Fatigue crack propagation of PVC-U and PVC-M pipes in a water environment

Noorasikin Samat[1], Alan Whittle[2] and Mark Hoffman[1]
The School of Materials Science and Engineering[1], The University of New South Wales
Sydney, NSW 2052, Australia
Iplex Pipelines Australia Ltd[2], Chipping Norton, NSW

Introduction

The use of unplasticised Poly(vinyl chloride) (PVC-U) and chlorinated polyethylene (CPE)-modified PVC (PVC-M) as pipes is in general practise nowadays. In water distribution system applications, PVC pipes are subjected to cyclic loading throughout their service lifetime and at the same time they are also continuously in contact with water. It is known that cyclic loading conditions induce the fatigue failure in PVC similar to that observed in other plastics[1]. Moreover, continuous contact with water could also result in sudden and unpredictable brittle failures[2]. Therefore, knowledge of the effect of this environment on the fatigue behaviour of PVC pipes is critical in order to ensure safe design.

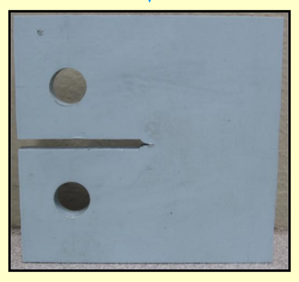
This study aims to evaluate the effect of water on the fatigue crack propagation behaviour of PVC-U and PVC-M (comprised 6 pphr of CPE) at two different frequencies, 1 Hz and 7 Hz and compare these results to those obtained from testing in air.

Experimental Works

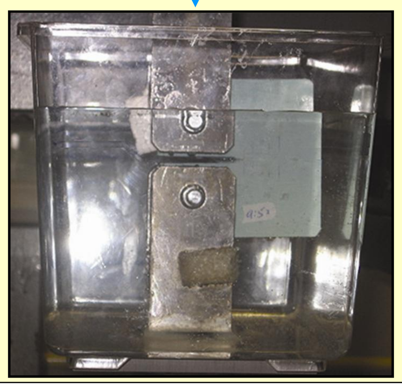
Formulation The PVC-U and PVC-M have a similar formulation ; A K67 PVC resin, with 1.5pphr of rutile titanium dioxide, a small amount of calcium carbonate and calcium/zinc thermal stabilizer, and PVC-M also contains 6 pphr of impact modifier (chlorinated polyethylene - CPE)

Sample preparation & Testing

~Pipe was cut, heated and flattened before cutting into compact tension (CT) specimens



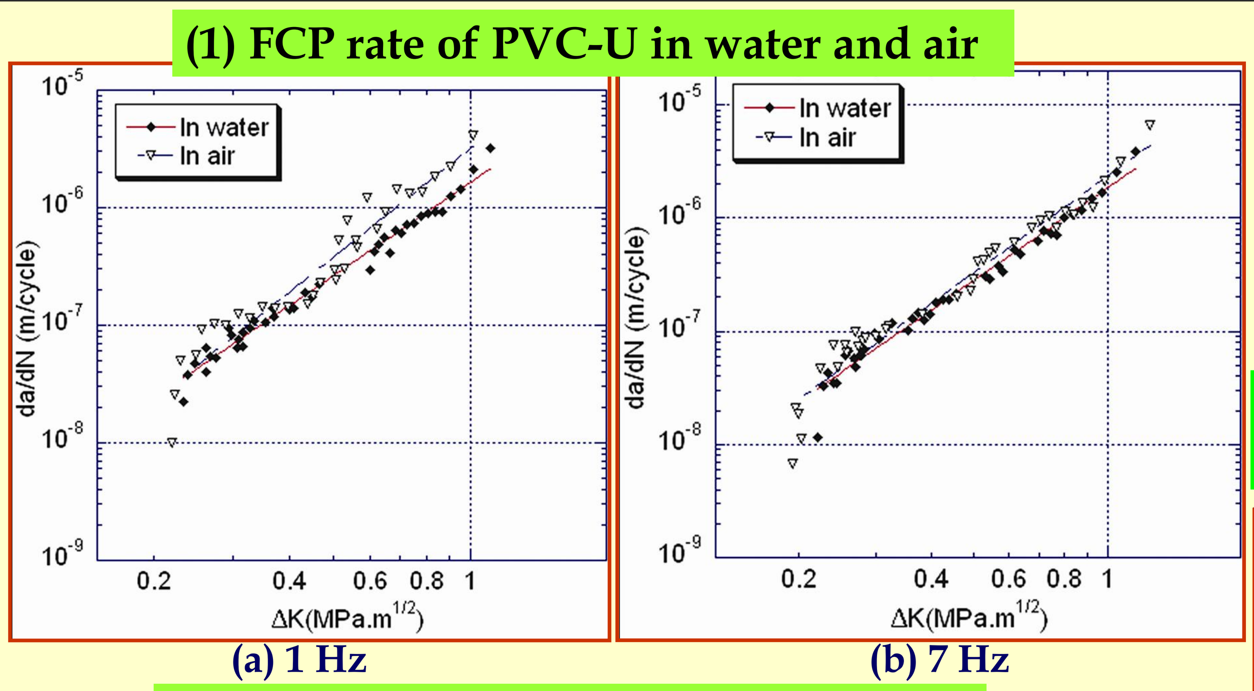
~Fatigue testing was performed with a sinusoidal waveform on MTS 810 Servo-hydraulic Testing Machine
~Crack length was monitored by a compliance method
~Tap water was used as the testing medium



**For the testing in air, the crack length was determined by using a travelling microscope*

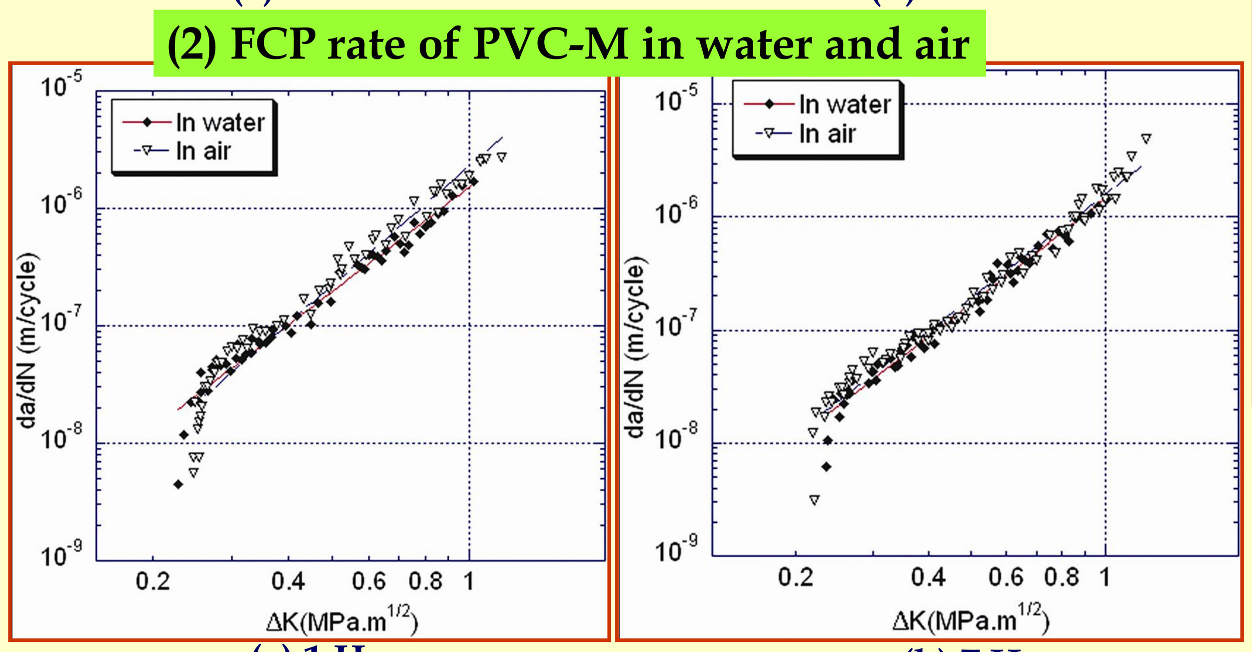
Result

(1) FCP rate of PVC-U in water and air



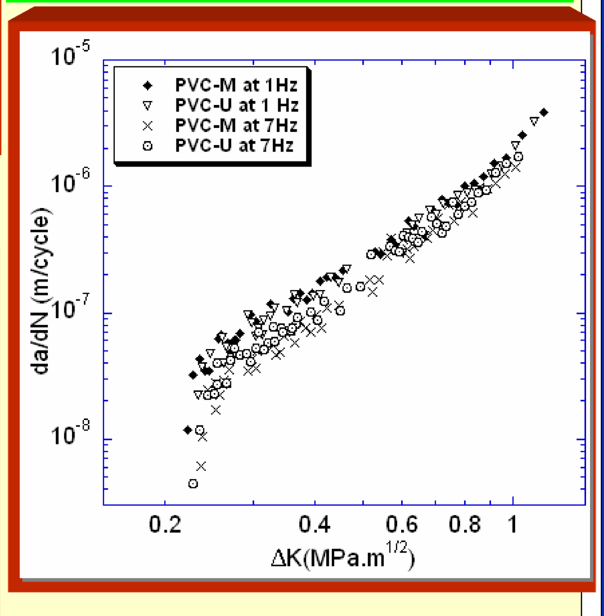
(a) 1 Hz (b) 7 Hz

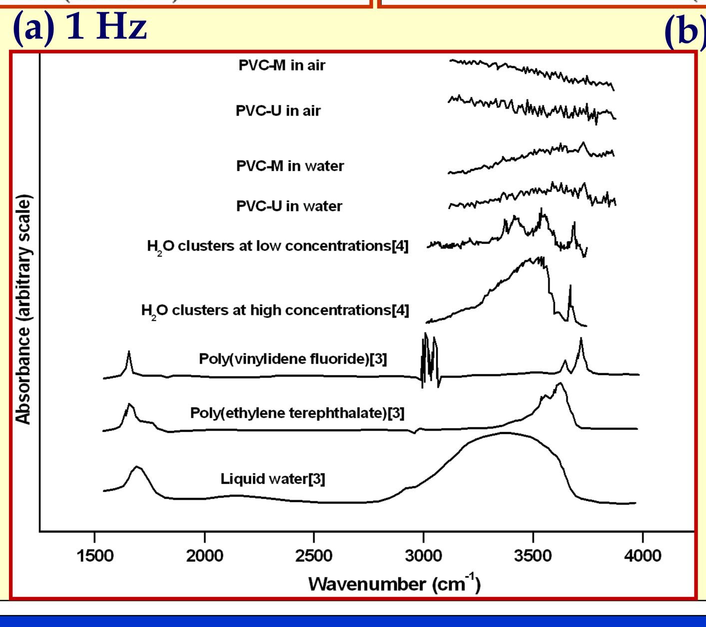
(2) FCP rate of PVC-M in water and air



(a) 1 Hz (b) 7 Hz

(3)FCP rate of PVC-U & PVC-M in water at 1Hz & 7Hz





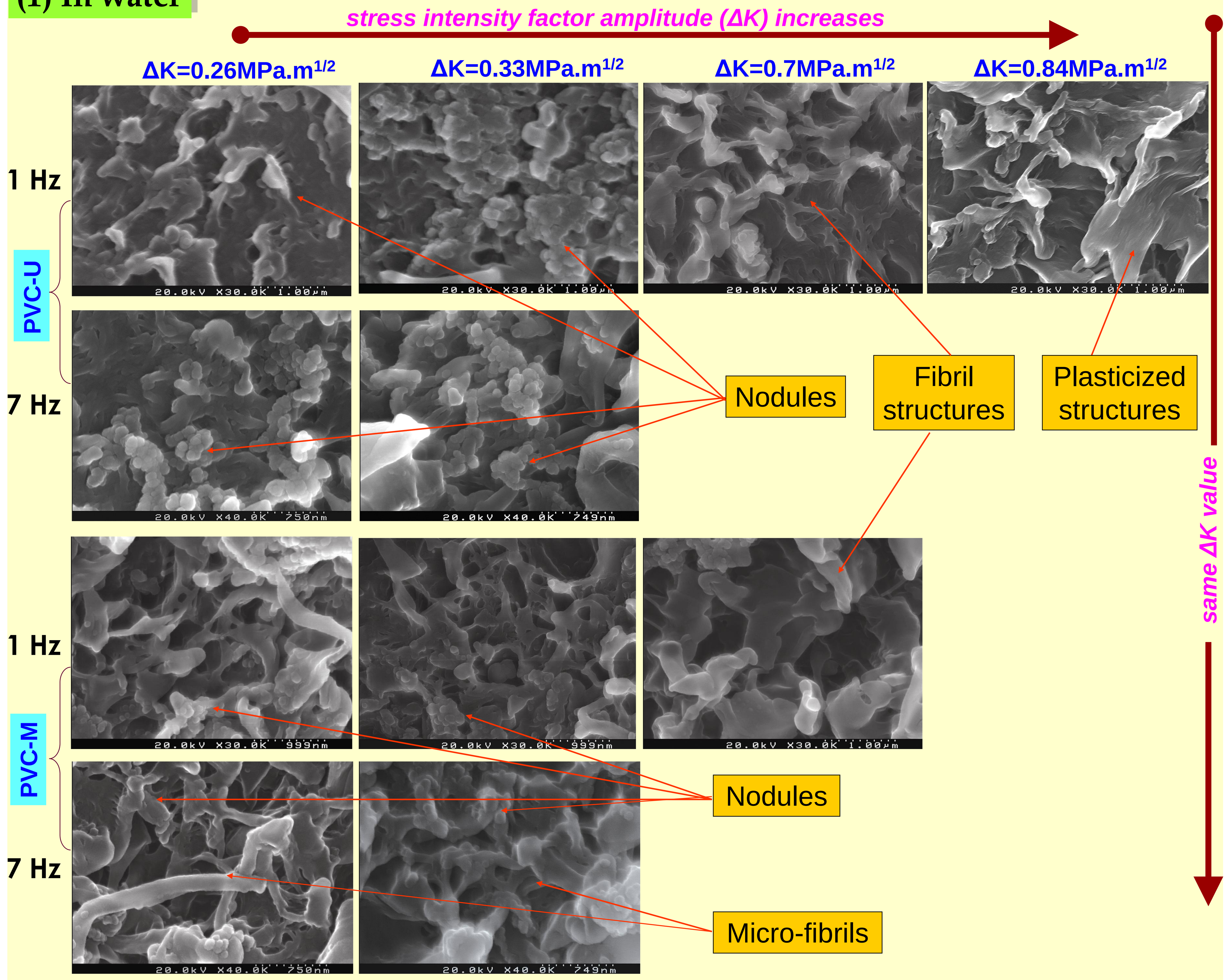
(4) Fourier Transform Infrared Spectroscopy (FTIR)

·The analysis for water spectra is usually done at frequencies in the range (3000 – 3800)cm^{-1}

·The evidence of water absorption are seen in samples (PVC-U and PVC-M) that were tested in water medium

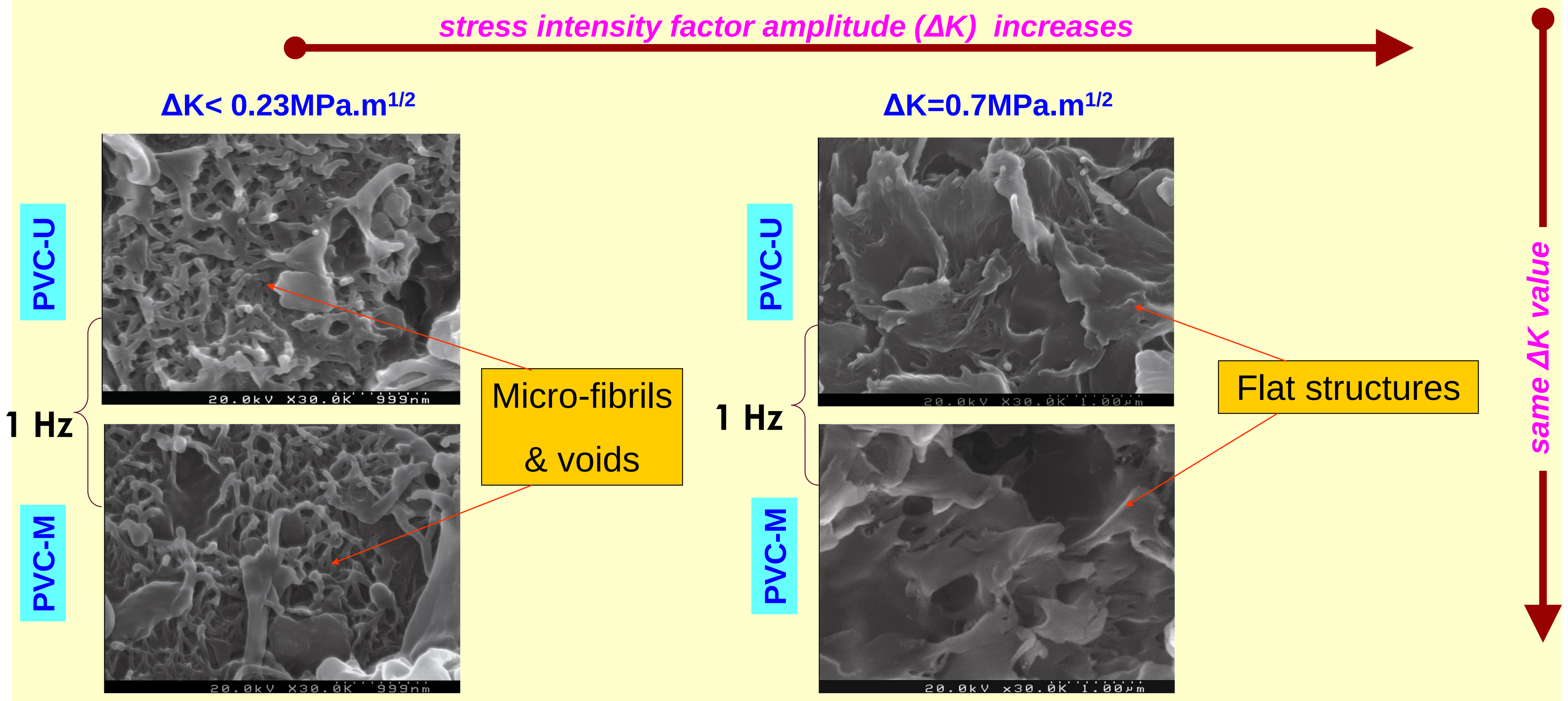
Fracture surface observations

(1) In water



The SEM observation in water – (1)at low ΔK – microvoids, microfibrils and *nodules* characteristics
– (2)at high ΔK – plasticized structures characteristics

(2) In air



The SEM observation in air – (1)at low ΔK – microvoids and microfibrils characteristics
– (2)at high ΔK – brittle fracture appearances– no voids & fibrils

Conclusions

1)The fatigue crack growth rates for PVC-U and PVC-M are slower in water than in air, particularly at lower frequencies.

2)Both specimens exhibited higher fatigue resistance with increasing cycling frequency, irrespective of the testing medium. However, the testing medium affects the fatigue threshold more significantly at lower frequencies in PVC-M.

3)The absorption of water molecules into the PVC matrix is evident with the existence of nodular and plasticized structures at low and high ΔK respectively and FTIR results, resulting in lower crack growth rates and higher thresholds.

References
[1] R. W. Hertzberg, J. A. Manson, *and* M. Skibo, *Polymer Engineering and Science,***15**, No. 4, 252 (1975)
[2]J.C. Arnold, *Journal of Materials Science*, **33,** 5193 (1998)
[3]H.Kusanagi and S.Yukawa, *Polymer*, **35**, No.26, 5637(1994)
[4]D.F.Coker, R.E. Miller, and R.O.Watts, *J.Chem.Phys*., **82**,8, 3554 (1985)