Anisotropic fracture toughness properties of a Nitronic 50 forging at 4.2 K

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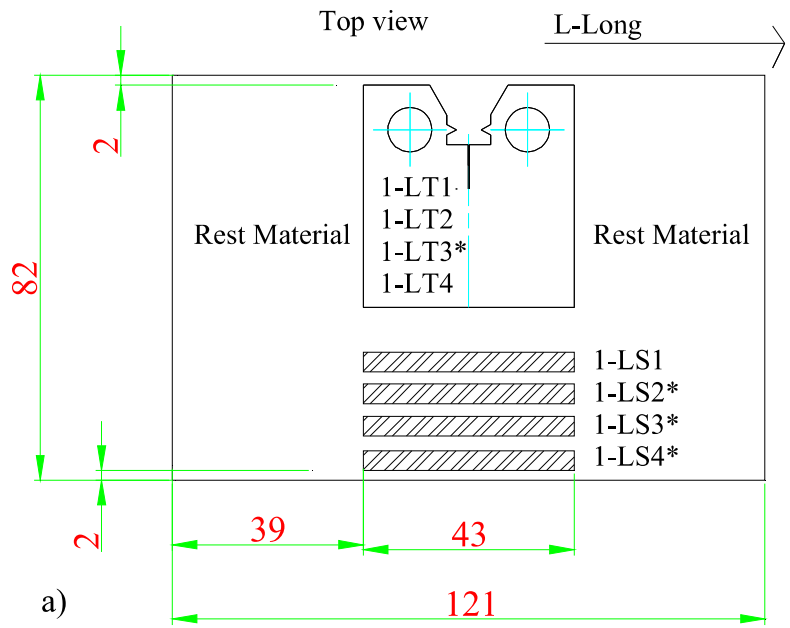
Motivation

- Fracture toughness measurements (ASTM 1820) on forged Nitronic 50 material at 4.2 K



E Young modulus
W width of specimen (36 mm)
B_e effective specimen thickness (4 mm)
a_i crack length (20-23 mm)

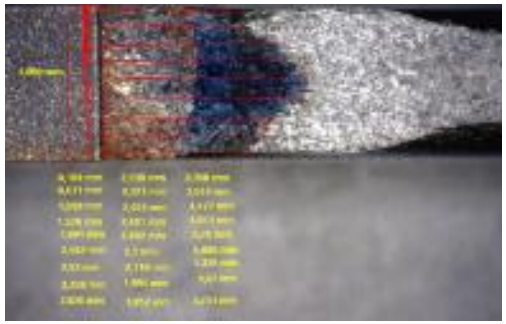
$$C_{LL(i)} = \frac{1}{EB_e}\left(\frac{W + a_i}{W - a_i}\right)^2 \left[2.1630 + 12.219\left(\frac{a_i}{W}\right) - 20.065\left(\frac{a_i}{W}\right)^2 - 0.9925\left(\frac{a_i}{W}\right)^3 + 20.609\left(\frac{a_i}{W}\right)^4 - 9.9314\left(\frac{a_i}{W}\right)^5\right] \qquad \text{(A2.10)}$$

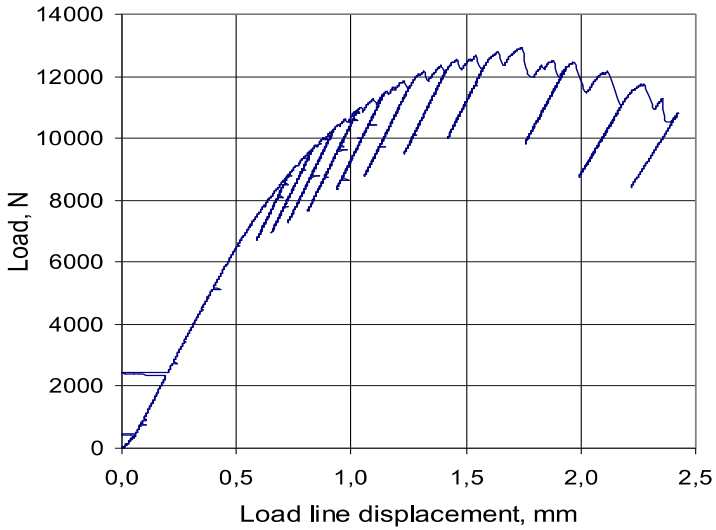
Motivation

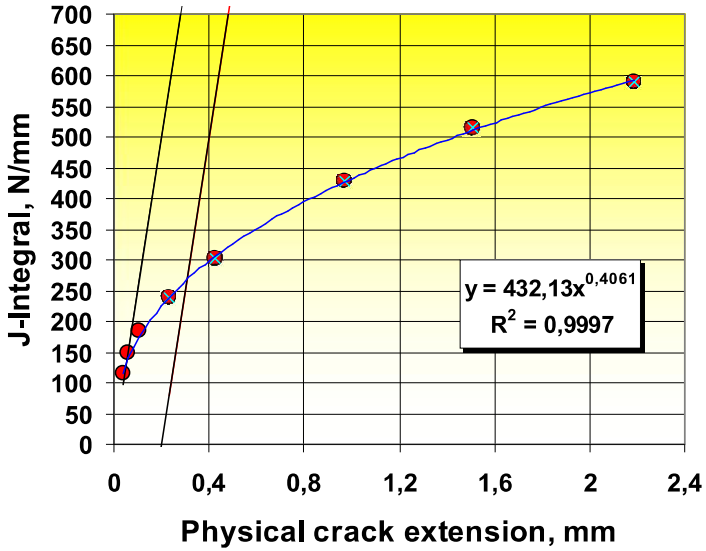
- Fracture toughness measurements (ASTM 1820) on forged Nitronic 50 material at 4.2 K

Result of LT3 direction specimen

J_q = 270 N/mm
K_{IC} = 235 MPa $m^{1/2}$



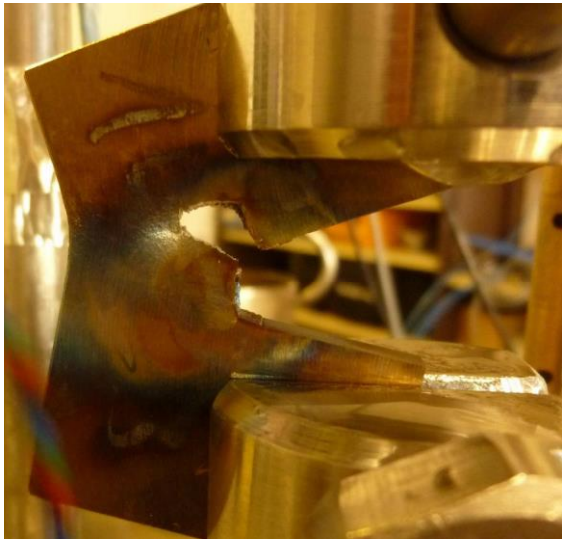


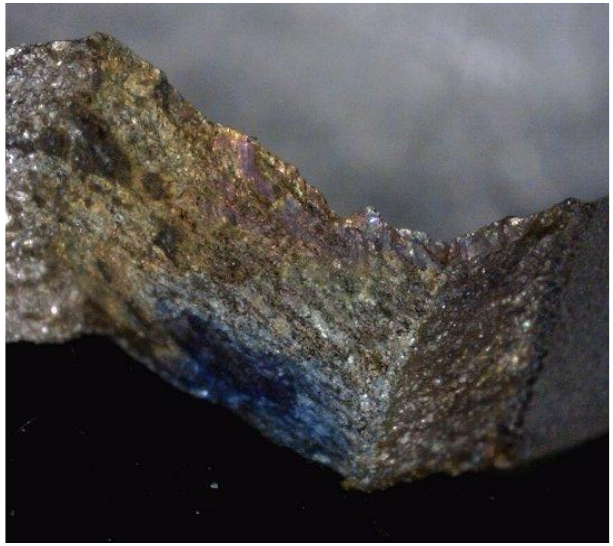


Motivation

- Fracture toughness measurements (ASTM 1820) on forged Nitronic 50 material at 4.2 K

  Result of LS direction specimen → 90° crack propagation for J-test



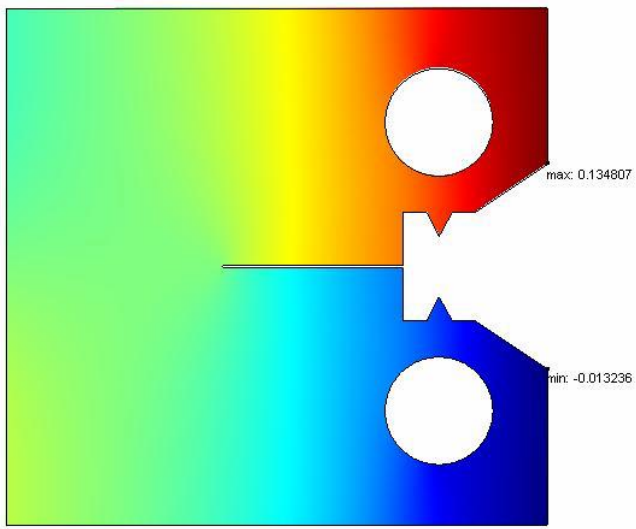


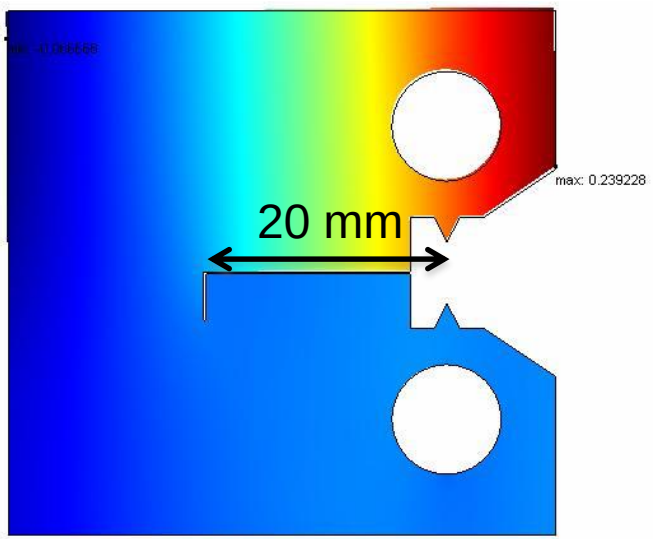
- 0° compliance function not applicable

  → necessary to define a 90° compliance

Compliance by FEM

- Modelling of crack opening at 2 kN loading of different crack lengths in 0° and 90° direction





a (0°) = 18 to 23 mm

a (0°) = 20 mm
a (90°) = 1 to 6 mm

Compliance by FEM

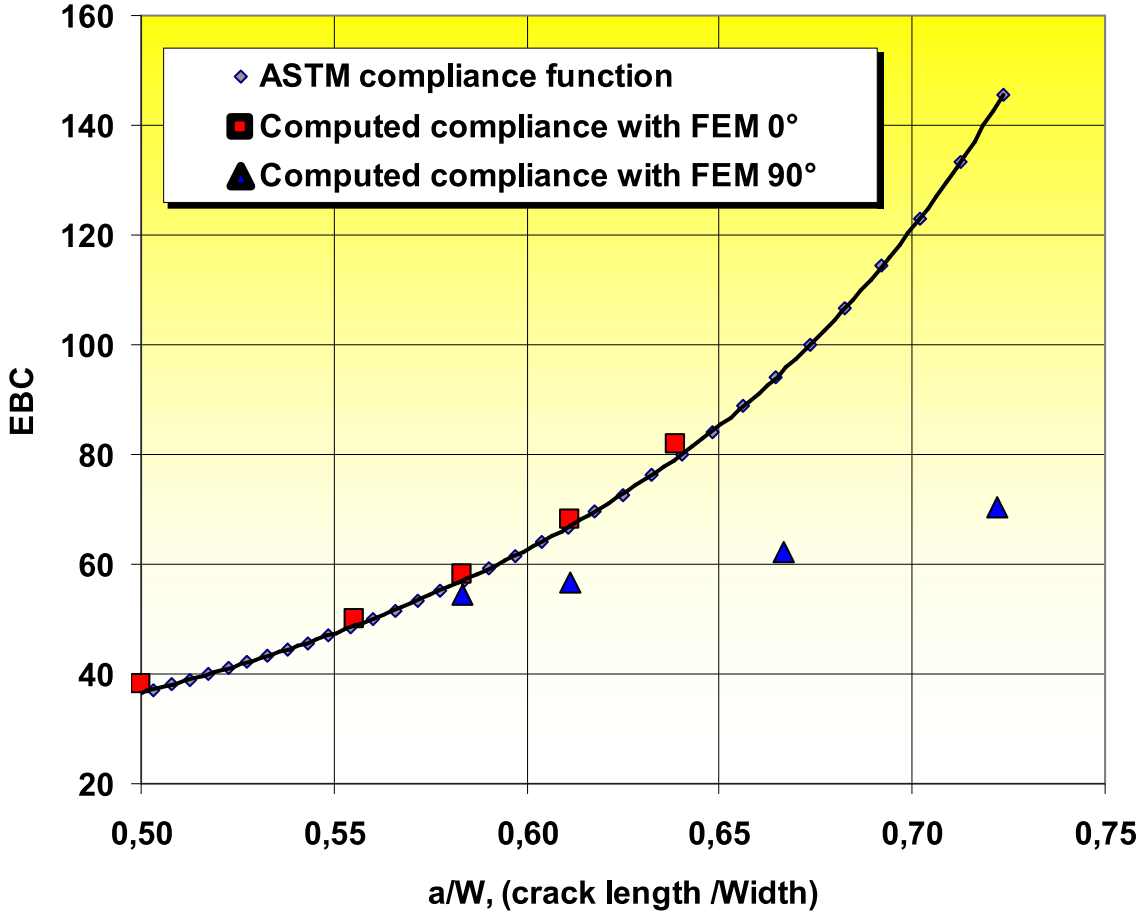
- Modelling of crack opening at 2 kN loading of different crack lengths in 0° and 90° direction

crack plane	a	a/W	disp, LL, mm	Stiff. N/mm	Compl. mm/N	EBC
0° plane	18	0,500	0,095	21053	4,750E-05	38,00
	20	0,556	0,125	16000	6,250E-05	50,00
	21	0,583	0,145	13793	7,250E-05	58,00
	22	0,611	0,170	11765	8,500E-05	68,00
	23	0,639	0,205	9756	1,025E-04	82,00
90° plane (20 mm 0° following this 90° in steps of 1, 2, 4, and 6 mm)	21	0,583	0,136	14706	6,800E-05	54,40
	22	0,611	0,142	14085	7,100E-05	56,80
	24	0,667	0,156	12821	7,800E-05	62,40
	26	0,722	0,176	11364	8,800E-05	70,40

E Youngs Modulus
B specimen thickness
C compliance

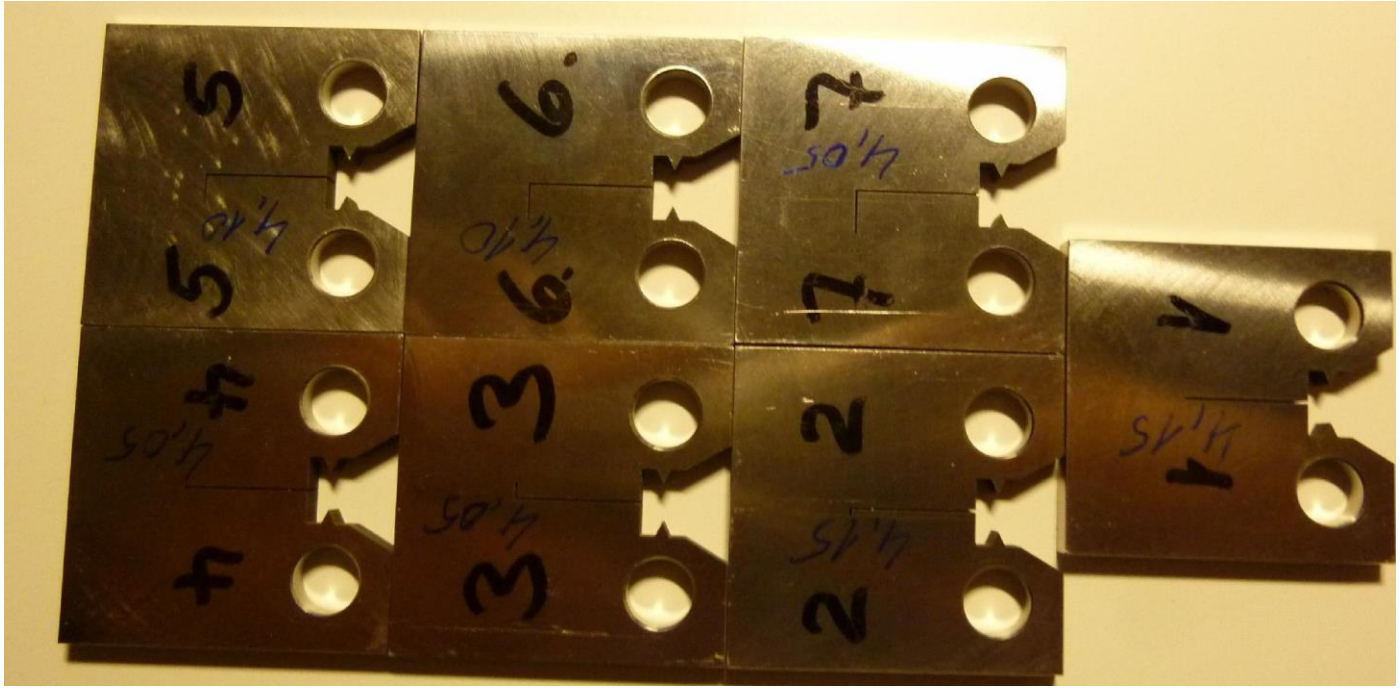
Compliance by FEM

- Comparison of EBC values from ASTM and FEM of different crack lengths in 0° and 90° direction



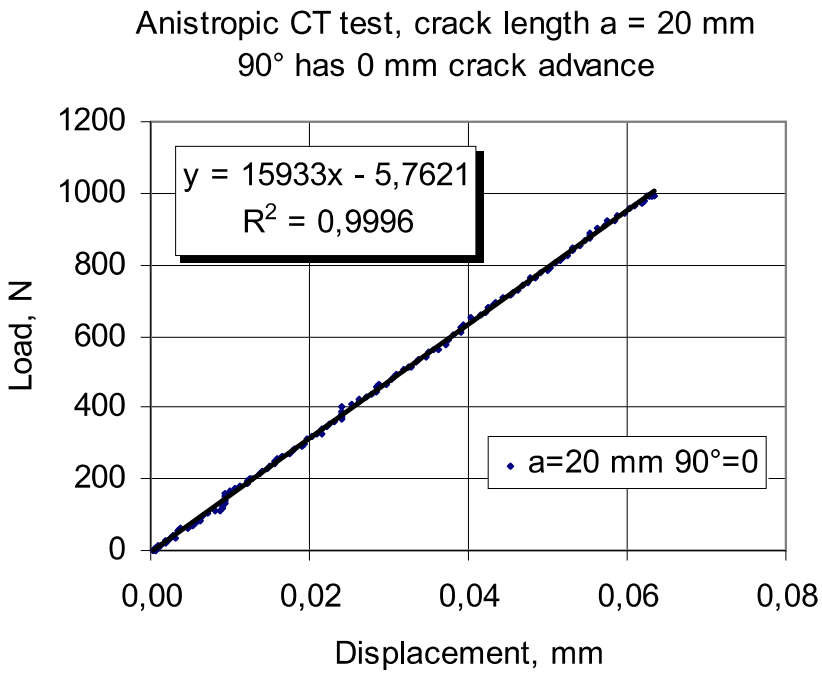
Compliance by Measurement

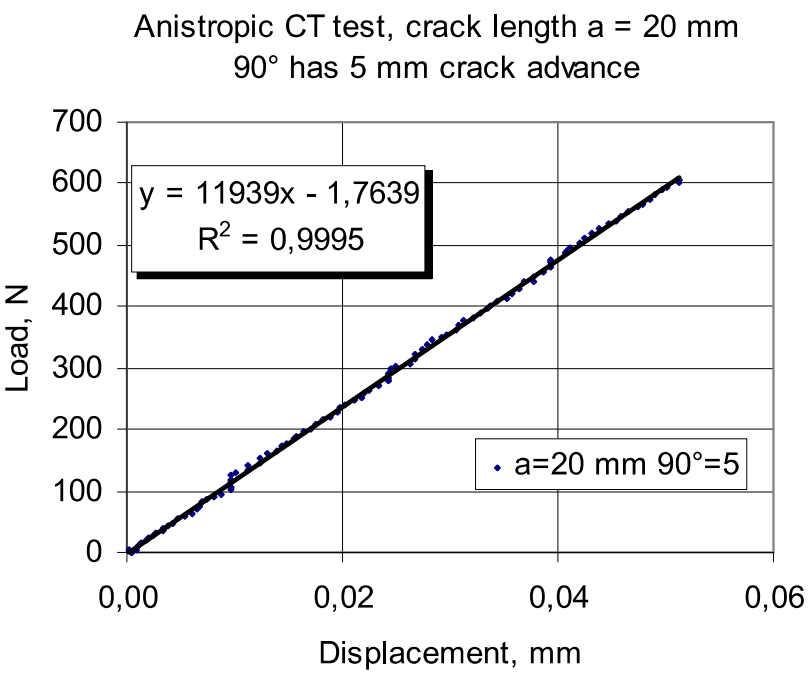
- Measure crack opening at 1 kN loading at RT of different crack lengths in 0° and 90° direction



Compliance by Measurement

- Measure crack opening at 1 kN loading at RT of different crack lengths in 0° and 90° direction





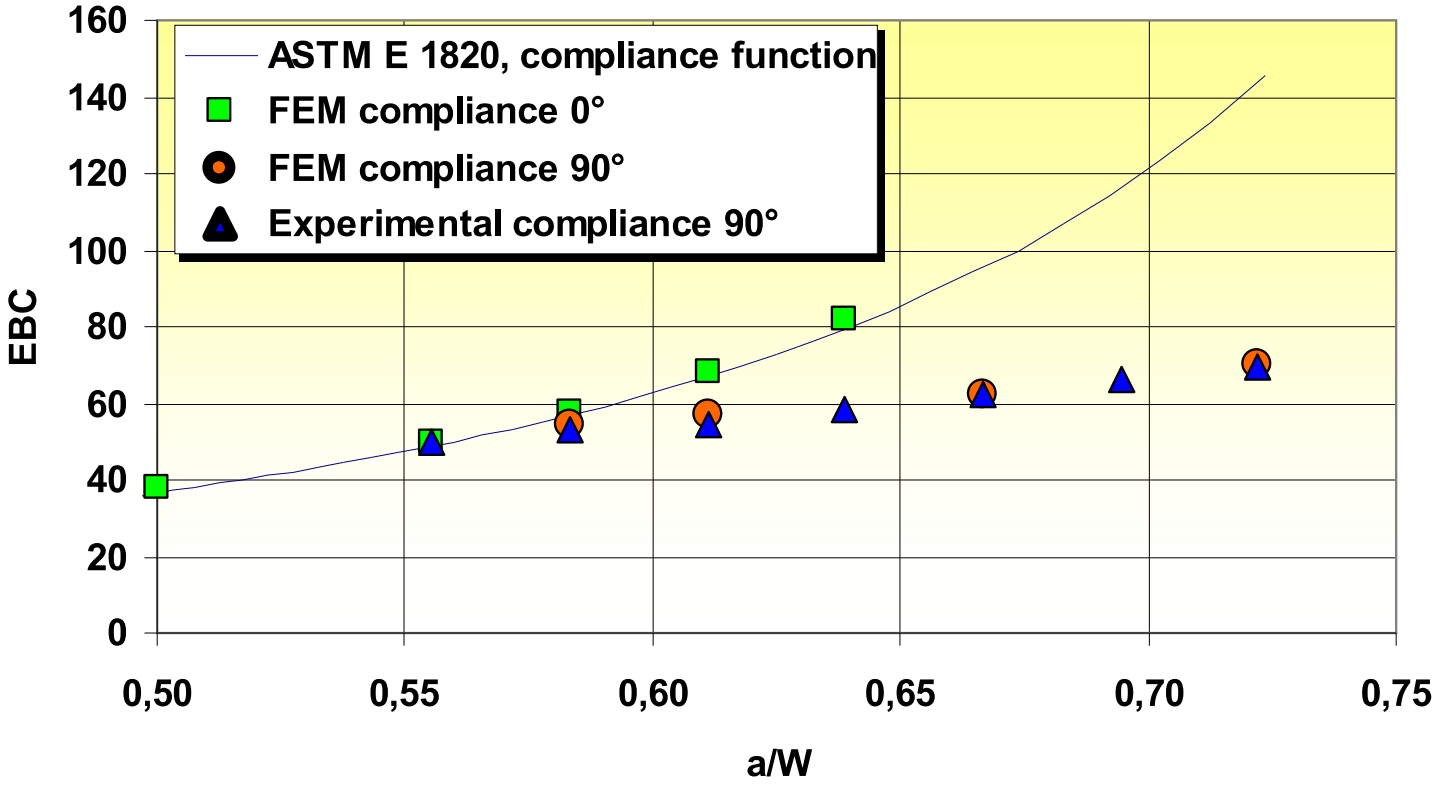
Compliance by Measurement

- Measure crack opening at 1 kN loading at RT of different crack lengths in 0° and 90° direction

Experimental compliance on March 12, 2014					
a, mm	B, mm	S, kN/mm	C, mm/N	EBC	a/W
0	4,15	15,933	6,27628E-05	50,0094	0,5555
1	4,15	15,009	6,66267E-05	53,0881	0,5833
2	4,05	14,239	7,02297E-05	54,6106	0,6111
3	4,05	13,275	7,53296E-05	58,5763	0,6389
4	4,10	12,661	7,89827E-05	62,1752	0,6666
5	4,10	11,939	8,37591E-05	65,9352	0,6944
6	4,05	11,139	8,97747E-05	69,8088	0,7222

Comparison of FEM and Measurement

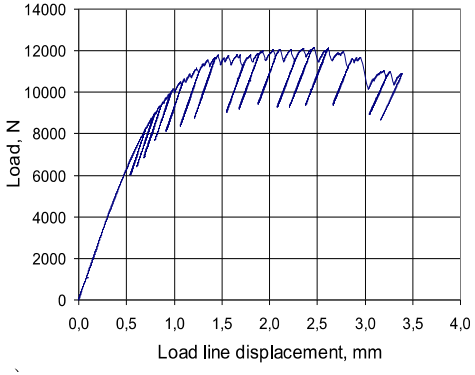
- Measure crack opening at 1 kN loading at RT of different crack lengths in 0° and 90° direction



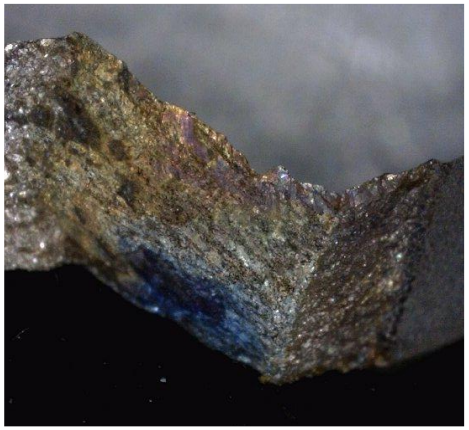
Evaluation of 90° K_{IC}

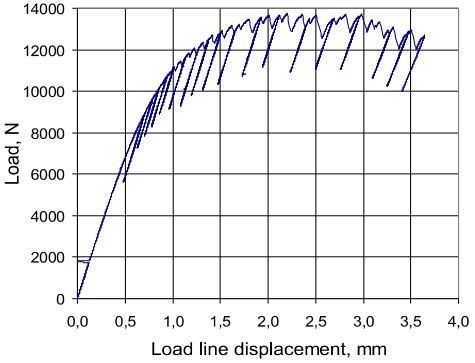
- Fracture toughness measurements (ASTM 1820) on forged Nitronic 50 material at 4.2 K

LS2

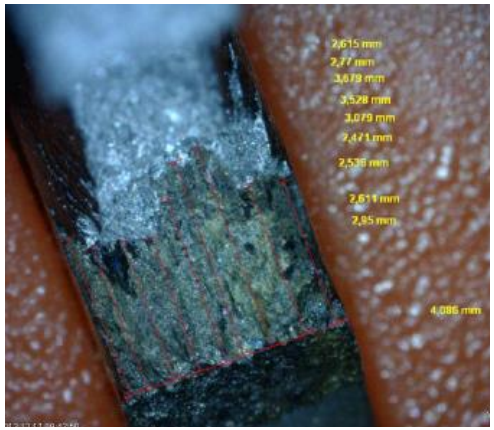


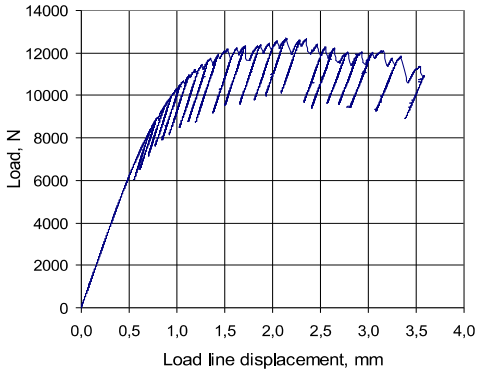
LS3





LS4





Results of 0° and 90° K_{IC}

- Fracture toughness measurements (ASTM 1820) on forged Nitronic 50 material at 4.2 K with 0° and 90° crack propagation

Specimen	Type of measurement	Crack extension plane	J_Q, N/mm	K_{IC}, MPa√m	comment
LS2	FCGR and J-test	90°	181	193	anisotropic
LS3	J-test	90°	200	202	anisotropic
LS4	J-test	90°	240	221	anisotropic
LT3	J-test	0°	270	235	isotropic

Summary

- Fracture toughness on Nitronic 50 to be measured in two directions.
- All three LS oriented specimens show a strong anisotropy making impossible to evaluate with existing J-test evaluation software.
- A new consistent compliance function has been determined by modelling anisotropic specimens and using a FEM approach.
- Measuring experimentally the stiffness of specimen with 90° crack the FEM procedure was verified.
- Using the new compliance function it was possible to determine the fracture toughness of these specimens.

Thank You!