BAMF Modelling of crack growth in laser deposit repaired 300M steel

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Aim: Develop certified, structurally significant repairs for high strength steel components such as landing gear

https://www.nwfdailynews.com/news/20180822/nose-down-f-35-grounded-during-investigation-second-f-35-suffers-bird-strike

Example case: F-35 NLG Piston, 300M Steel

Why Laser Cladding as a repair technology?

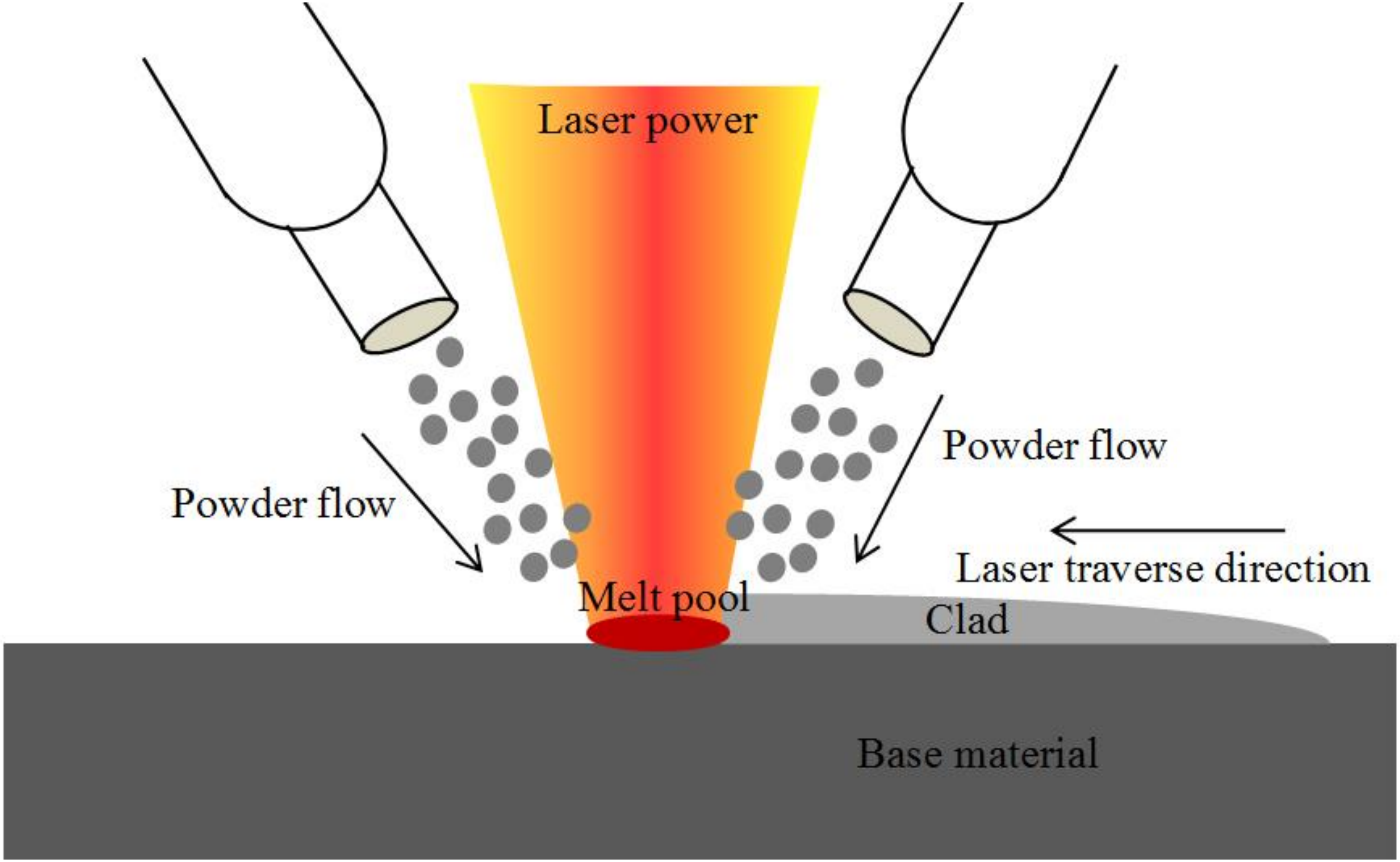
- Makes repair of expensive components possible
- Can repair components when lead-time may be excessive
- Can improve performance of the part

Liu, Q., Janardhana, M., Hinton, B., Brandt, M., and Sharp, P., *Laser cladding as a potential repair technology for damaged aircraft components.* International Journal of Structural Integrity, 2011. 2(3): pp. 314-331.
Liu, Q., Walker, K.F., Djugum, R., and Sharp, P.K., *Repair of Australian military aircraft components by additive manufacturing technology*, in *NATO Specialists Meeting on Additive manufacturing for Military Hardware*. 2016: Tallinn, Estonia.
Liu, Q., Djugum, R, Sun, S., Walker, K., Choi, J., and Brandt, M., *Repair and Manufacturing of Military Aircraft Components by Additive Manufacturing Technology*, in *17th Australian Aerospace Congress*. 2017: Melbourne, Australia.

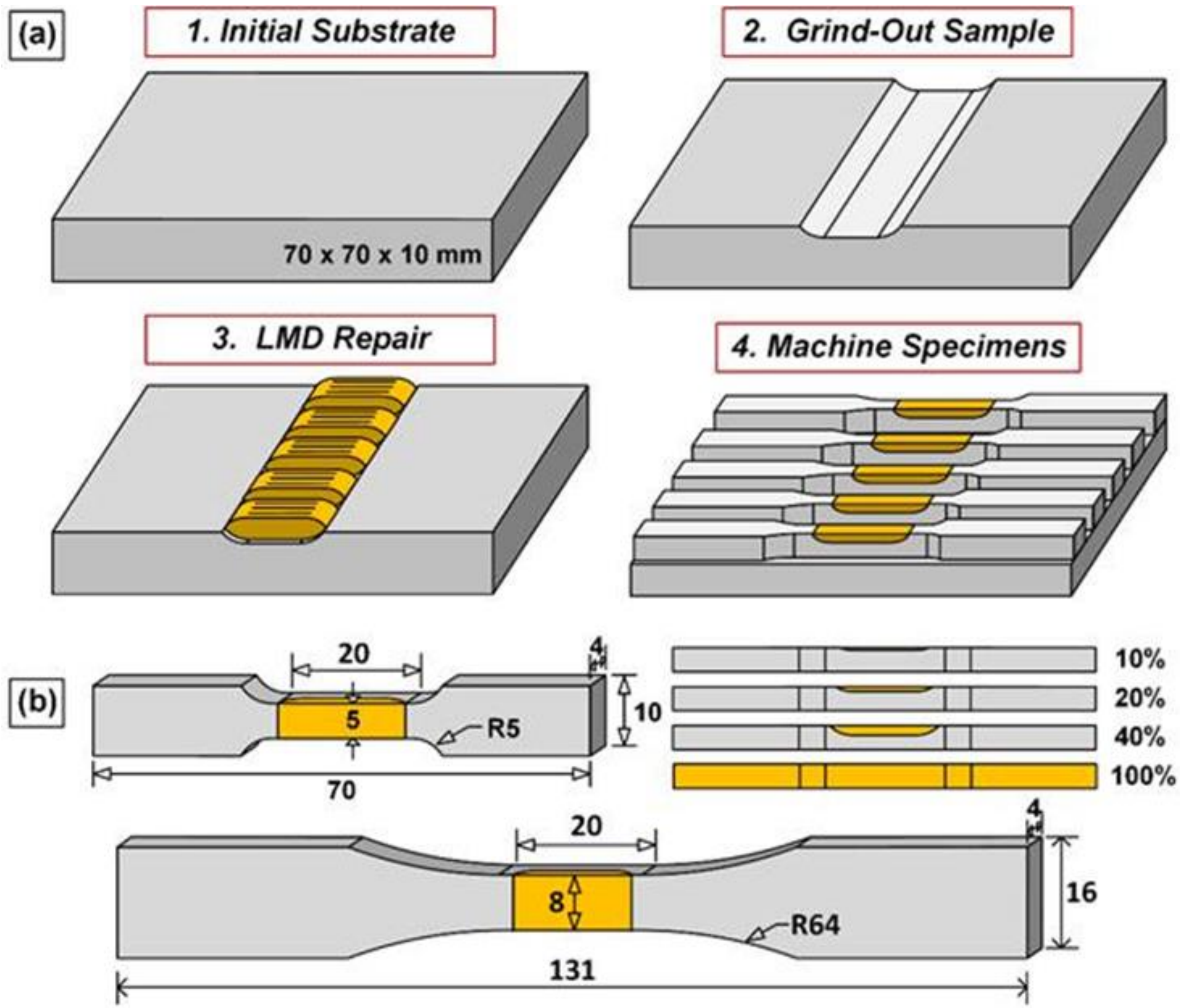
Advantages of Laser Cladding

- Low dilution and heat input
- Low material distortion
- Low porosity, no micro-cracking, minimal heat affected zone, no or minimal damage to the substrate
- Good metallurgical bond
- Good mechanical properties
- Powder blend and process can be managed to achieve desired mechanical properties

Laser Cladding Process

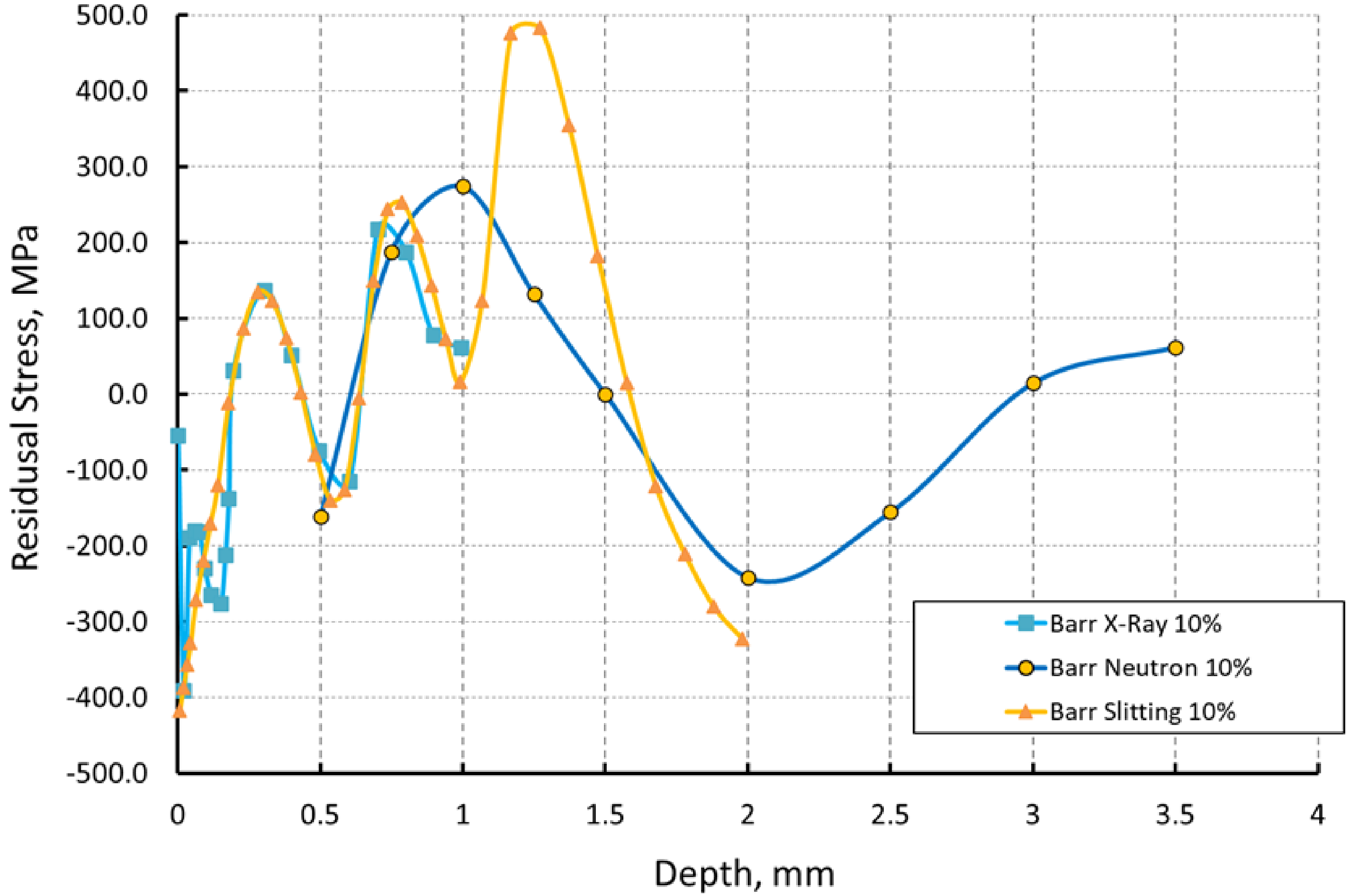


Laser clad repaired fatigue specimens



The slots were filled until the deposit reached the original surface, after which a further four sacrificial layers were deposited. This was done to ensure no untempered martensite remained in the deposited section when machining the final test specimen, as the top layers of the deposit do not experience in-situ tempering. This meant that in the case of the 10% repair depth, there were a total of five layers; one layer to fill the slot, and then the four sacrificial layers. For the 20% case, a total of six layers were deposited. In the case of the 40% repair depth, a total of eight layers were deposited.

Residual stress – 10% Repair Depth



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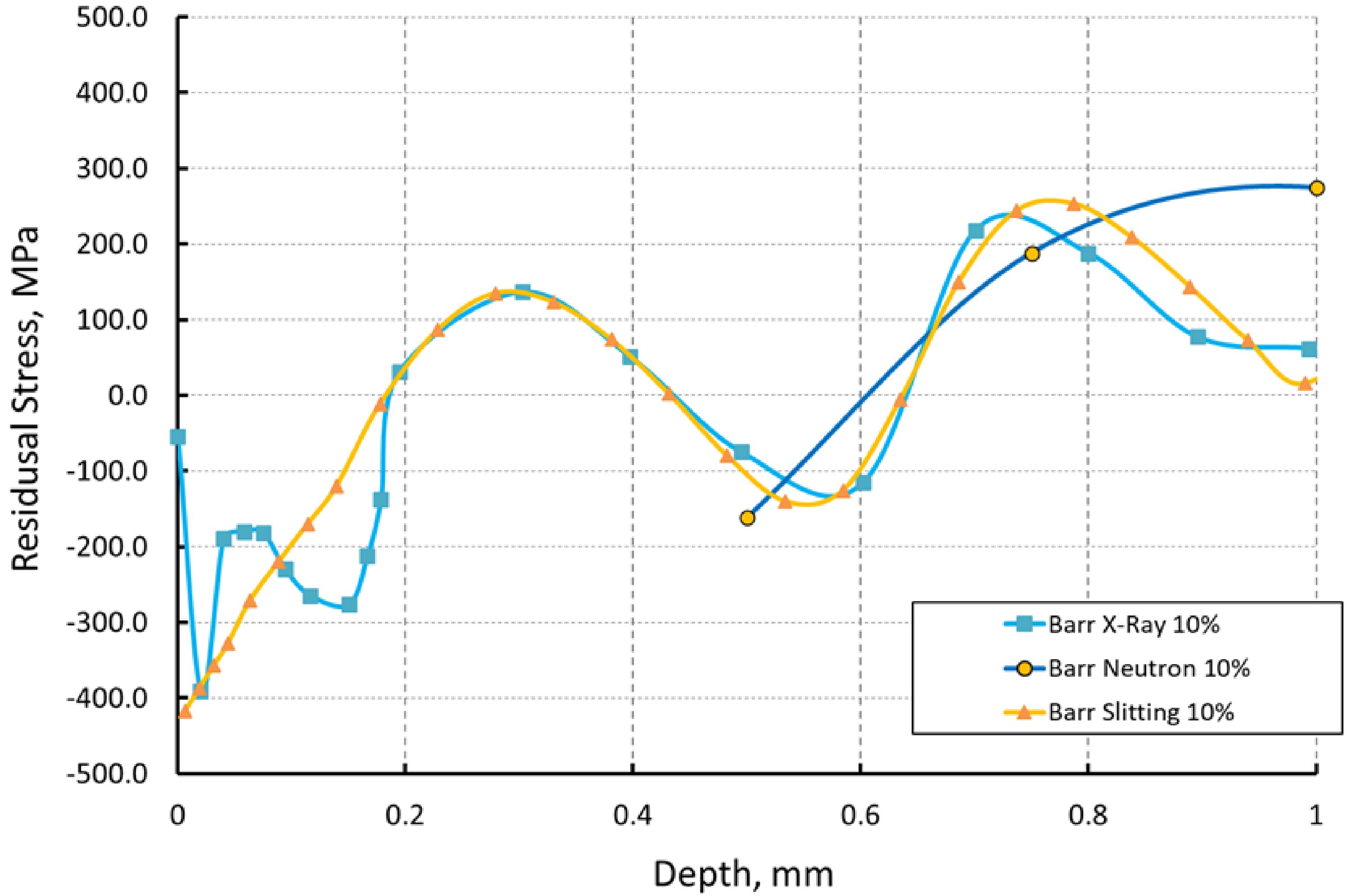
Residual stress – 10% Repair Depth (zoom)



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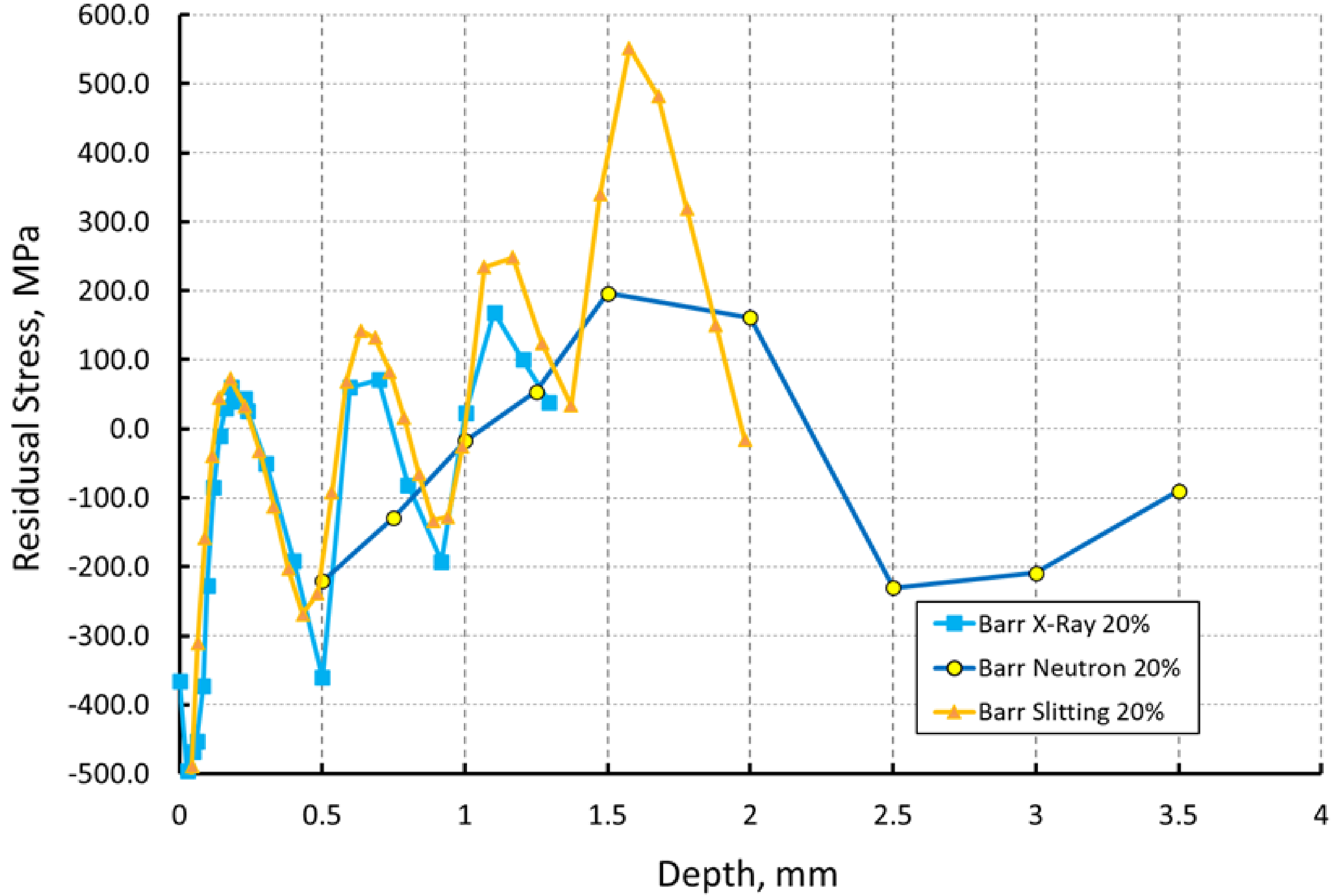
Residual stress – 20% Repair Depth



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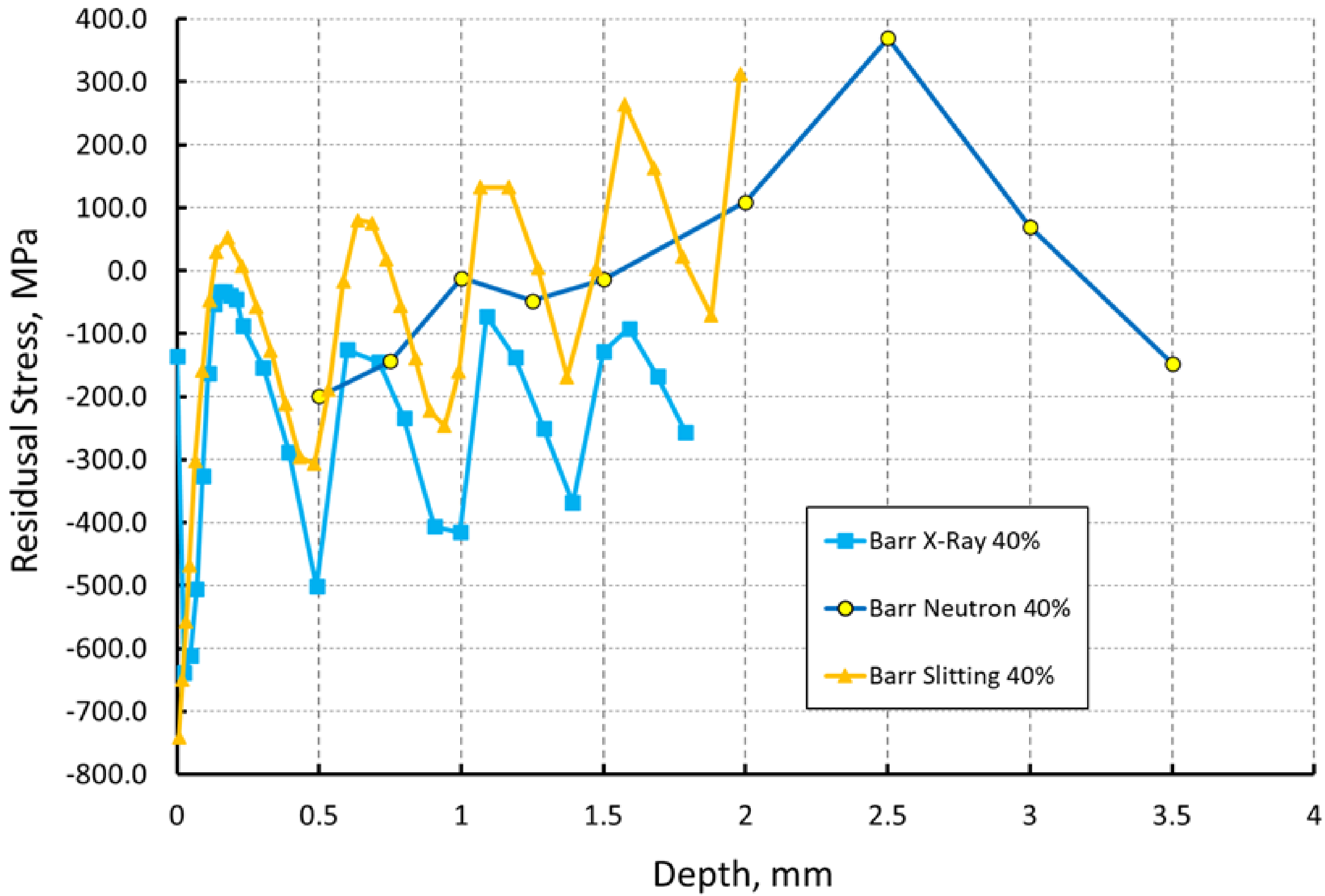
Residual stress – 40% Repair Depth



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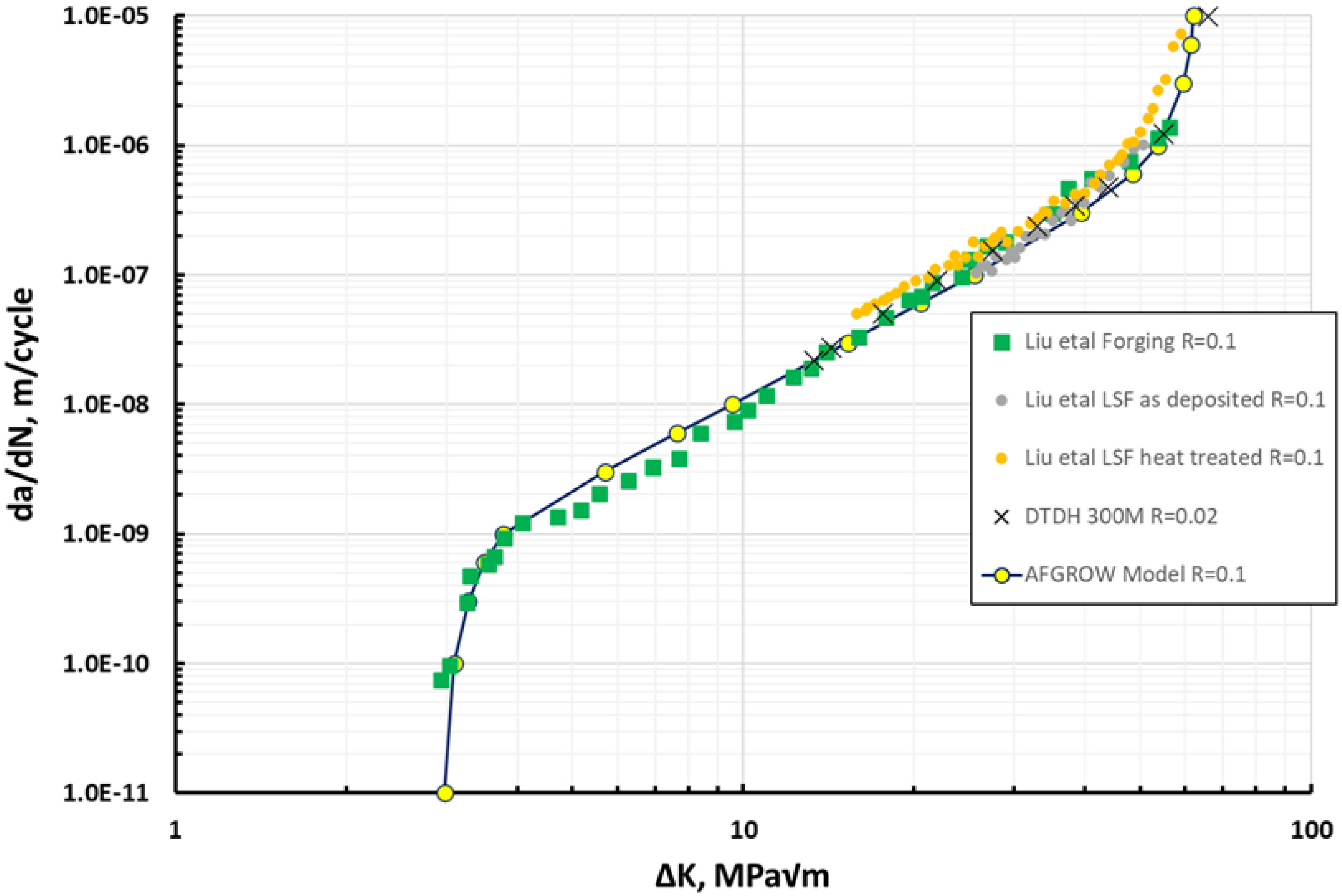
300M Rate Data R=0.1



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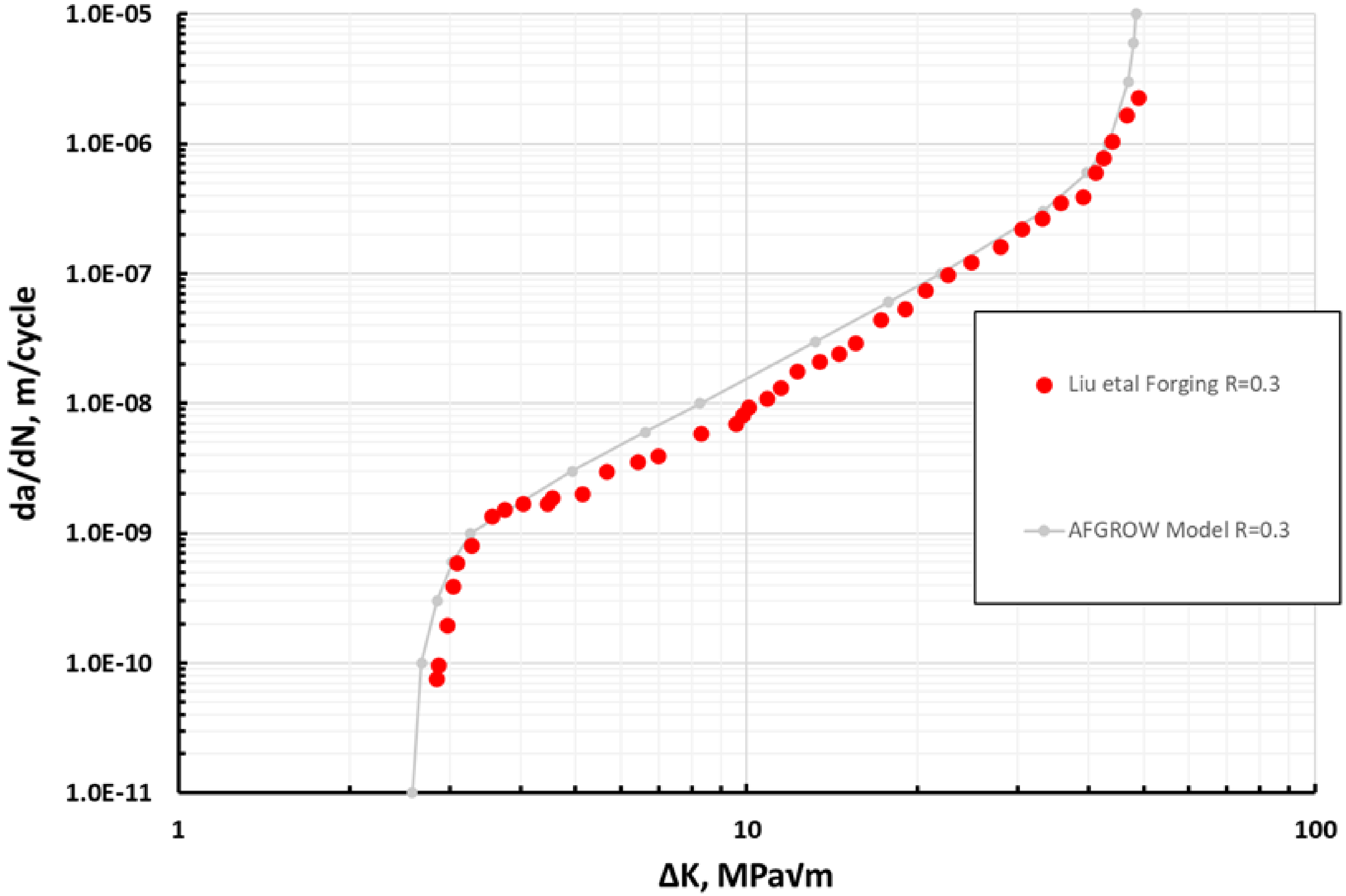
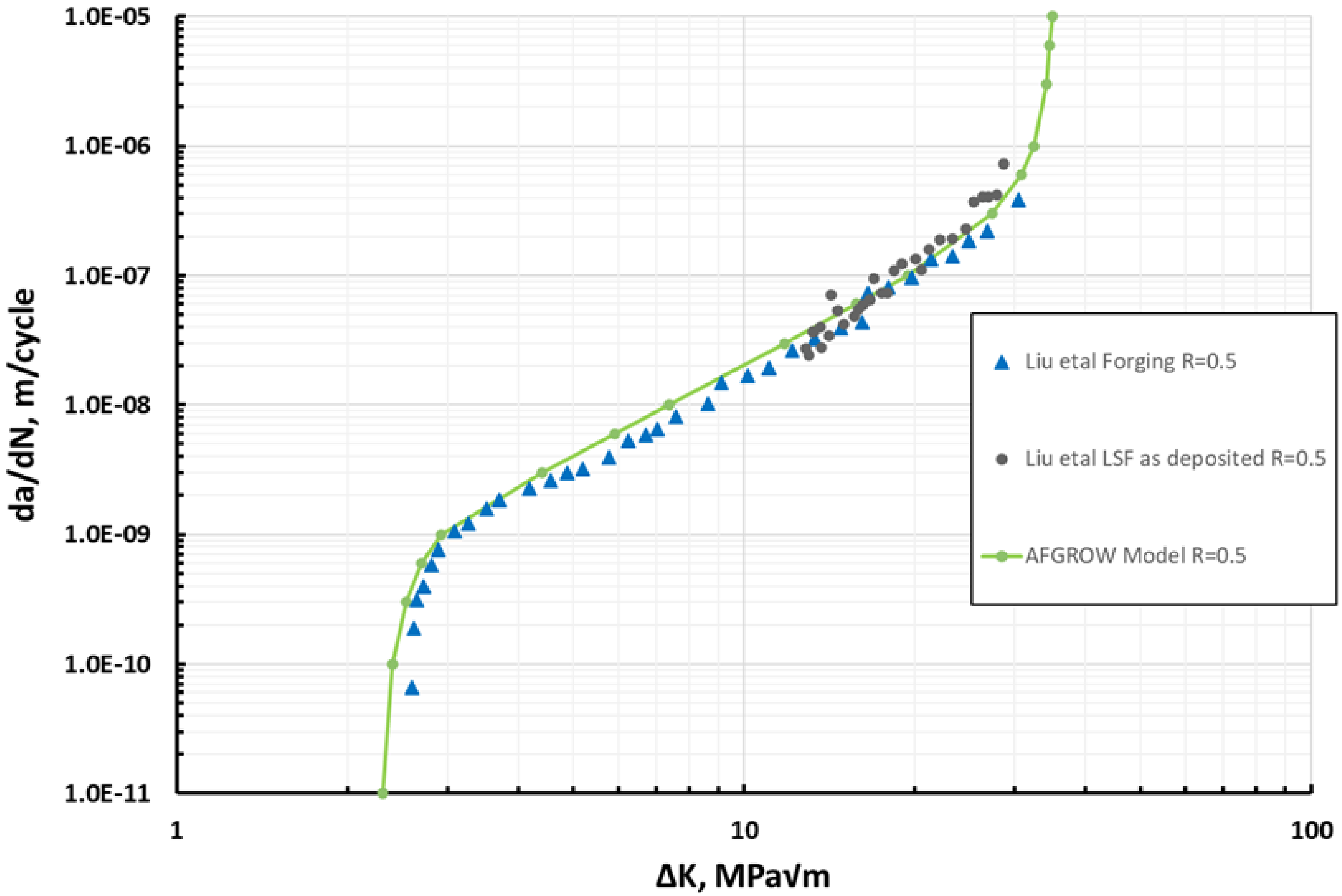
300M Rate Data R=0.3



300M Rate Data R=0.5



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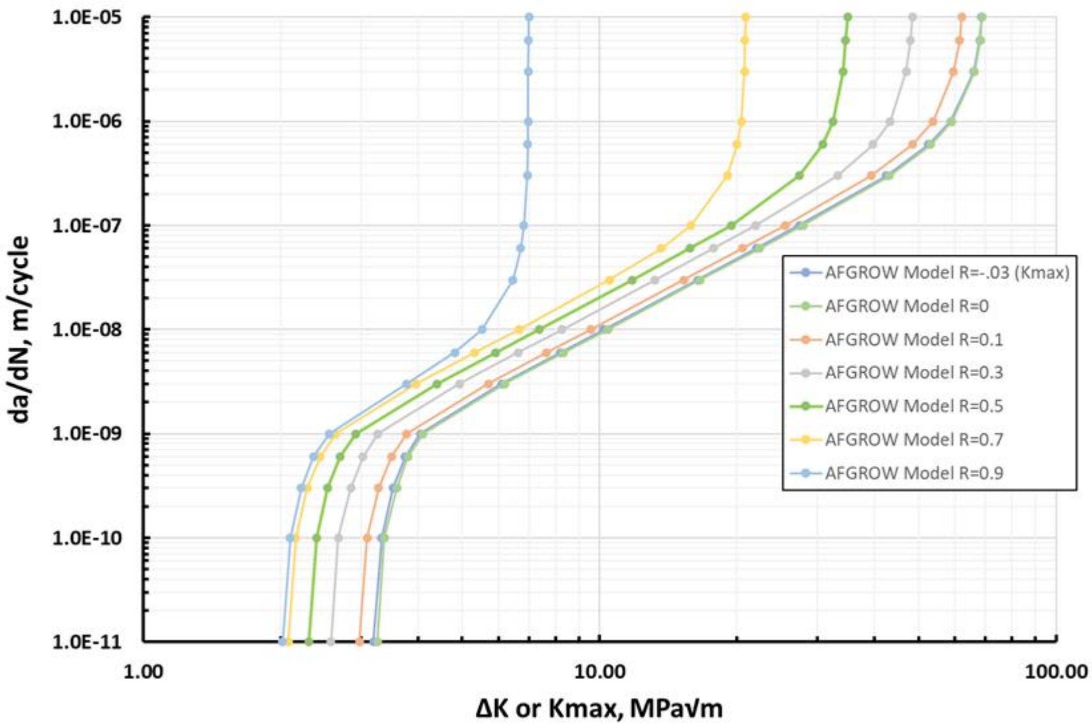
AFGROW Model for Rate Data – Full Range of R



	ΔK (K_{max} for -ve R), MPa√m						
da/dN	Stress Ratio, R						
m/cycle	-0.3	0	0.1	0.30	0.5	0.7	0.9
1.00E-11	3.20	3.26	2.98	2.58	2.31	2.08	2.02
1.00E-10	3.33	3.38	3.10	2.68	2.40	2.16	2.10
3.00E-10	3.53	3.60	3.28	2.85	2.54	2.29	2.22
6.00E-10	3.75	3.80	3.50	3.03	2.70	2.44	2.36
1.00E-09	4.05	4.11	3.78	3.27	2.92	2.64	2.56
3.00E-09	6.10	6.20	5.70	4.93	4.40	3.96	3.78
6.00E-09	8.22	8.35	7.65	6.63	5.92	5.33	4.82
1.00E-08	10.20	10.42	9.55	8.27	7.39	6.65	5.53
3.00E-08	16.40	16.60	15.27	13.23	11.80	10.50	6.46
6.00E-08	22.01	22.40	20.50	17.75	15.75	13.64	6.72
1.00E-07	27.35	27.90	25.55	22.00	19.40	15.85	6.83
3.00E-07	42.40	43.10	39.30	33.19	27.40	19.03	6.94
6.00E-07	52.50	53.10	48.40	39.65	30.83	20.00	6.96
1.00E-06	58.70	59.05	53.74	43.25	32.47	20.42	6.97
3.00E-06	66.00	66.20	59.60	46.95	34.10	20.75	6.98
6.00E-06	68.00	68.20	61.40	47.90	34.55	20.82	6.99
1.00E-05	68.60	68.80	62.00	48.40	35.00	20.90	7.00

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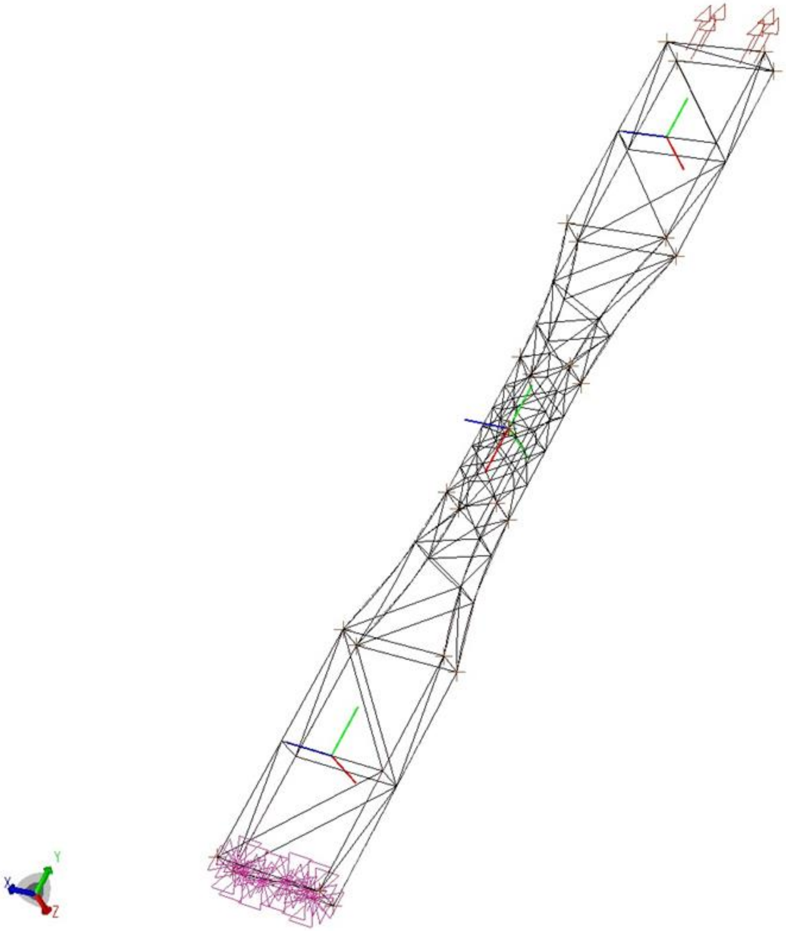
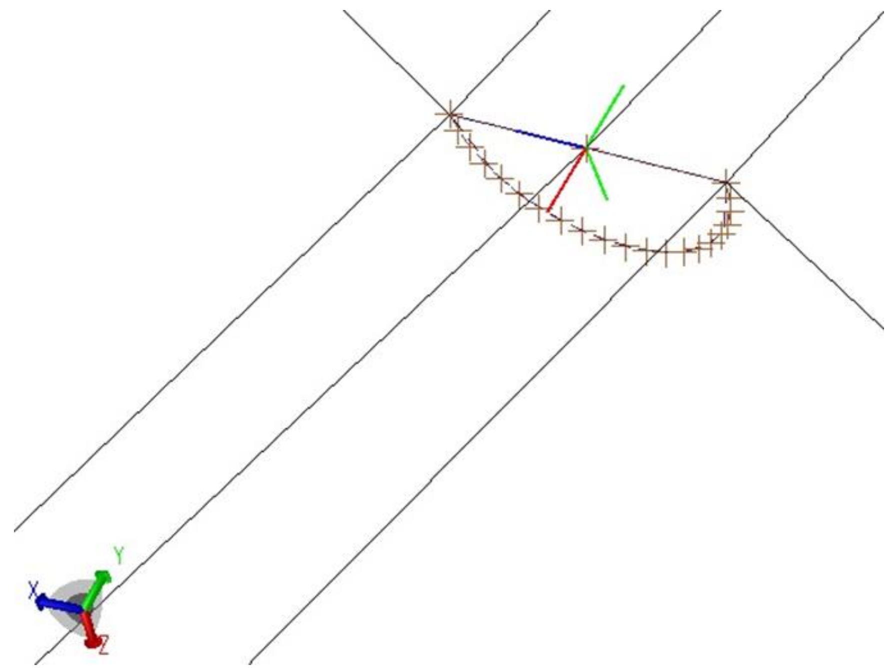
BAMF Model





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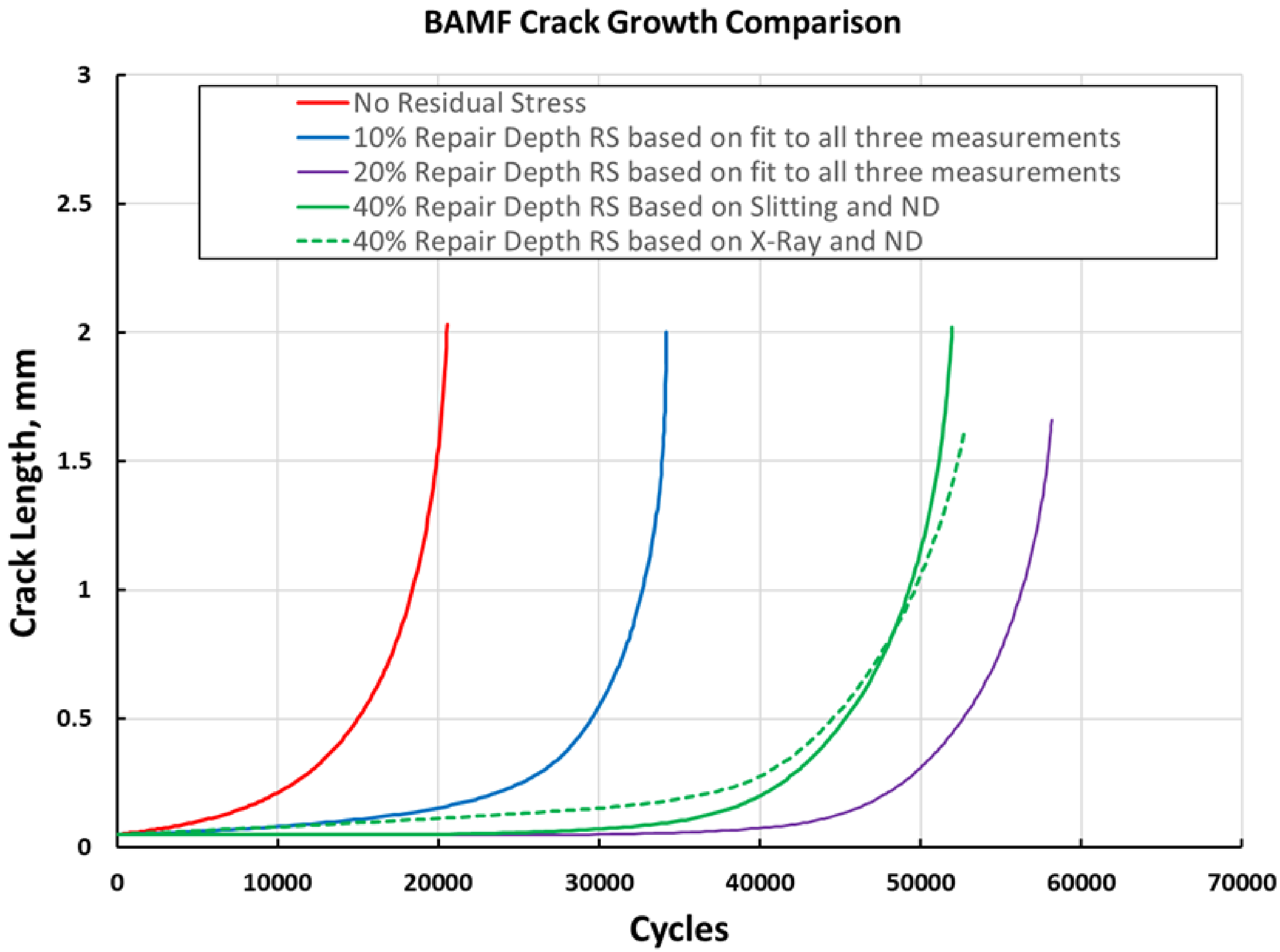
BAMF Results



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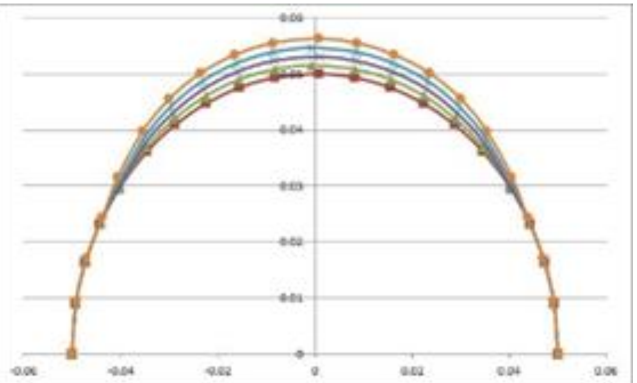
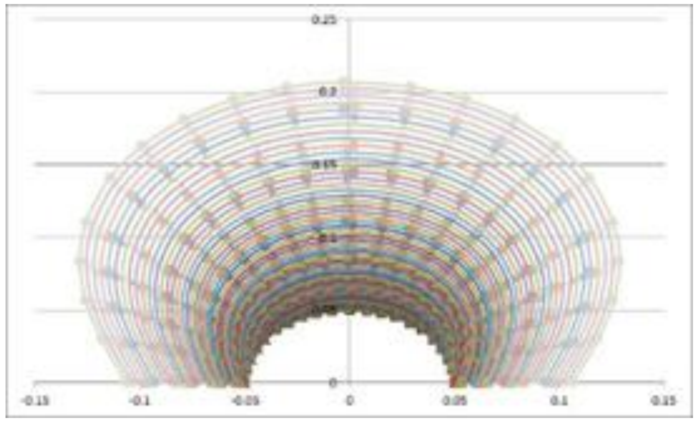
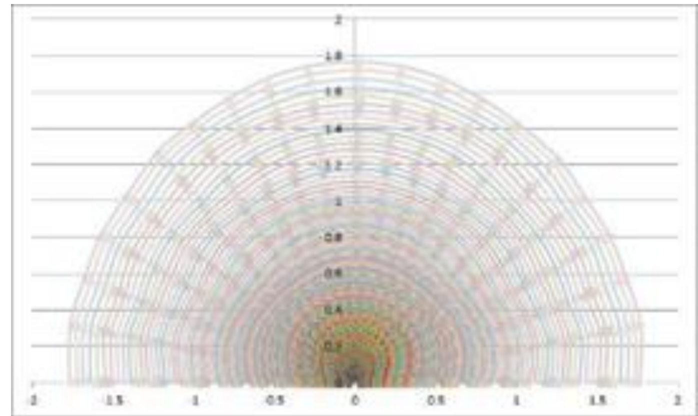
Crack shape evolution in BAMF, 40% Repair depth case



5 increments



50 increments



130 increments

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Work in progress/to be done

- Complete fatigue test program, constant amplitude loading with marker bands (contrasting high/low R)
- Quantitative fractography
- Conduct baseline fatigue crack growth rate testing of specimens made completely from laser clad material
- Figure out how to analyse for a crack growing in two materials with different crack growth rate properties!!! How do we do that in BAMF???????????
- Writing up a journal paper on the RS measurements (also including other cases involving ultra high strength steels)
- Journal paper **Role of deposition strategy and fill depth on the tensile and fatigue performance of 300M repaired through laser metal deposition** submitted to IJF. Includes some crack growth modelling (AFGROW/FASTRAN) which ignores RS and any difference between wrought and LMD properties – correlates reasonably well on a total life basis! Might be because beneficial effect of RS balances out with inferior rate properties for LMD material.

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