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Role of Vertical Structures on Heat Exchange within Acoustic Standing Waves

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Abstract

Thermoacoustic cooling was proposed in the 1980's as an alternative environmentally friendly technology. Based on a gas cycle, the concept involved the immersion of a porous substrate and heat exchangers within a pressurized vessel. High amplitude acoustic standing waves supplied by an electrodynamically driven linear actuator, was used as the power source. Despite promising theoretical performance predictions, heavily based on broadly distributed software, no working prototype has ever demonstrated efficiencies that are competitive with that of conventional or other alternative technologies. The purpose of the study reported here was to quantify the cooling performance of cylindrical tubes and simplified heat exchanges in acoustic standing wave. The role of convected vortical structures, forming "hot spots," on the actual heat exchanger performance was elucidated through the use of combined particle image velocimetry (PIV) and particle laser induced fluorescence (PLIF) data. It was found that convected vortical structures tend to significantly degrade heat exchanger performance relative to predictions from linear acoustic models based on irrotational flow solutions. Computational studies of streaming flows within large amplitude standing waves were performed to illustrate their influence of the thermal performance of thermoacoustic devices. The results prompt the reconsideration of performance limits to include these factors in future thermoacoustic cooling system design.