.4	0
10MBV26CT101AXQ01 Oil Temperature Upstream of Bearings, °C	47.6	44.9	-2.7	46.1	44.6	-1.5	47.1	46.1	-1
10MBX03CP101XQ01 Oil Pressure in the AGS, bar	161.3	161.1	-0.2	162.0	161.1	-0.9	161.7	161.5	-0.2
10MBX06CT101XQ01 Oil Temperature in the AGS Oil Tank, °C	52.8	52.3	-0.5	47.9	53.2	5.3	47.8	50.0	2.2

Parameter deviation: In line with performed operations.

Associated events:
- oil addition;
- cleaning of filtering elements

4. *Evaluation of Bearings Vibration and Temperature Parameters*

Parameter / Mode	Average value before / after repairs / deviation, MU								
	No-load operation			Average 80 MW			Nominal 165-167 MW		
10MBD11CY102XQ01 RMS, bearing No. 1, (V), mm/s	1.7	1.5	**-0.2**	2.6	1	**-1.6**	2.3	1.2	**-1.1**
10MBD12CY101XQ01 RMS, bearing No. 2, (V), mm/s	2.5	2.1	**-0.4**	2.3	1.8	**-0.5**	2.2	1.6	**-0.6**
10MKD11CY021XQ01 RMS, bearing No. 3, (V), mm/s	2.9	2.8	**-0.1**	2.9	2.5	**-0.4**	2.9	2.3	**-0.6**
10MKD11CY022XQ01 RMS, bearing No. 3, (O), mm/s	1.8	1.2	**-0.6**	1.7	1.2	**-0.5**	1.5	1.1	**-0.4**
10MKD11CY023XQ01 RMS, bearing No. 3, (P), mm/s	2.9	3	**0.1**	2.9	2.4	**-0.5**	3	2.6	**-0.4**
10MKD12CY021XQ01 RMS, bearing No. 4, (V), mm/s	0.7	0.8	**0.1**	0.7	0.7	**0**	0.6	0.7	**0.1**
10MKD12CY022XQ012 RMS, bearing No. 4, (O), mm/s	1.9	1.4	**-0.5**	2	1.6	**-0.4**	2.1	1.5	**-0.6**
10MKD12CY023XQ01 RMS, bearing No. 4, (P), mm/s	2.2	1.7	**-0.5**	2.3	1.5	**-0.8**	2	1.6	**-0.4**
10MBD11CY940XQ01 Shaft Vibration, Bearing No. 1, µ	28	29.8	**1.8**	26.2	28.6	**2.6**	32.3	36.7	**4.4**
10MBD12CY940XQ01 Shaft Vibration, Bearing No. 2, µ	19	0.6	**-18.4**	18.2	0.5	**-17.7**	20.1	0.5	**-19.6**
10MKD11CY940XQ01 Shaft Vibration, Bearing No. 3, µ	123.4	101.3	**-22.1**	127	102.2	**-24.8**	129.6	106.1	**-23.5**
10MKD12CY940XQ01 Shaft Vibration, Bearing No. 4, µ	69.2	71.7	**2.5**	69.2	69	**-0.2**	71.1	69.6	**-1.5**
10MBD11CT101AXQ01 Babbit Temperature, Bearing No. 1 (101A), °C	79.4	79.1	**-0.3**	79.5	78.8	**-0.7**	80	81	**1**
10MBD11CT101BXQ01 Babbit Temperature, Bearing No. 1 (101B), °C	78.5	78.1	**-0.4**	78.7	78	**-0.7**	78.9	79.9	**1**
10MBD11CT101CXQ01 Babbit Temperature, Bearing No. 1 (101C), °C	78.5	78.3	**-0.2**	78.7	78.2	**-0.5**	79.2	80.1	**0.9**
10MBD12CT101AXQ01 Babbit Temperature, Bearing No. 2 (101A), °C	78.9	84	**5.1**	81.2	87.3	**6.1**	82.5	89.9	**7.4**
10MBD12CT101BXQ01 Babbit Temperature, Bearing No. 2 (101B), °C	78.5	83.4	**4.9**	80.6	86.6	**6**	81.9	89.2	**7.3**
10MBD12CT101CXQ01 Babbit Temperature, Bearing No. 2 (101C), °C	78.2	83.2	**5**	80.3	86.5	**6.2**	81.5	89	**7.5**
10MKD11CT101OUT Babbit Temperature,	63.3	62.2	**-1.1**	61.8	61.6	**-0.2**	62.9	62.7	**-0.2**

Bearing No. 3 (101), °C									
10MKD11CT102OUT Babbit Temperature, Bearing No. 3 (102), °C	63.6	61.8	**-1.8**	62	61.6	**-0.4**	63.2	62.7	**-0.5**
10MKD12CT101OUT Babbit Temperature, Bearing No. 4 (101), °C	63.9	61.9	**-2**	62.8	61.7	**-1.1**	63.7	63	**-0.7**
10MKD12CT102OUT Babbit Temperature, Bearing No. 4 (102), °C	68.2	66	**-2.2**	67.4	65.8	**-1.6**	68	67.2	**-0.8**
10MBD12CT102AXQ01 Babbit Temperature of the O-Ring (st. G), Bearing No. 2 (102A), °C	63.9	61.9	**-2**	66.5	64.9	**-1.6**	71.5	71.1	**-0.4**
10MBD12CT102BXQ01 Babbit Temperature of the O-Ring (st. G), Bearing No. 2 (102B), °C	62.6	61.2	**-1.4**	64.9	64.2	**-0.7**	69.5	70.4	**0.9**
10MBD12CT102CXQ01 Babbit Temperature of the O-Ring (st. G), Bearing No. 2 (102C), °C	62.7	61.1	**-1.6**	65.1	63.9	**-1.2**	69.7	69.9	**0.2**
10MBD12CT104AXQ01 Babbit Temperature of the O-Ring (st. T), Bearing No. 2 (104A), °C	66.2	66.3	**0.1**	66.5	66.7	**0.2**	66.6	67	**0.4**
10MBD12CT104BXQ01 Babbit Temperature of the O-Ring (st. T), Bearing No. 2 (104B), °C	65.7	65.5	**-0.2**	65.8	65.9	**0.1**	66	66.2	**0.2**
10MBD12CT104CXQ01 Babbit Temperature of the O-Ring (st. T), Bearing No. 2 (104C), °C	65.9	65.5	**-0.4**	66	65.8	**-0.2**	66.2	66.2	**0**

Deviations of parameters:	The most significant deviations are observed on the bearing No. 2 of the compressor (reduction of absolute vibration; increase in journal bearing babbit temperatures; inaccuracy of relative vibration readings). Less significant is the reduction of RMS in: the turbine bearing No. 1, generator bearings No. 3, 4, as well as reduction of shaft vibration in the generator bearing No. 3.
Associated events:	Disassembly / assembly / adjustment of the compressor relative vibration sensors; work related the compressor bearing (replacement of the support); installation of new working blades of the GT at st. 1, 2, 3; GT rotor balancing (turbine bearing side); GTU shaft train alignment; exhaust manifold geometry adjustment.

CONCLUSION

1. *After the repairs completion, the parameters controlled by the PRANA system correspond to "3170463 RE Operating Manual for Gas Turbine Unit GTE-160," with the exception of deviations indicated in the paragraphs below.*
2. *Changes in vibration parameters and bearing support temperatures correspond to the measures taken and can be evaluated as positive, with the exception of an increase in compressor journal bearing temperature and the uncertainty of readings in relative vibration of the compressor bearing. It is recommended to restore a channel measuring the compressor relative vibration.*
3. *A positive effect of reduced resistance in the air duct is registered due to the replacement of AIS filter element and compressor blades cleaning.*
4. *Changes in pressure at the outlet of compressor (and compressor pressure ratio respectively) can be associated with control instrumentation calibration and with IGV settings adjustment (if performed). Taking into account the positive effect of reducing resistance in the air duct, it is recommended to re-calibrate pressure sensor at the outlet of compressor, check whether changes have been made to IGV setting at ultimate opening angles.*
5. *Detected deviations in the parameter "Temperature at GT exhaust (108B)" 10MBA22CT108BXQ02 during the start-up after repairs are caused by the thermocouple measurement channel malfunction or by poor contact.*
6. *There is a positive effect on level increase in the oil tank, associated with measures on re-filling the oil tank.*
7. *In order to correctly assess the technical and economic indices of GTU in particular and CCGT in general, it is recommended to retrofit a standard weather station with additional equipment for barometric pressure measuring, archiving the signals in the power unit APCS archive.*

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Chief Specialist on Turbine Equipment	/*Signature*/	A.A. Filin

Appendix. Diagram of parameters changed.

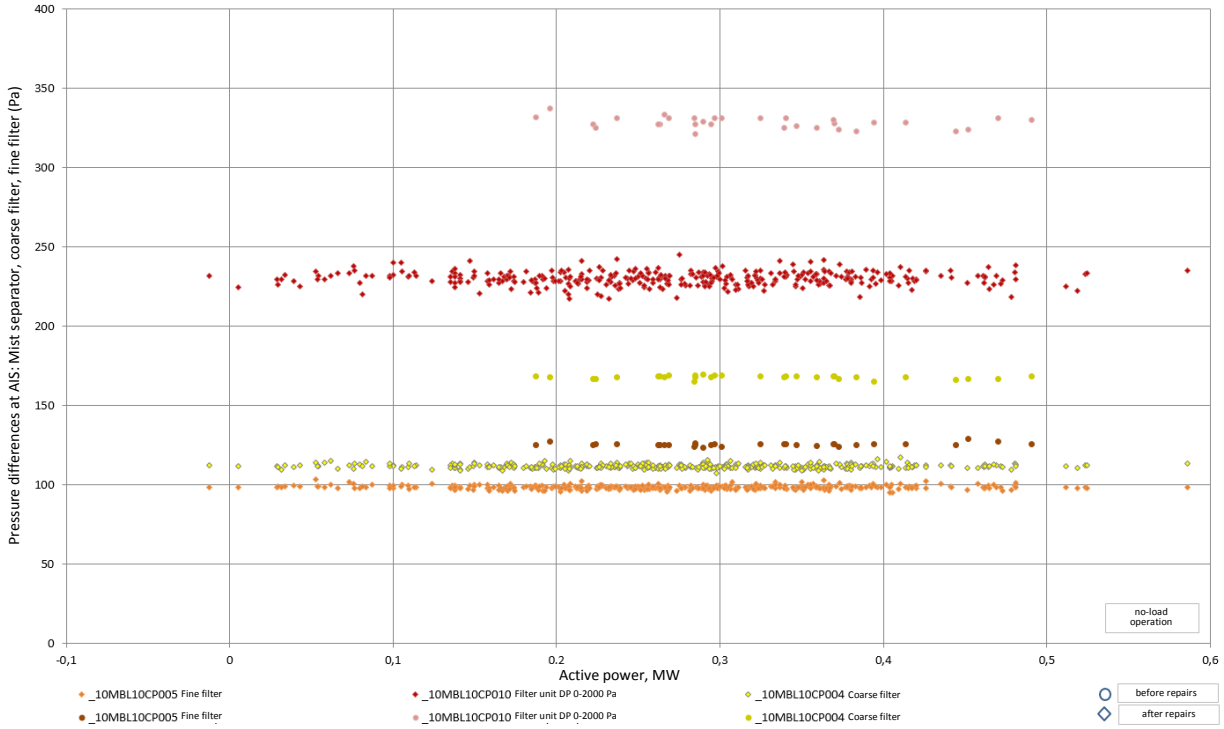

Fig. 1.1. AIS parameters, no-load operation before/after repairs

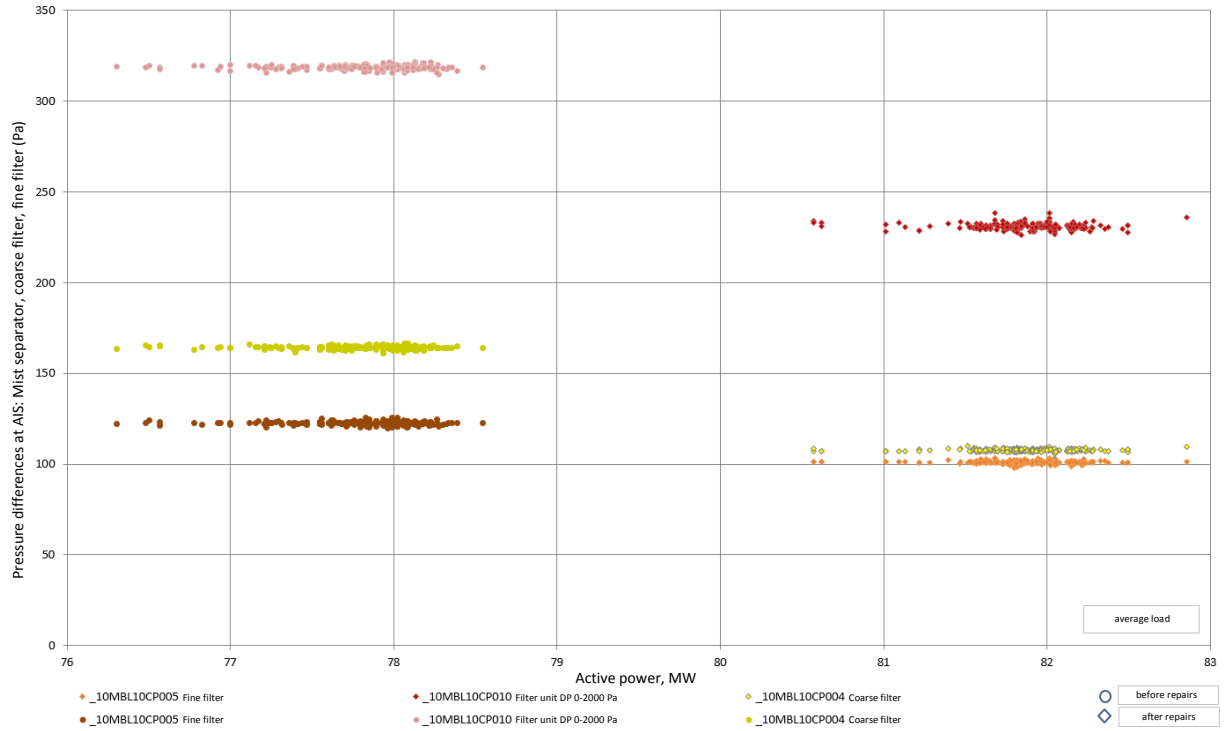

Fig. 1.2. AIS parameters, average load mode before/after repairs

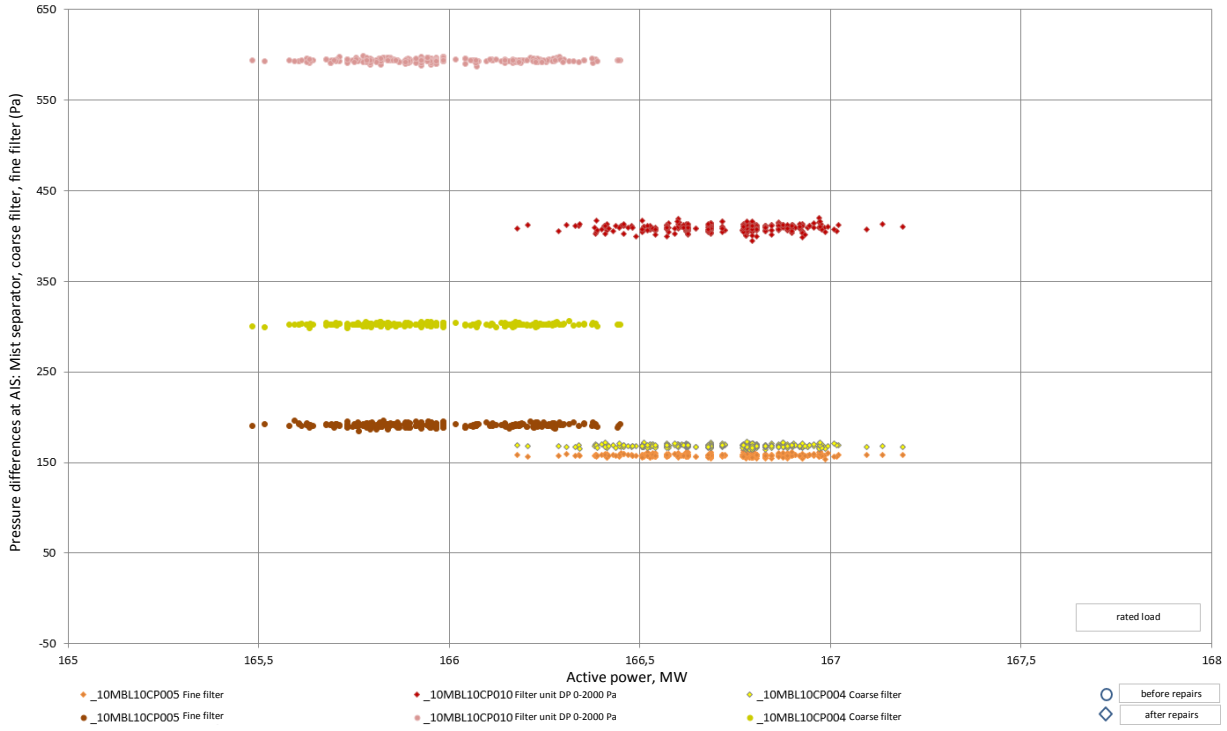

Fig.1.3. AIS parameters, nominal load mode before/after repairs

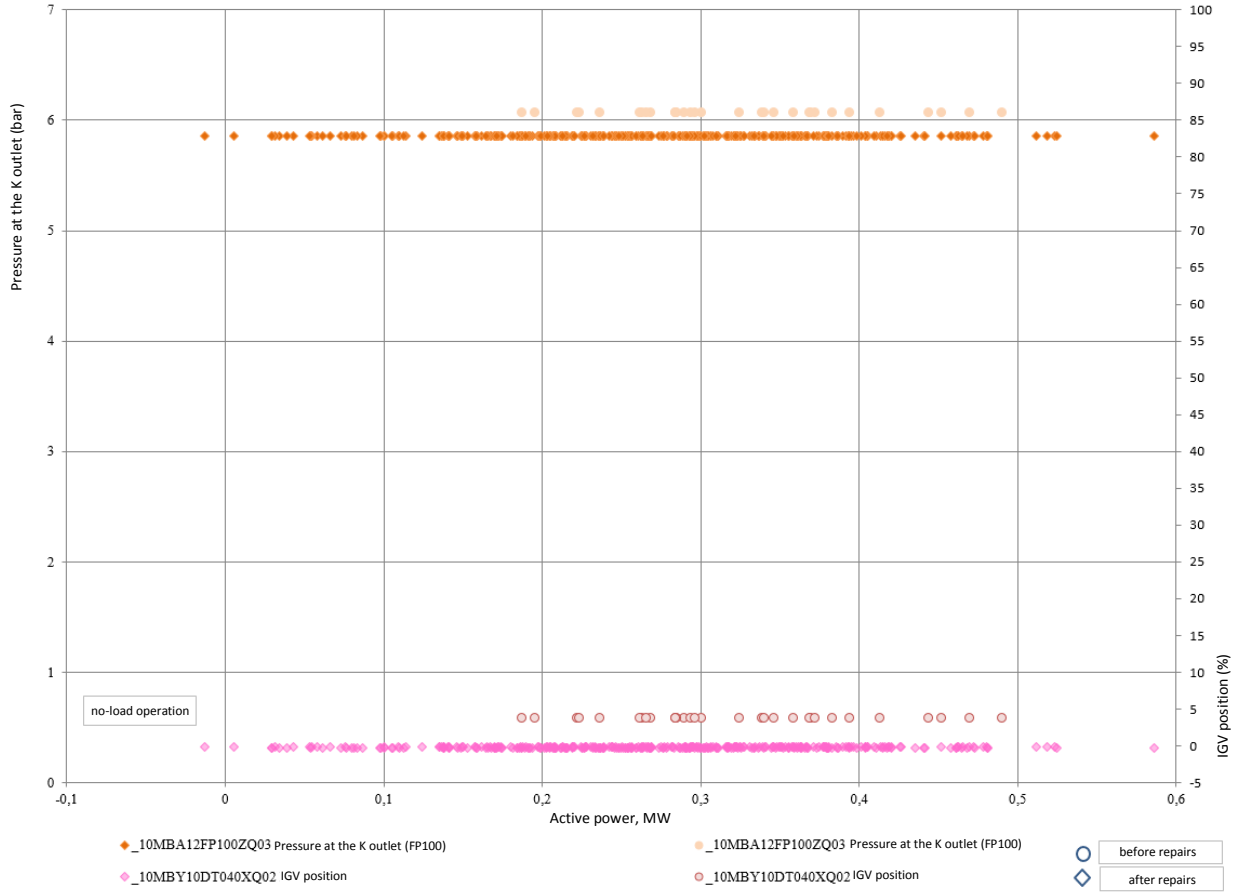

Fig. 2.1. Pressure at the compressor outlet, no-load operation before/after repairs

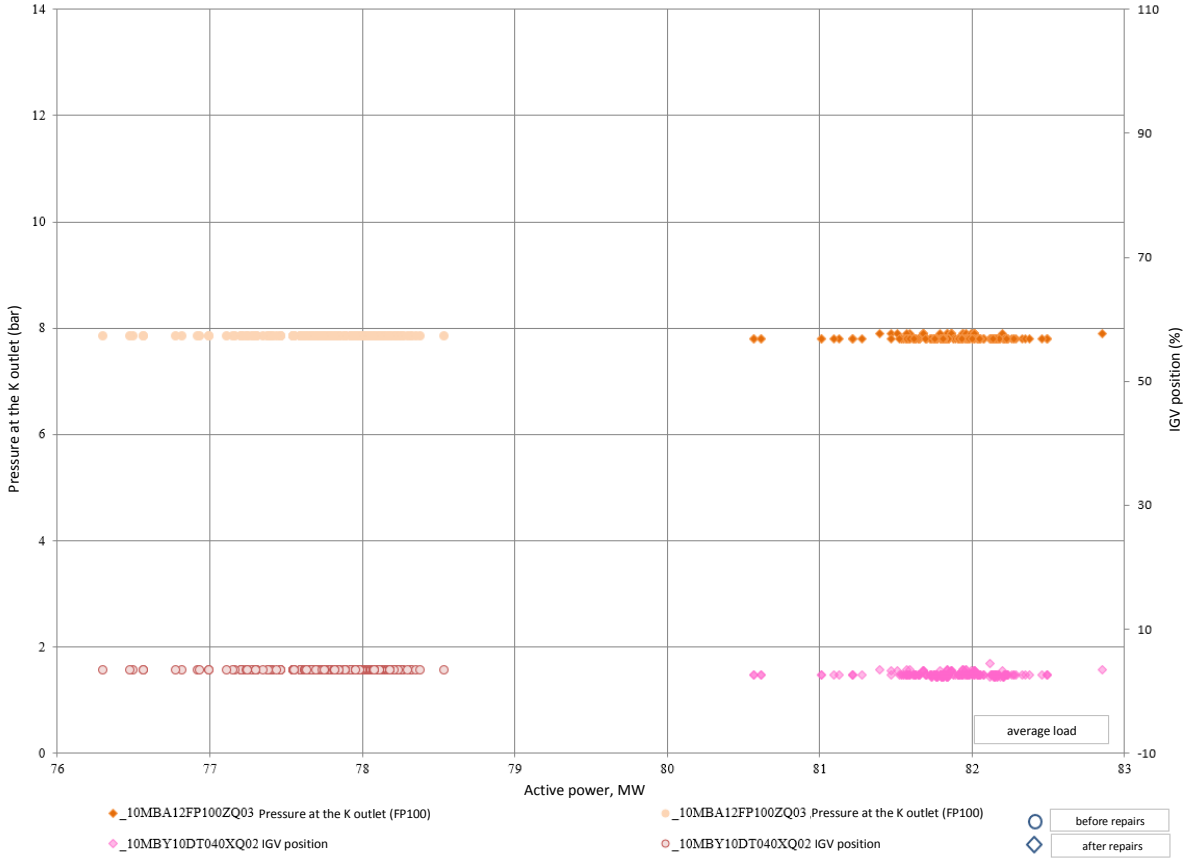

Fig. 2.2. Pressure at the compressor outlet, average load mode before/after repairs

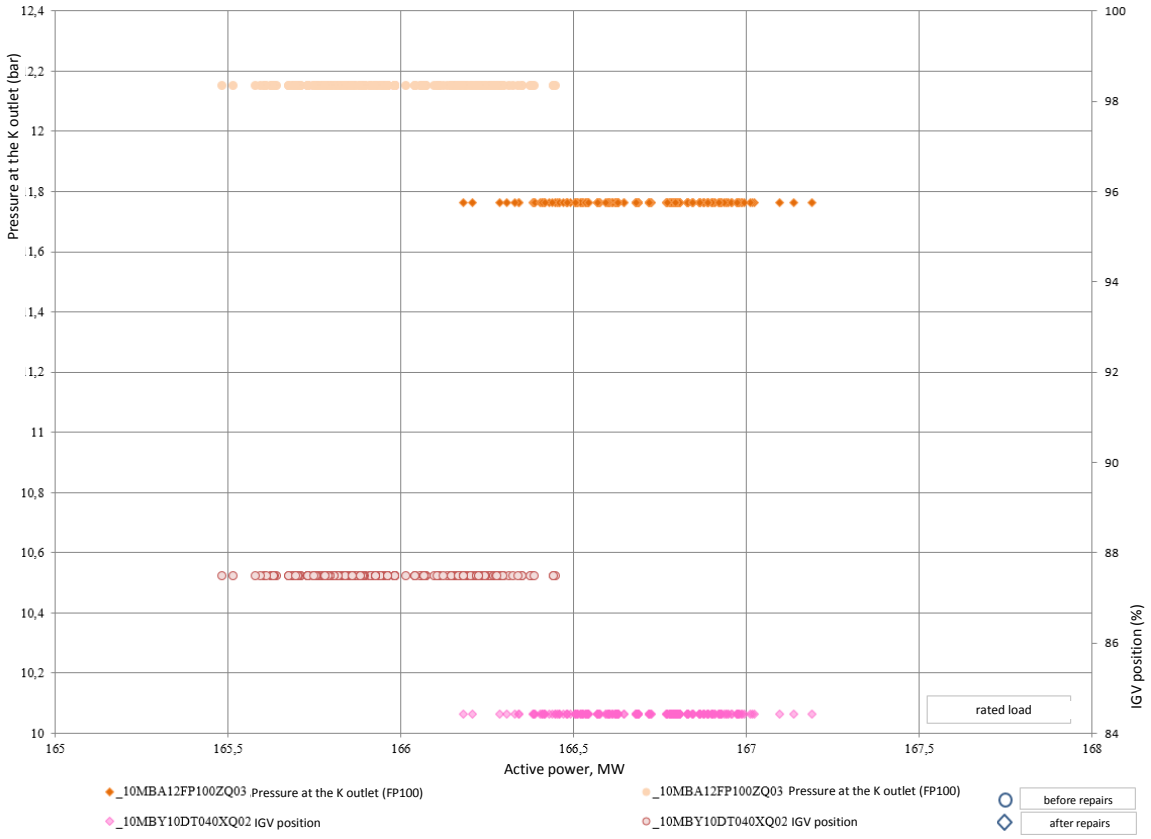

Fig. 2.3. Pressure at the compressor outlet, nominal load mode before/after repairs

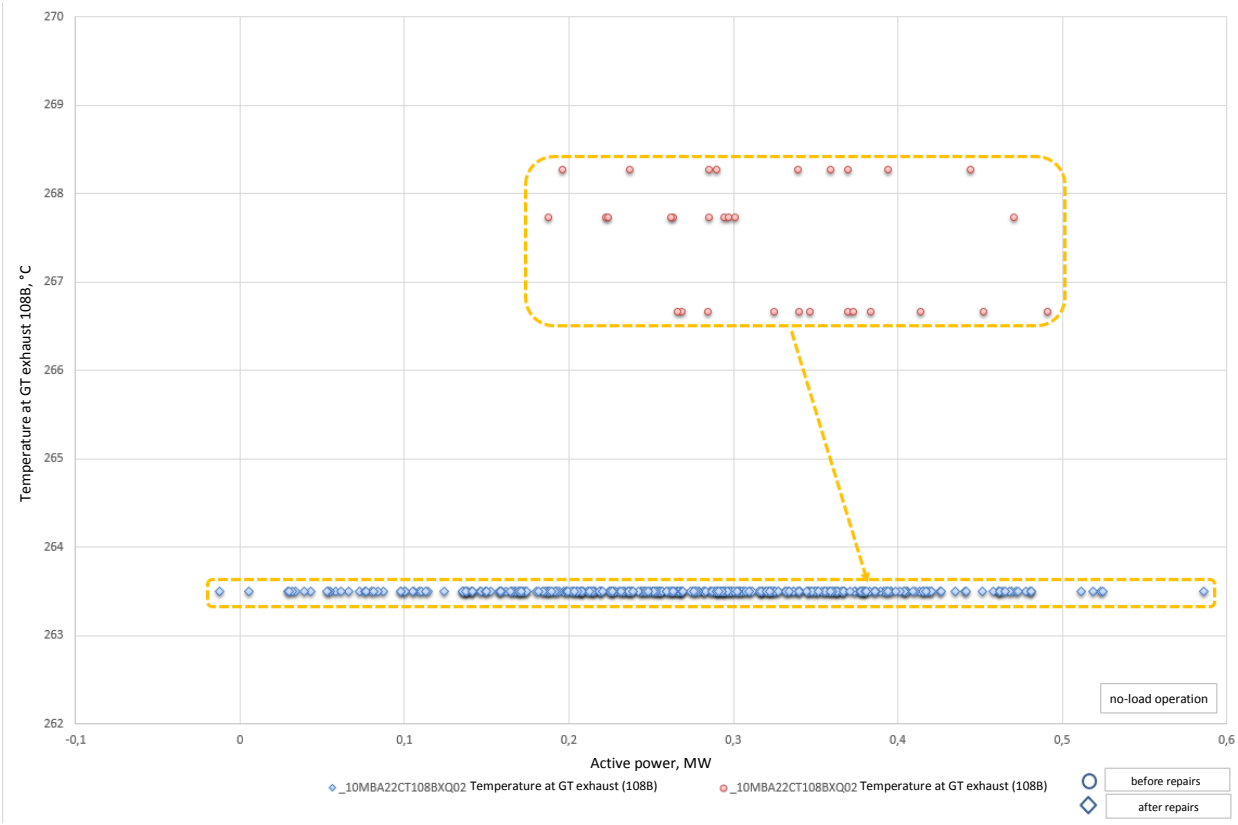

Fig.3.1. Temperature at GT exhaust 108B, no-load operation before/after repairs

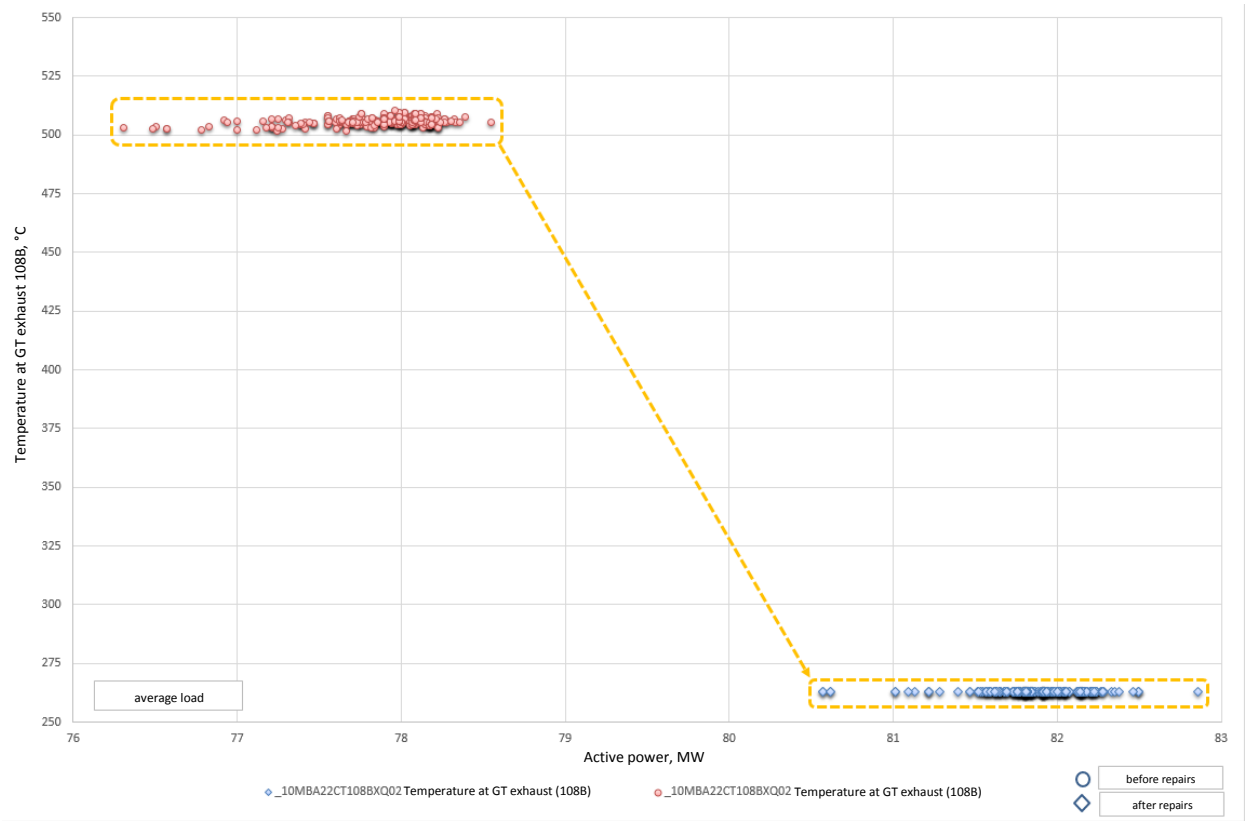

Fig. 3.2. Temperature at GT exhaust 108B, average load mode before/after repairs

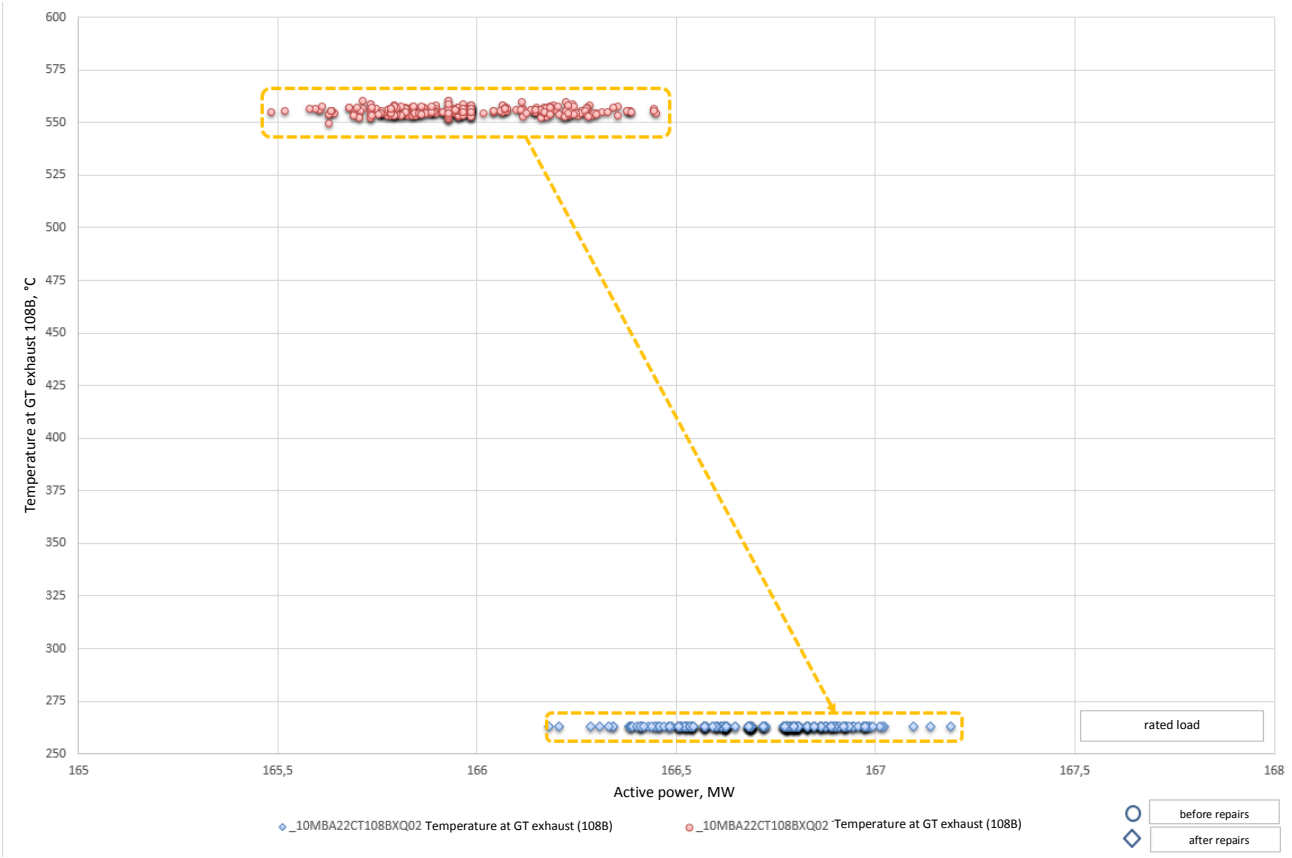

Fig. 3.3. Temperature at GT exhaust 108B, nominal load mode before/after repairs

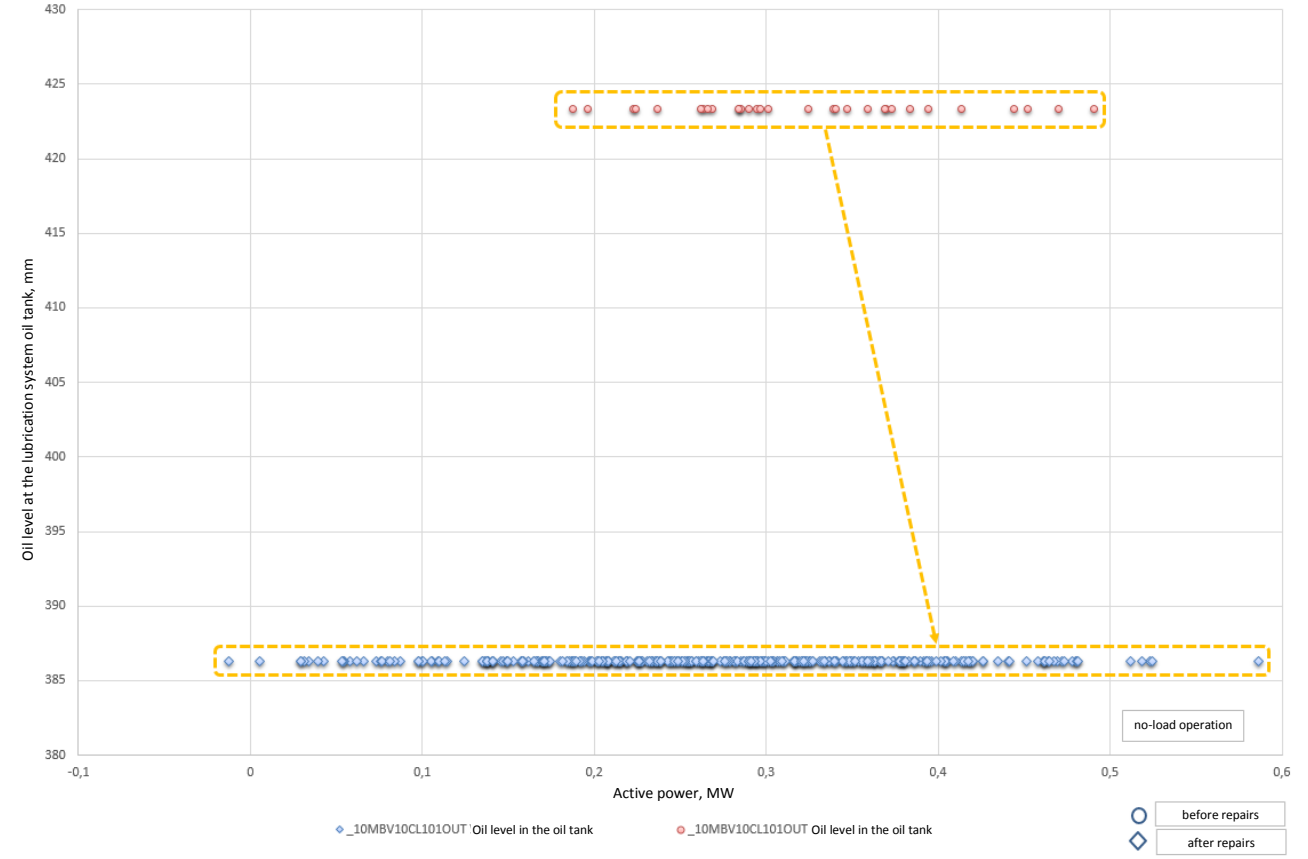

Fig. 4.1. Oil level in the oil tank, no-load operation before/after repairs

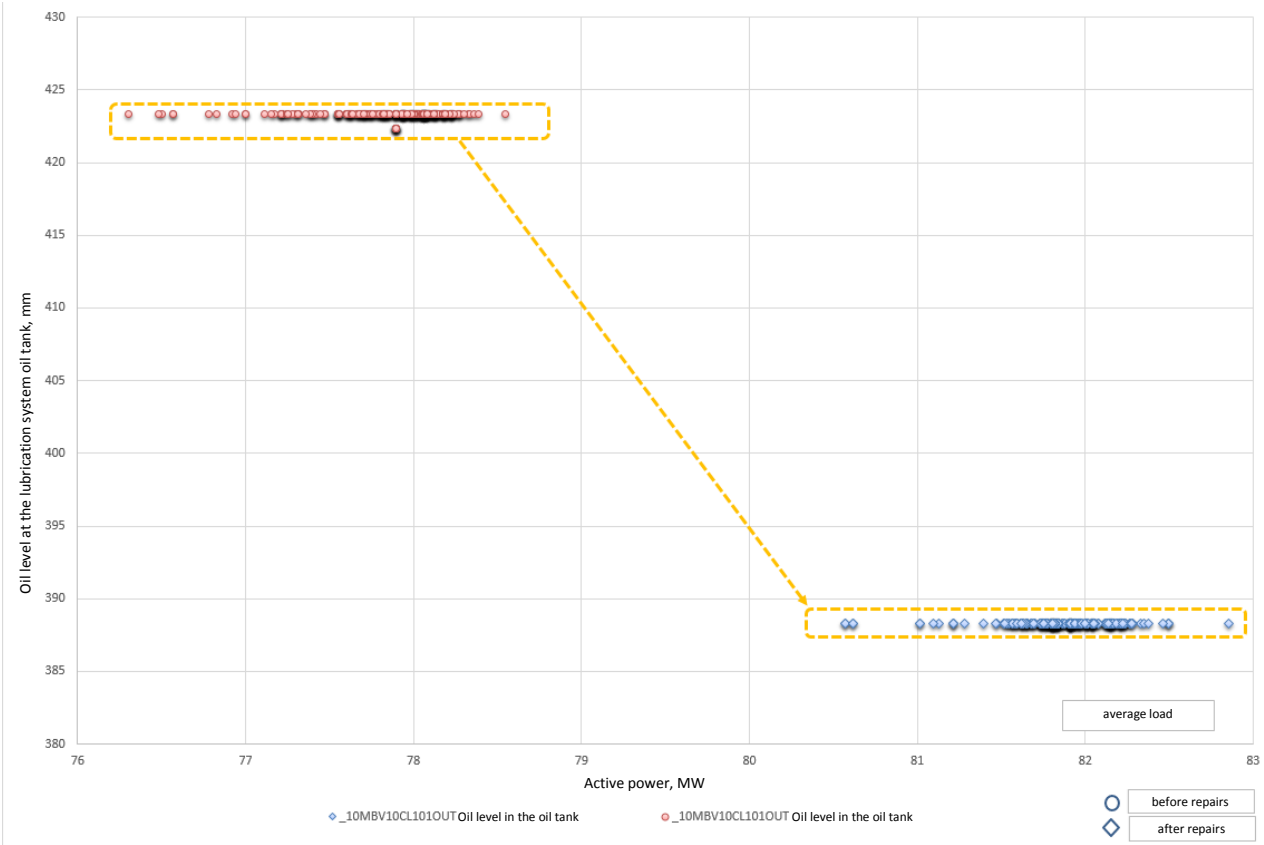

Fig. 4.2. Oil level in the oil tank, average load mode before/after repairs

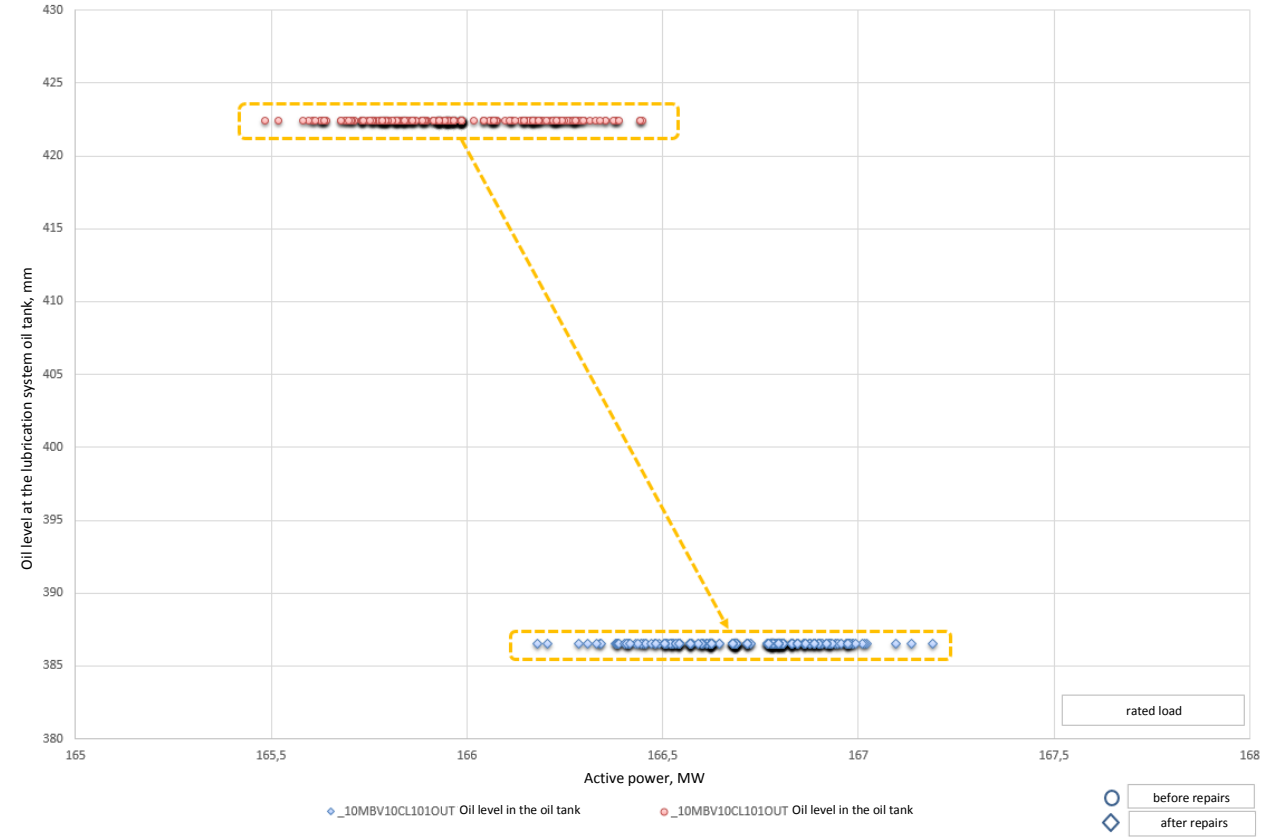

Fig. 4.3. Oil level in the oil tank, nominal load mode before/after repairs

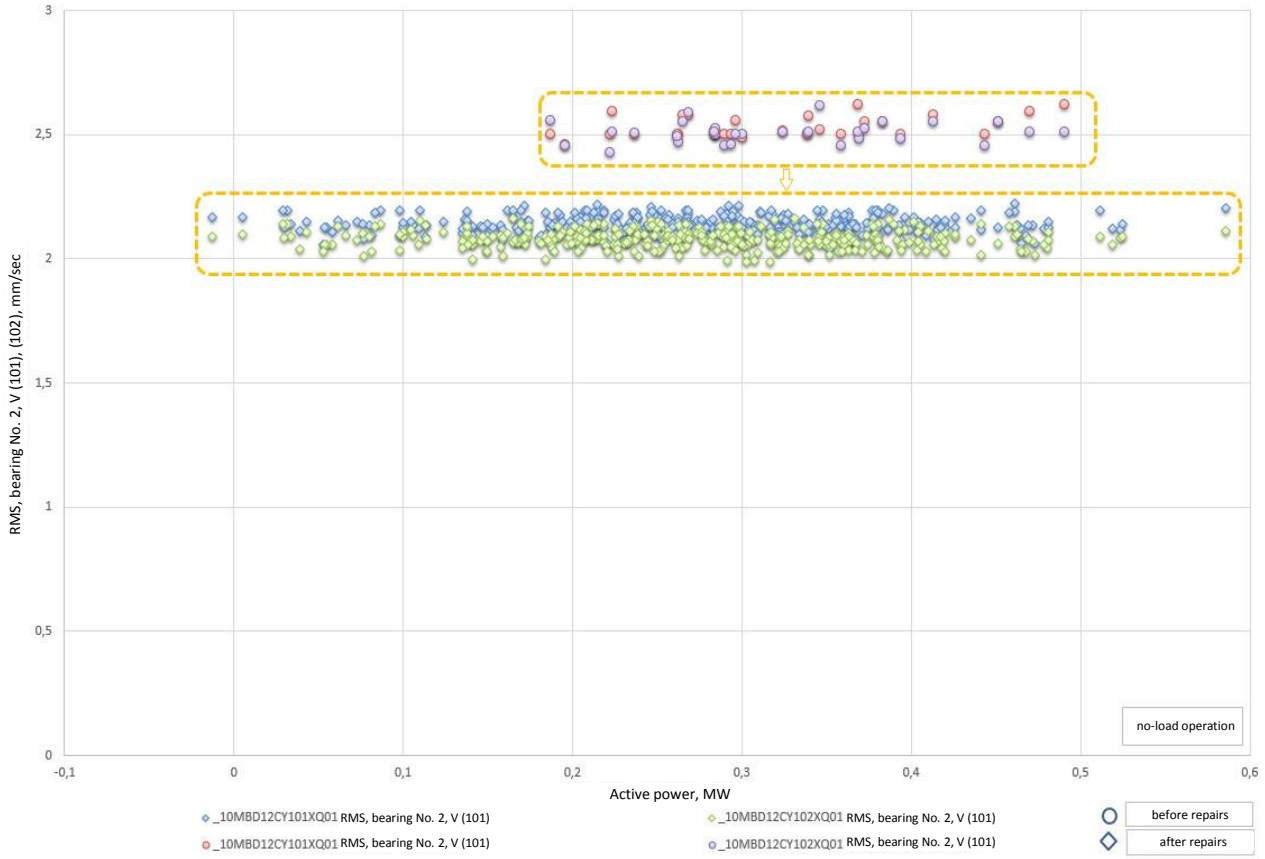

Fig. 5.1. RMS, bearing No. 2 (V), no-load operation before/ after repairs

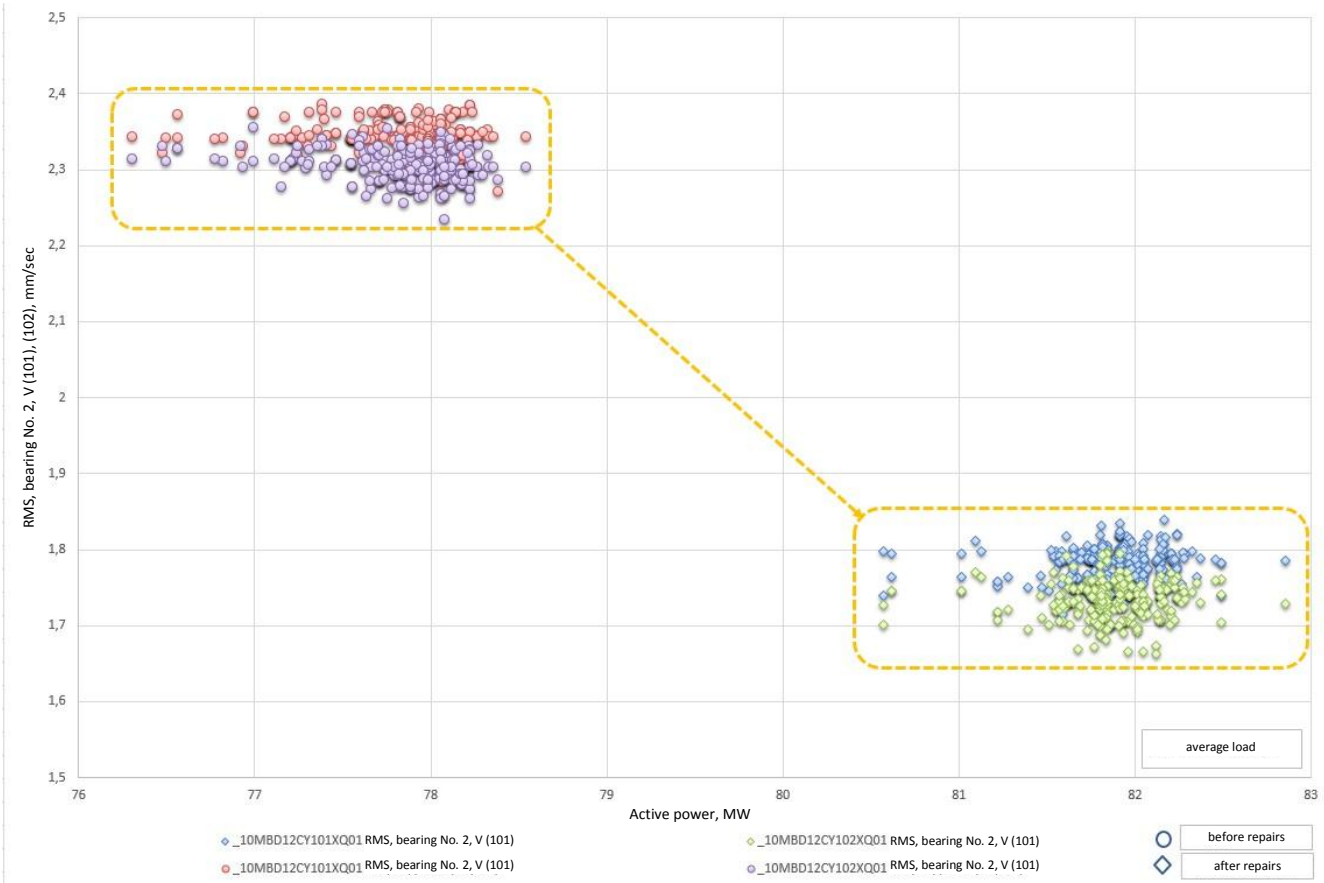

Fig. 5.2. RMS, bearing No. 2 (V), average load mode before/ after repairs

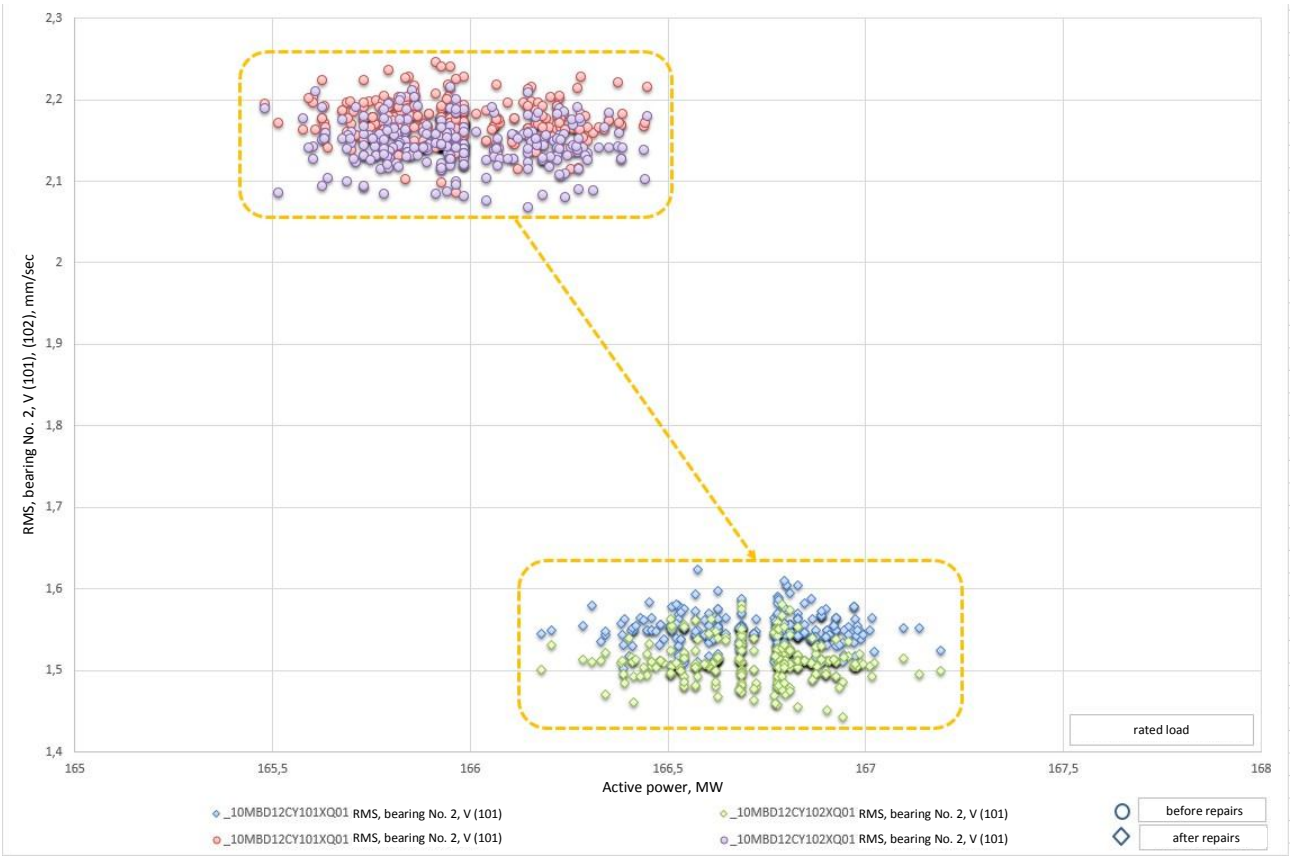

Fig. 5.3. RMS, bearing No. 2 (V), nominal load mode before/ after repairs

Fig. 6.1. Shaft vibration, bearing No. 2, No. 3, no-load operation before/after repairs

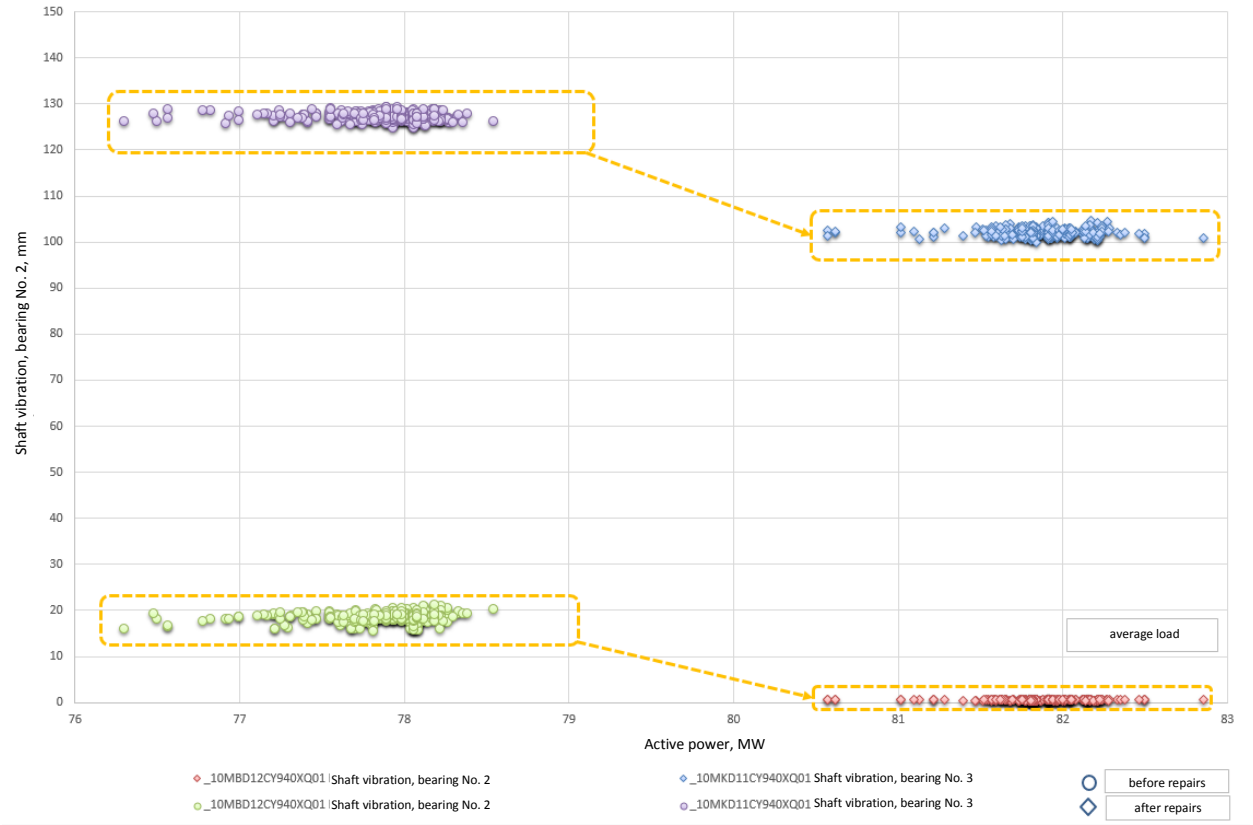

Fig. 6.2. Shaft vibration, bearing No. 2, No. 3, average load mode before/after repairs

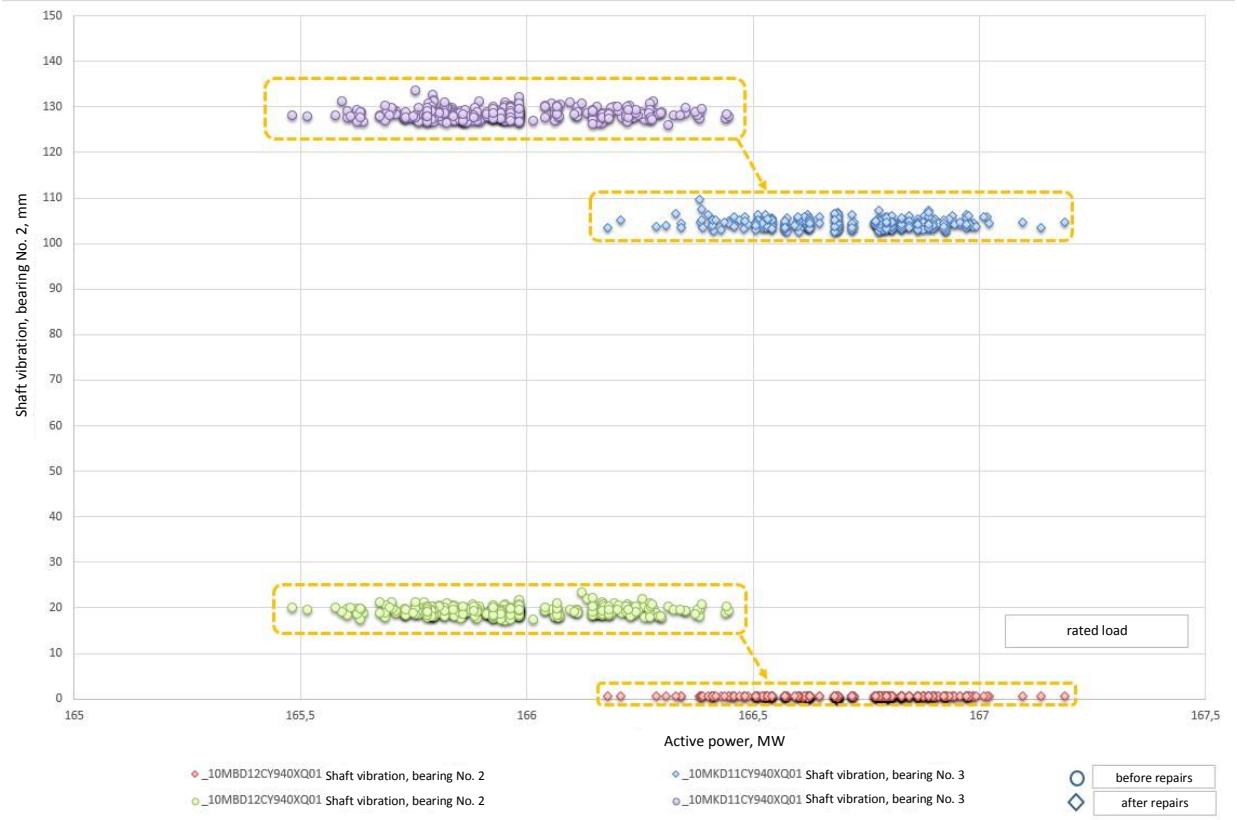

Fig. 6.3 Shaft vibration, bearing No. 2, No. 3, rated load mode before/after repairs

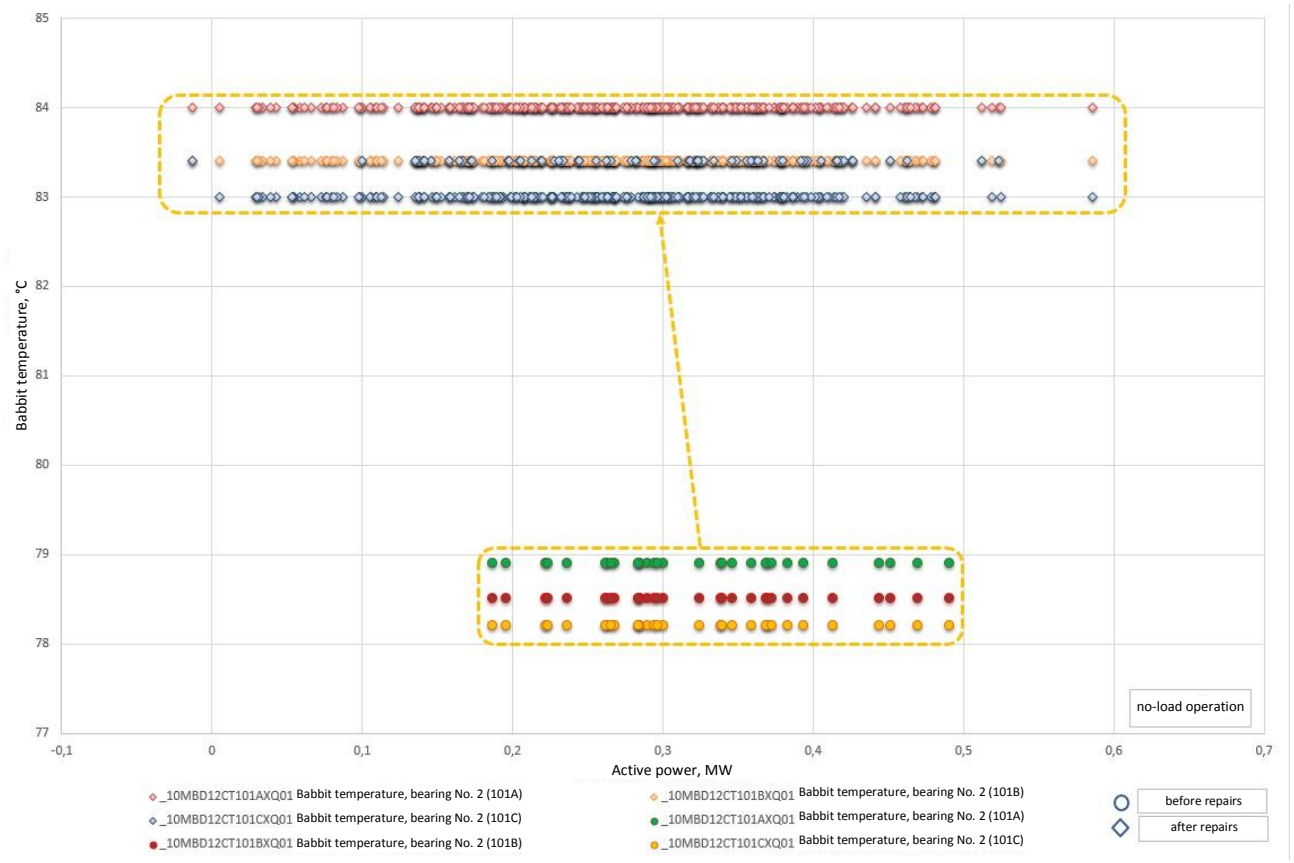

Fig. 7.1. Babbit temperature, bearing No. 2, no-load operation before/after repairs

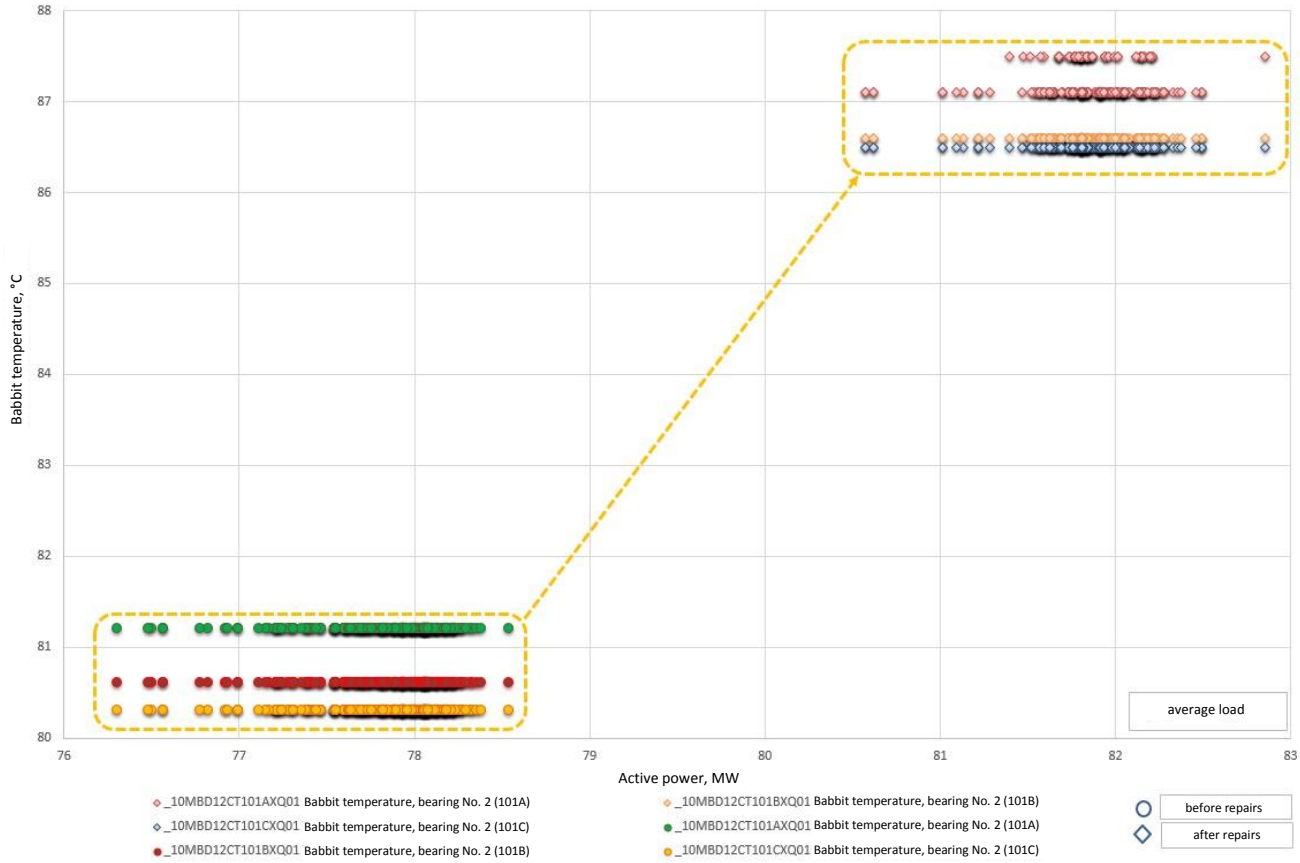

Fig. 7.2. Babbit temperature, bearing No. 2, average load mode before/after repair

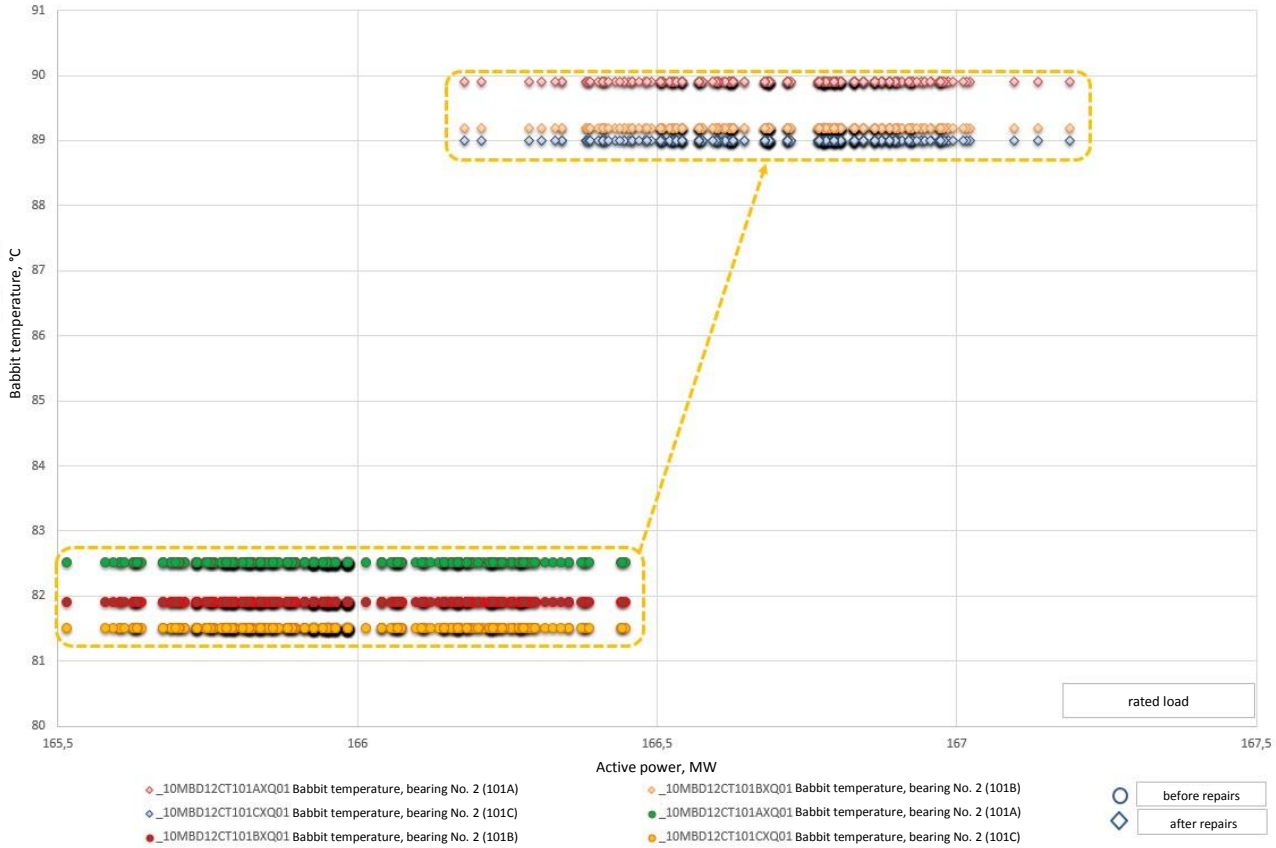

Fig. 7.3. Babbit temperature, bearing No. 2, nominal load mode before/after repair