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A review of bias flow liners for acoustic damping in gas turbine combustors

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A B S T R A C T

The optimized design of bias flow liner is a key element for the development of low emission combustion systems in modern gas turbines and aero-engines. The research of bias flow liners has a fairly long history concerning both the parameter dependencies as well as the methods to model the acoustic behaviour of bias flow liners under the variety of different bias and grazing flow conditions. In order to establish an overview over the state of the art, this paper provides a comprehensive review about the published research on bias flow liners and modelling approaches with an extensive study of the most relevant parameters determining the acoustic behaviour of these liners. The paper starts with a historical description of available investigations aiming on the characterization of the bias flow absorption principle. This chronological compendium is extended by the recent and ongoing developments in this field. In a next step the fundamental acoustic property of bias flow liner in terms of the wall impedance is introduced and the different derivations and formulations of this impedance yielding the different published model descriptions are explained and compared. Finally, a parametric study reveals the most relevant parameters for the acoustic damping behaviour of bias flow liners and how this is reflected by the various model representations. Although the general trend of the investigated acoustic behaviour is captured by the different models fairly well for a certain range of parameters, in the transition region between the resonance dominated and the purely bias flow related regime all models lack the correct damping prediction. This seems to be connected to the proper implementation of the reactance as a function of bias flow Mach number.

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1. Introduction

“To stop pulsation, drill one hole […]; if that doesn't work, drill two holes!” This quote from Putnam [1, p. 168] paraphrases the advice he found in a trade journal [2] and humorously demonstrates the fact that orifices can be applied to damp acoustic pulsations.

One particular feature of the holes in a combustor liner is, that they are always purged with a cooling flow. This bias flow through the orifices has been found to have a substantial effect on the absorption characteristics of the liner. In his experiments, Bechert [3] could confirm that the absorption mechanism is dominated by the transfer of acoustic energy into the shedding vorticity when a bias flow is present. In order to distinguish such a configuration from a perforated liner without flow, it is commonly referred to as *bias flow liner*. The main advantages over Helmholtz and quarter-wave resonators are, that the bias flow liner is able to provide a broadband damping and that the actual components are already available in a combustor.

While an acoustically well designed combustor liner could decide over the stability of the combustion, its acoustic properties are rarely considered in the design of a new combustor (see the industry overview given in [4]). While a considerable amount of research is available, the industry is clearly hesitant to rely on the existing models.

The high potential of bias flow liners as dampers in a gas turbine combustor is well-known. However, it still seems to be an open question, under which circumstances this potential can be retrieved. One obvious complexity is due to the multitude of parameters that are involved. The amount of literature that deals with acoustic properties of orifices or perforations in general is overwhelming, so that all the parameters considered here have been addressed in the literature in some way. However, most geometries or operating conditions are very far from what is encountered in a gas turbine combustor. In particular, the presence of the bias flow is often not considered, while it is a key parameter for the combustor application. On the other hand, there exist plenty of studies aimed at the combustor application and many important conclusions could be drawn. Commonly, these studies are focused on one parameter, which additionally might be limited in its range, so a generalization of conclusions can only be assumed.

It seems to be necessary to take a step back and look at the broader picture. The scattered fragments of information need to be collected and put into perspective. However, the available experimental data varies immensely in setup, experimental method, and describing quantities, so that an unified set of data is required for the evaluation of the information. The goal of