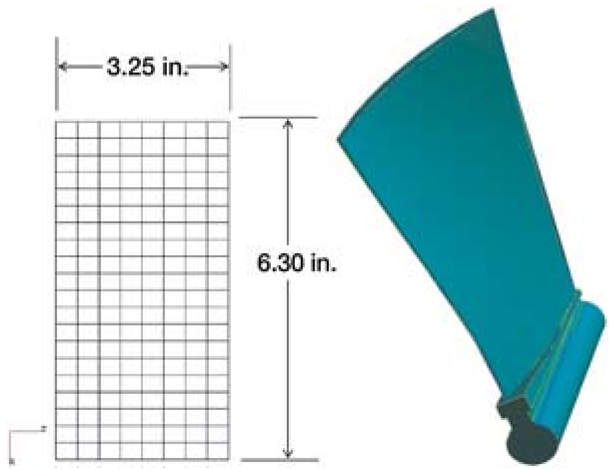
Vibration Characteristics Determined for Stainless Steel Sandwich Panels With a Metal Foam Core for Lightweight Fan Blade Design

The goal of this project at the NASA Glenn Research Center is to provide fan materials that are safer, weigh less, and cost less than the currently used titanium alloy or polymer matrix composite fans. The proposed material system is a sandwich fan construction made up of thin solid face sheets and a lightweight metal foam core. The stiffness of the sandwich structure is increased by separating the two face sheets by the foam layer. The resulting structure has a high stiffness and lighter weight in comparison to the solid face-sheet material alone. The face sheets carry the applied in-plane and bending loads (ref. 1). The metal foam core must resist the transverse shear and transverse normal loads, as well as keep the facings supported and working as a single unit. Metal foams have ranges of mechanical properties, such as light weight, impact resistance, and vibration suppression (ref. 2), which makes them more suitable for use in lightweight fan structures. Metal foams have been available for decades (refs. 3 and 4), but the difficulties in the original processes and high costs have prevented their widespread use. However, advances in production techniques and cost reduction have created a new interest in this class of materials (ref. 5).

The material chosen for the face sheet and the metal foam for this study was the aerospace-grade stainless steel 17-4PH. This steel was chosen because of its attractive mechanical properties and the ease with which it can be made through the powder metallurgy process (ref. 6). The advantages of a metal foam core, in comparison to a typical honeycomb core, are material isotropy and the ease of forming complex geometries, such as fan blades. A section of a 17-4PH sandwich structure is shown in the following photograph.

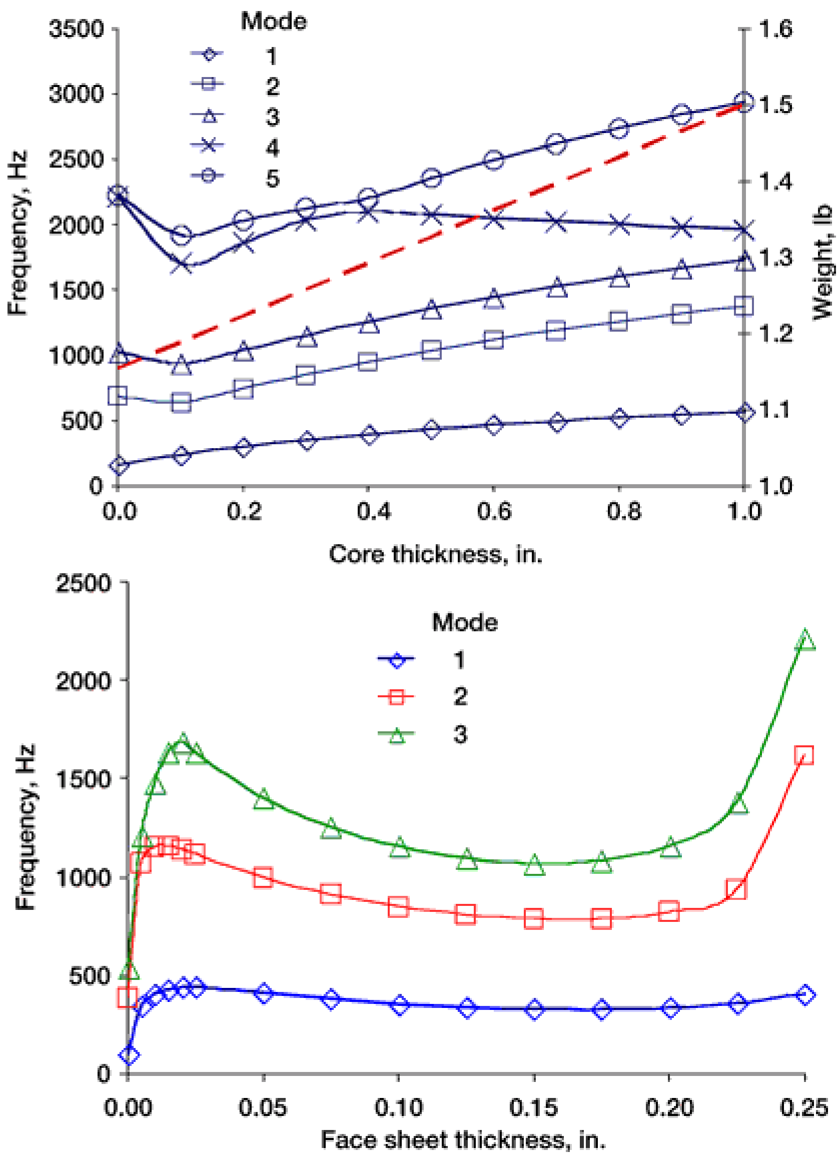
Side view of a 17-4 stainless steel foam panel with face sheets.

Part of process of designing any blade is to determine the natural frequencies of the particular blade shape. A designer needs to predict the resonance frequencies of a new blade design to properly identify a useful operating range. Operating a blade at or near the resonance frequencies leads to high-cycle fatigue, which ultimately limits the blade's durability and life. So the aim of this study is to determine the variation of the resonance frequencies for an idealized sandwich blade as a function of its face-sheet thickness, core thickness, and foam density. The finite element method is used to determine the natural frequencies for an idealized rectangular sandwich blade. The proven Lanczos method (ref. 7) is used in the study to extract the natural frequency. The fan blade geometry and the mesh of the idealized plate are shown in the next figure.



Left: Mesh of an idealized blade. Right: Typical fan blade geometry.

The variation of the resonance frequency with foam-core thickness is shown in the graph on the left for a 6.3- by 3.25-in. plate with a 0.1-in. constant face-sheet thickness. The foam core assumed was a 17-4PH 80PPI[1] with a 6.0-percent relative density in comparison to a solid material. On the other hand, the results of varying the ratio of foam-core thickness to the face-sheet thickness to keep the overall thickness constant at 0.5 in. are shown for the first three resonance frequencies in the figure on the right. The variation of the frequency of an actual sandwich blade profile shown earlier is presented as a function of face-sheet thickness and foam-core density.



Left: Variation of the five resonance frequencies as a function of the core thickness for a 6.3- by 3.25-in. plate with a 0.1-in. face-sheet thickness. Right: Variation of the resonance frequency as a function of the face-sheet thicknesses for a 6.3- by 3.25- by 0.5-in. constant-thickness plate.

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[1]Eighty pores per inch.

References

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