Test protocol #768/020821-001

On workability check of high temperature strain gages on [redacted][1] LPT blades

(extract, translated to the English language)

Some content is hidden for confidentiality reasons: 1 – engine type, 2 – strain gage type (similar to HPM STN120-3AA-A900 type)

Test date August 2, 2021

Test #1

SG type: STN120-3AA-A900-N010-45

Strain gage installed with ceramic cement on a [redacted][1] LPT 3rd stage blade (installation sketch shown below).

SG resistance including lead wires is 140 Ohm (nominal 120 Ohm).

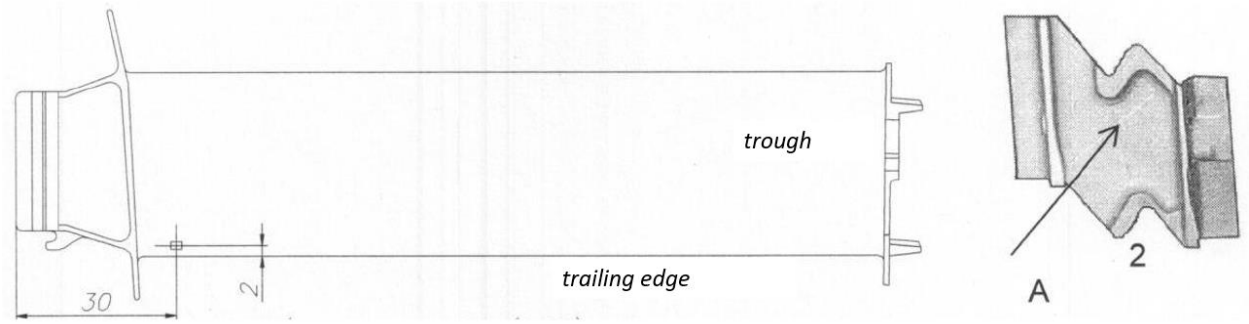

Figure 1. Installation of SGs on the blade

Blade #	σ_K, kgf/mm^2	f, Hz	Test time, min	N×10^6, cycles	Test results
AE0717 01-T	6	232	20	0,28	SG signal 400 mV, sine wave clear
	12	233	20	0,28	SG signal 740 mV – non-linearity compared to 6 kgf/mm^2, sine wave with a very little distortion

Test #2

SG type:

1. [redacted][2]
2. STN120-3AA-A900-N010-45

Strain gage installed with ceramic cement on a [redacted][1] LPT 1st stage blade (installation sketch shown below).

SG resistance including lead wires is:

1. 143 Ohm (nominal 120 Ohm);
2. 131 Ohm (nominal 120 Ohm).

Test is carried out using vibration test system TV 5220. Calibration coefficient: 1 MPa = 0,0247 mm

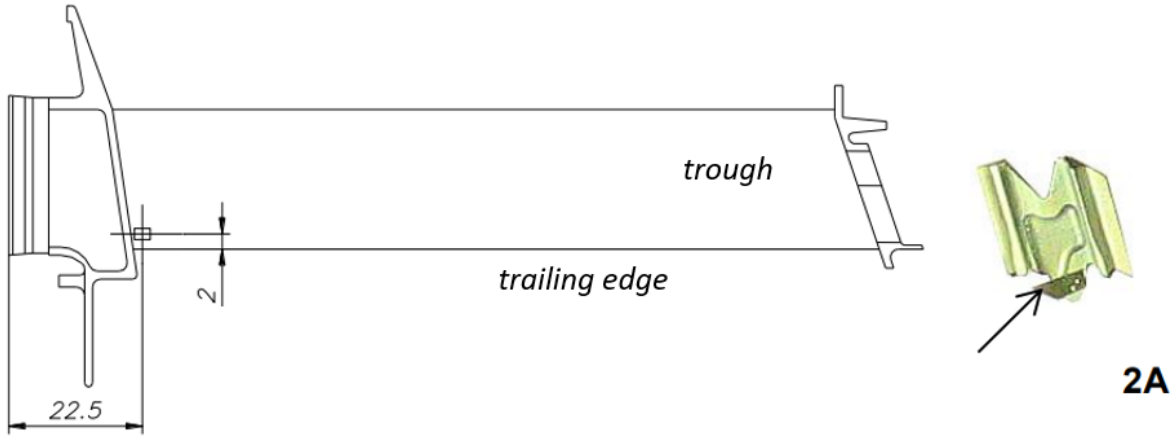

Figure 2. Installation of SGs on the blade

Blade #	σ_K, MPa	Swing, mm	f, Hz	Test time, min	N×10^6, cycles	SG signal, mV	Test results
1. [redacted][2]							
1 AE158 094-8	60	1,48	270	10	0,16	980	sine wave clear
	80	1,98		10		1300	after 5 minutes sine wave slightly distorted
	100	2,47		9	0,15	1450	worked for 9 minutes until out of service – no sine wave, R_{SG} = 153 Ohm

Blade #	σ_K, MPa	Swing, mm	f, Hz	Test time, min	N×10^6, cycles	SG signal, mV	Test results
2. STN120-3AA-A900-N010-45							
2 AE151 825-6	60	1,48	269	10	0,16	1750	sine wave clear
	80	1,98				2350	
	100	2,47				2900	
	120	2,96	268			3400	
	140	3,46		2		3950	worked for 2 minutes until out of service – no sine wave, R_{SG} = 1098 Ohm

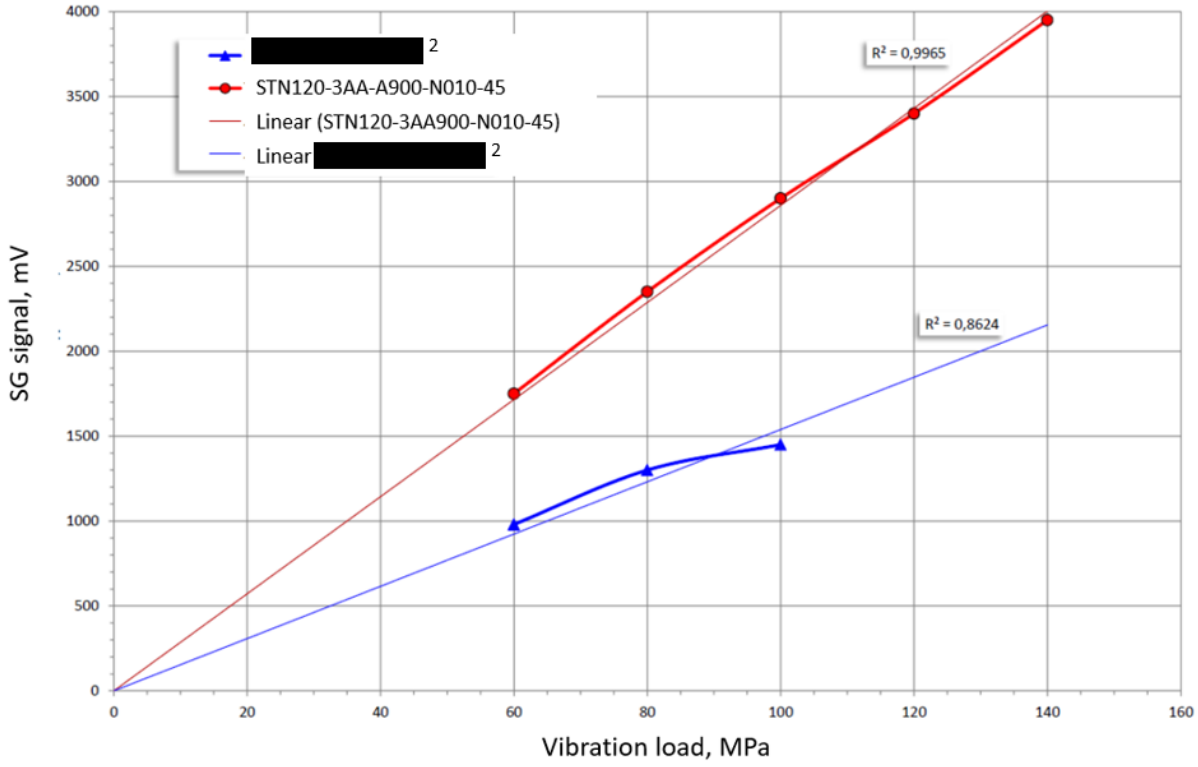

Figure 3. Dependance of SG signal from the vibration load signal (trend lines with approximation confidence value R^2 are given)

End of test protocol

To check the non-linearity issue, HPM performed an internal test of the gages from the same batch using KGU-3M tuning fork calibration device.

Strain gages are installed on tuning forks #23/24 made of 40HNMA steel (DIN 1.6511) using Hitec HG-1 ceramic cement. Odd prong: STN120-3AA-A900-N010-45 (same type as in test protocol #768/020821-001), V1 and V2 signals in the graph; even prong: STF120-3AA-A900-F010-45 (similar configuration, used for reference), V3 and V4 signals in the graph.

Test results

Maximum amplitude reachable in KGU-3M tuning fork device is 2,5 mm, which corresponds to strain amplitude in the SG location ~160 MPa.

Waveforms and SG signal spectra at tuning fork oscillation amplitude 2,5 mm are shown in figures 4 and 5. As seen from figures 4 and 5, SG signals are clear sine waves, without distortions. The same can be observed at lower amplitudes.

Dependance of SG signal from tuning fork oscillation is shown in figure 6. As seen in figure 6, SGs on tuning fork 23/24 have linear amplitude characteristic.

At maximum tuning fork oscillation amplitude of 2,5 mm all SGs worked for approximately 15 minutes.

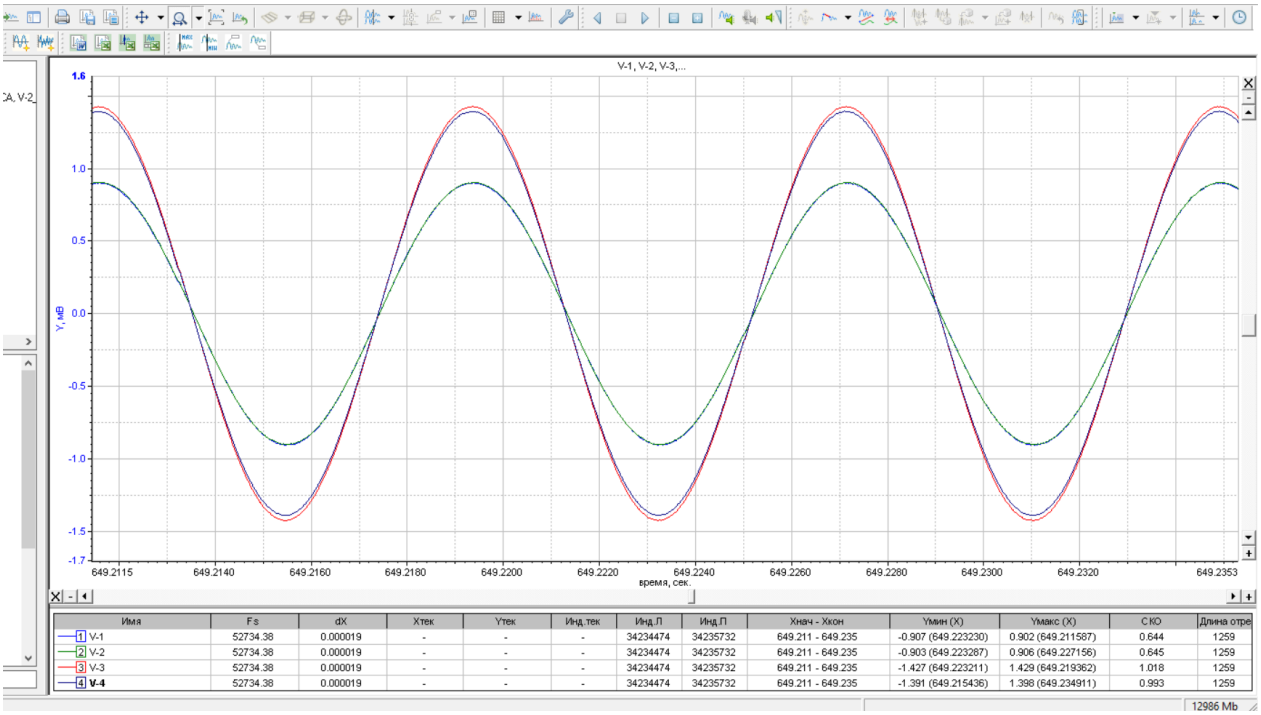

Figure 4. V1, V2, V3, V4 signals waveforms at tuning fork oscillation amplitude of 2,5 mm

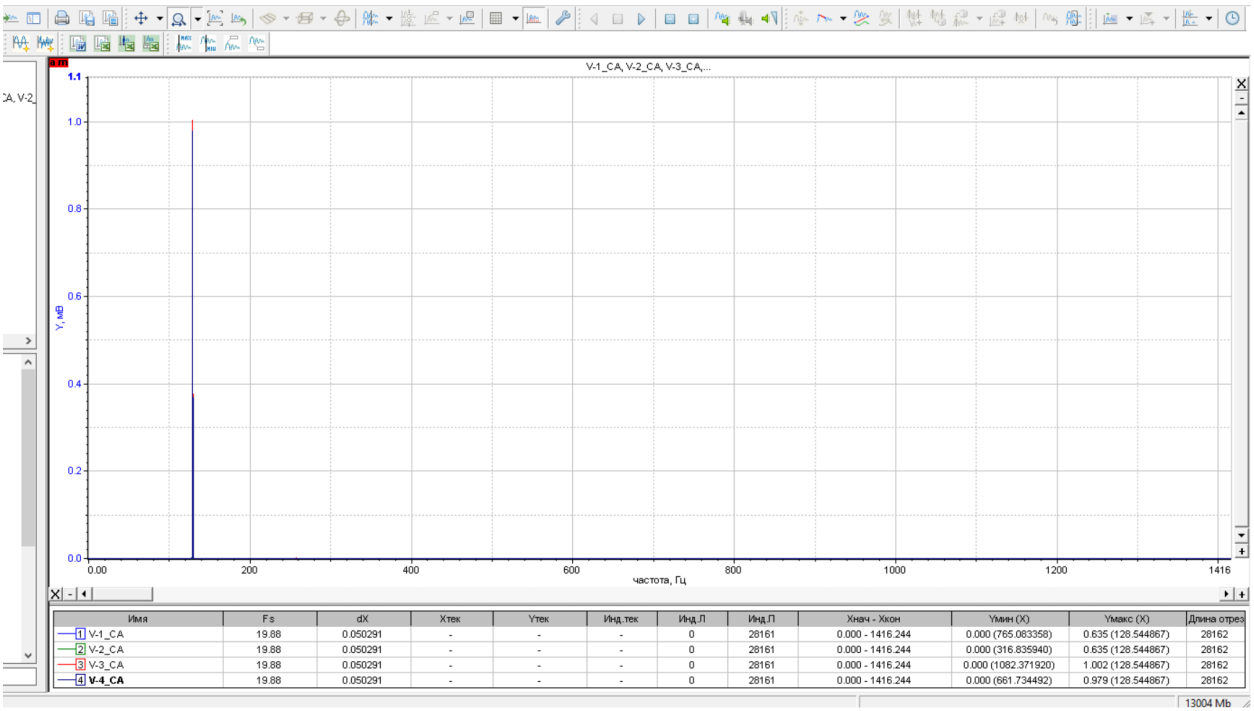

Figure 5. V1, V2, V3, V4 signals spectra at tuning fork oscillation amplitude of 2,5 mm

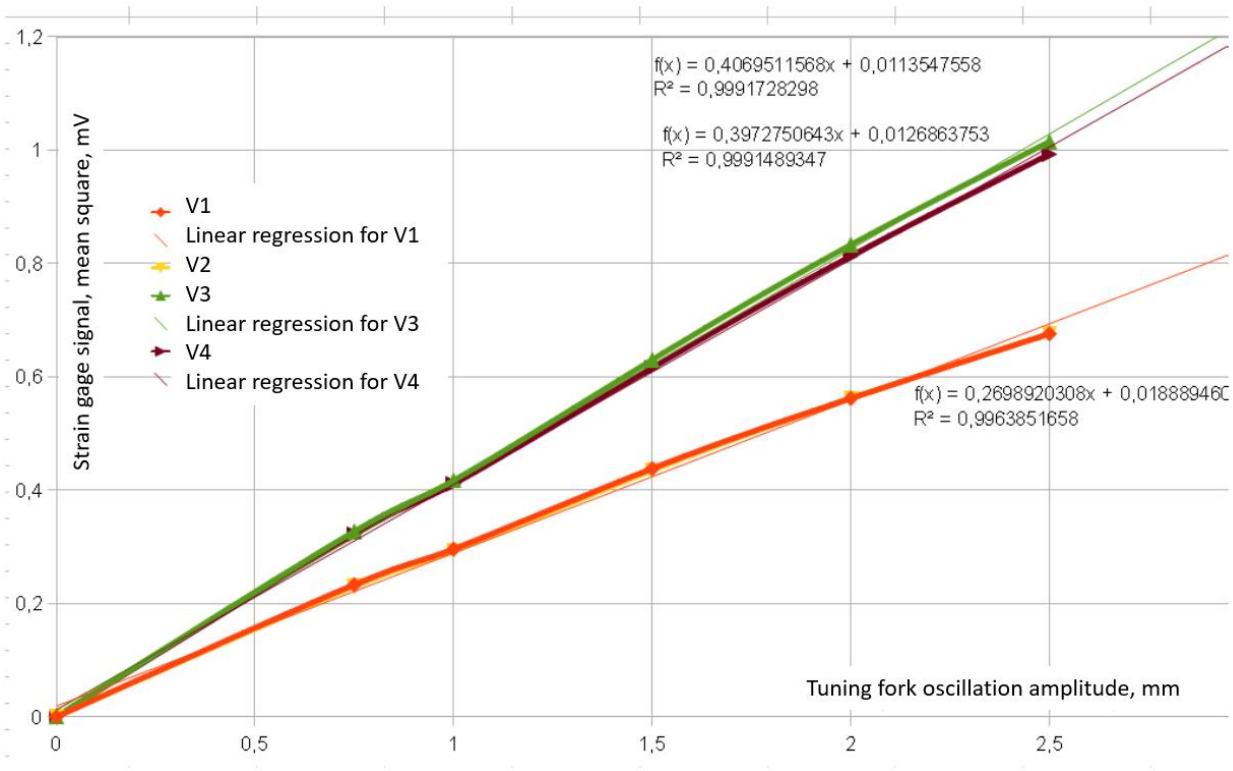

Figure 6. Strain gage signal dependance on tuning fork oscillation amplitude (V1, V2, V3, V4)