Efficient gated proximal optimisation with covariance swarm algorithm to enhance the performance of thermoacoustic refrigeration

Sajid Hameed Siddiqui* **and Akash M. Langde**
Anjuman College of Engineering and Technology, Nagpur 440 001, India

Thermoacoustic refrigeration utilises sound waves to achieve low temperatures and replaces harmful refrigerants with inert gases. However, inaccuracies in predicting oscillatory heat transfer coefficient (OHTC) and transient behaviour during dynamic phases pose challenges. A novel 'gated proximal vector optimisation with Covariance Gradient Swarm Algorithm' is proposed to address these issues, which enhances the accuracy. In thermoacoustic systems, the relationship between input parameters and the OHTC is complex and challenging to capture. This is made possible by the integration of gated recurrent proximal policy deep operator networks optimisation, which effectively captures nonlinearities and transient responses, thereby improving prediction accuracy and realistically evaluating true system performance. Moreover, the relationship between system parameters and efficiency is nonlinear with multiple peaks. The covariance adaptive swarm gradient algorithm mitigates exploitation-exploration trade-off challenges, preventing stagnation, optimising convergence rates, and promoting diversity, thereby overcoming the limitations of existing methods and improving the system performance. The result achieved by the proposed model has a lower prediction error, a higher heat transfer rate, and achieves a high coefficient of performance.

Keywords: Exploitation-exploration trade-off, oscillatory heat transfer coefficient, stagnation, swarm intelligence, thermoacoustic refrigeration.

operates within the stack (regenerator in travelling wave devices or stack in standing wave devices) by using a fluid medium (gas). Working fluid expands and contracts as it moves through these channels due to the passage of acoustic waves. By supplying an appropriate wavelength and frequency of the acoustic wave, cold heat energy is delivered to one surface of the stack and hot heat to another, allowing for refrigeration. TAR/engines are also beneficial in waste heat recovery[5–8]. A common approach to predicting the oscillatory heat transfer coefficient (OHTC) is the empirical correlation method, which relies on experimental data to establish correlations between the OHTC and relevant parameters. However, this method may lack generalizability and may not capture the intricate dynamics of thermoacoustic systems. Computational fluid dynamics simulations provide a more detailed and physics-based prediction method; however, they are computationally intensive and may struggle to capture the transient nature of thermoacoustic processes accurately. Analytical methods, such as perturbation theory, provide insights into the underlying physics but may be limited in their applicability to complex, real-world scenarios. Additionally, challenges arise due to the non-linear, time-dependent, and multi-scale nature of thermoacoustic systems, making it difficult to develop universally accurate predictive models. In summary, while various prediction methods exist, challenges persist in achieving a balance between accuracy, computational efficiency, and applicability to diverse thermoacoustic refrigeration setups[9–12]. The coefficient of performance (COP) in thermoacoustic refrigeration is predicted using methods in artificial intelligence (AI). Techniques in machine learning, such as support vector machines (SVMs), neural networks (NNs), and regression models, have been employed