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An integrated approach to low-cycle/thermo mechanical fatigue design for automobile exhaust materials/components

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With stringent environmental regulations and lightweight/fuel economy demands, advanced automobile exhaust system design relies on utilization of materials to its maximum capacity against low- cycle fatigue (LCF) and thermo mechanical fatigue (TMF) failure. Traditionally, characterization of material's LCF/TMF resistance was obtained through extensive testing and correlation, which drives the cost up for design. An integrated creep-fatigue theory (ICFT) has been developed at the National Research Council, Canada, to address constitutive modelling and life prediction, in a self-consistent and unified fashion, based on i) deformation decomposition by participating mechanisms and ii) holistic damage accumulation by nucleation and propagation of surface/subsurface cracks in coalescence with internally distributed damage. Automotive exhaust system materials such as ductile cast iron and austenitic cast steel are used as example materials for demonstration in good agreement with experimental results and metallurgical examinations. This enlightens the understanding of the roles each mechanism plays in LCF/TMF processes, thus helping material and component design specifically targeting the most damaging mechanism(s) encountered in service.

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