152 Feasibility of Resonances Avoidance by a Shape Memory Actuated Morphing Thin-shell Cylinder

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Abstract.

Shape memory alloy actuators produce powerful and repeatable actuating forces. One application area is morphing the shape of the bypass duct of turbofan engines by which the cross-sectional area can be changed. This brings many benefits including fuel economy and noise reduction during take-off and landing. Firstly, a new and compact configuration of morphing nozzle cylinder was introduced. This work also investigated the changes in natural frequencies and mode shapes of the cylinder associated with static shape change. The change in transfer function adopted the kinetic energy spectrum of the whole structure. This was to avoid the problem of localization of measuring points for variable mode shapes. The kinetic energy spectrum was also predicted in finite element model using shape function of brick elements. Monitored sound pressure level demonstrated the feasibility of minimizing the time spent on resonance when excitation frequency was changing gradually. Moreover, the morphing cylinder was able to adjust the shape by itself to reduce vibration according to excitation frequency by adding a simple feedback control unit.

Introduction

Morphing Cylinder Design. The configuration of the morphing cylinder was shown in Figure 1. Upon heating, the spacers on cylinder resisted the contraction of actuators so circumferentially shear loads deformed the cylinder. Upon cooling, the self-stiffness of cylinder re-stretched the actuators a repeatable working cycle was formed.

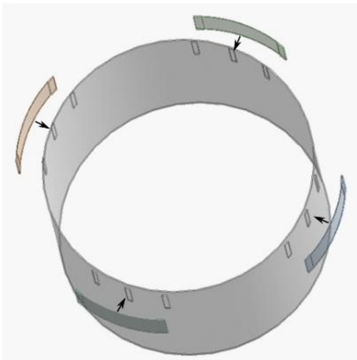

Figure 1 Titanium alloy cylinder attaced with four shape memory alloy actuators plates.

Morphing Cylinder Simulation. The shape memory effect was modelled using reversed coefficient of thermal expansion. The de-twinning process was modelled using temperature dependent multilinear plasticity. The Young's modulus of shape memory alloy was also temperature dependent.

Dynamic Characteristics of Morphing Cylinder. Figure 2 shows both the static deformation and natural frequencies against varied temperature. For mode shapes, the circumferential and longitudinal nodes numbers stayed same for varied temperature. But there were observable axial variations.

Fabrication. The manufacturing of titanium cylinder involved expensive process such as precise rolling and laser welding. This was to achieve a highly circular shape. The cutting of shape memory alloy required a strictly controlled machining tolerance. The combination of the preciseness of both parts ensured a symmetric deformation of cylinder and the correlation with the simulated model. Also, the early cyclic fatigue of shape memory alloy was studied in this work.

Kinetic Energy Transfer Function. The overall kinetic energy spectrums of cylinder were shown in Figure 3, which shows significant natural frequencies shifting.

Reducing Resonance Time when Engine Starting up or Closing down. Figure 4 shows when an aeroengine starts up, the cylinder can pre-heat itself and the natural frequency is increased. Then by rapid cooling down, the resonance time can be reduced.

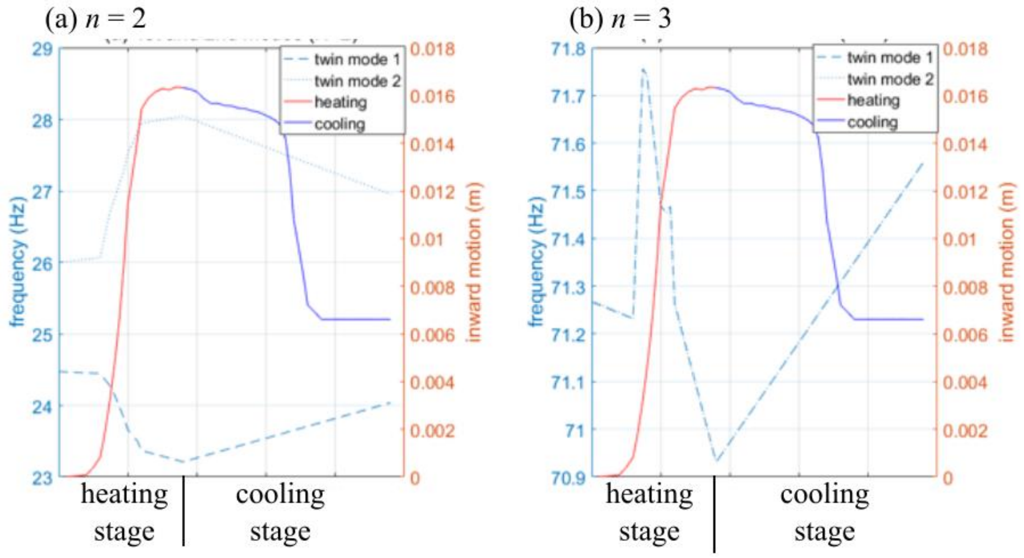

Figure 2 Both graphs shows the static deflections (solid curves) and narual frequencies (dotted and dashed lines) against varied temperature. The dotted and dashed line represented a pair of twin modes in cylindrical strucutres. The left graph shows the information of a resonant mode with circumferential node of *n* = 2, while the right graph shows the mode with *n* = 3.

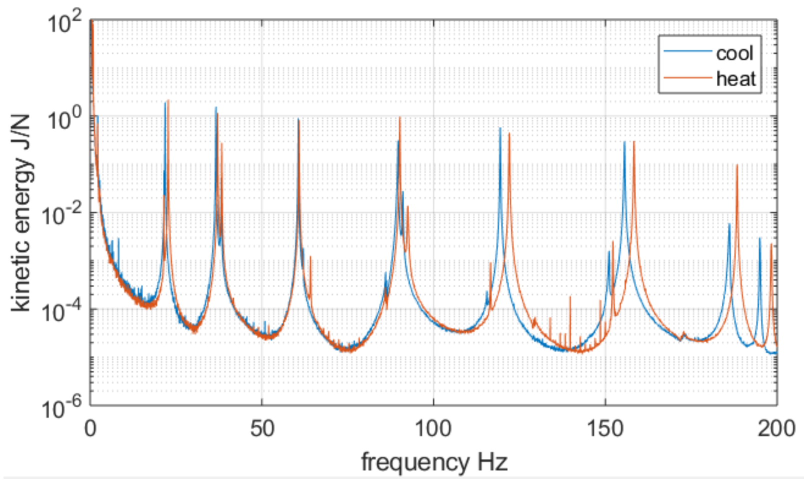

Figure 3 Overall kinetic energy transfer function at cooling down status and peak heating status.

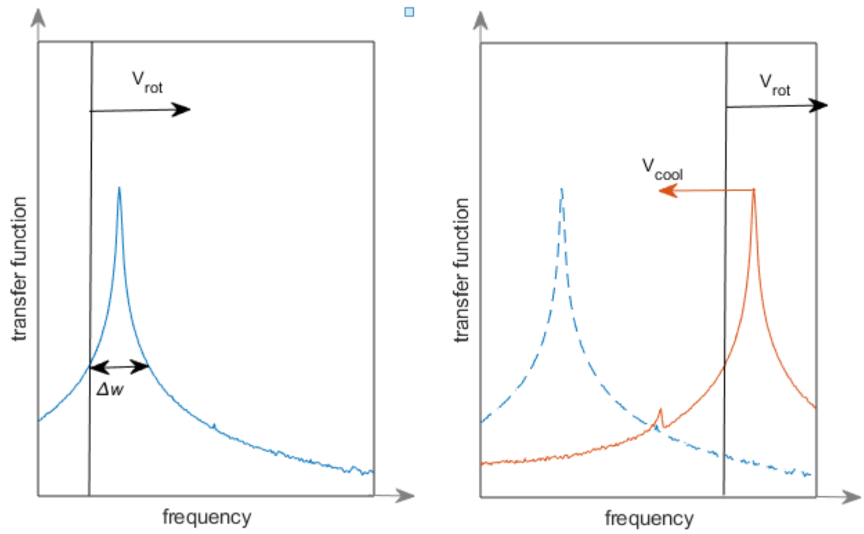

Figure 4 When rotor speed of a aeroengine gradually increases or decrease, the resonant time can be reduced by manipulating the shap memory alloy heating.