# Telephone cord blisters in multilayer thin films [Abstract]

# Telephone cord blisters driven by pockets of energy concentration in multilayer films

B. Yuan[a], C. M. Harvey[a], R. C. Thomson[b], G. W. Critchlow[b], D. Rickerby[c], S. Wang[a,d,+]

[a]*Department of Aeronautical and Automotive Engineering, Loughborough University, Loughborough, Leicestershire LE11 3TU, UK*

[b]*Department of Materials, Loughborough University, Loughborough, Leicestershire LE11 3TU, UK*

[c]*Surface Engineering Precision Institute, Cranfield University, Cranfield, Bedfordshire MK43 0AL, UK*

[d]*School of Machinery and Equipment Engineering, Hebei University of Engineering, Handan, China*

Blisters are frequently observed to nucleate and develop, apparently spontaneously, in thin compressed films. For instance, circular and straight blisters that nucleate and grow from a central region or an edge can develop into telephone cord blisters (TCBs) and web blisters, which propagate forward with wavy boundaries between the coating film and the superalloy substrate. Yuan et al. [1–4] modelled the nucleation and growth of TCBs as being driven by pockets of energy concentration (PECs), with primary and secondary buckling subsequently driving the development, and with energy being seamlessly transmitted to the TCB tip to provide the necessary crack-driving force. Yuan et al. [1–4] reported completely-analytical formulae to predict the morphology parameters of TCBs in films with isotropic materials subjected to biaxial compressive residual stresses, that is, local width and height, and global wavelength and transverse amplitude. The current work further develops the authors' PECs theory for TCBs in multilayer films, which are typical of many advanced coating systems, such as thermal barrier coating systems. Variable through-thickness Young's modulus, Poisson's ratio and coefficient of thermal expansion are introduced into the theory, and the resulting equations are valid across the ranges of TCB width and transverse amplitude-to-wavelength ratio. Mechanical conditions for the TCB formation in multilayer films are also presented. The developed theory agrees very well with experimental results. This work provides mechanical understanding on blister development, coating adhesion and blister shape, and can guide improvements in the industrial design of coating material systems.

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[+]*Corresponding author*

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+*Corresponding author*