INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Thesis Title: A Numerical Investigation of Roughness Facilitated Turbulent Rayleigh-Bénard Convection

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Thesis Submitted to the Department/ Center	:	Mechanical Engineering
Date of completion of Thesis Viva-Voce Exam	:	2/11/2023
Key words for description of Thesis Work	:	Rayleigh-Bénard Convection, Turbulent flows, Plumes, Thermal boundary layer

SHORT ABSTRACT

The present work involves a numerical investigation of roughness-aided Rayleigh-Bénard convection (RBC) to elucidate the dominant flow mechanism responsible for augmented heat transfer. Direct numerical simulations (DNS) in a 2D rectangular cell with air as working fluid reveal that multi-scale roughness, containing irregular triangular elements, is efficient in sustaining enhanced heat transfer scaling exponent even in the high Rayleigh range, $10^8 \leq Ra \leq 10^{11}$. The activation of small-scale roughness elements is seen to play a pivotal role in sustaining an augmented heat transport at higher Ra. Detailed analysis of the near-wall dynamics unveils the complex role of the roughness elements and the associated throat, valley, and tip regions in influencing dominant flow structures and heat transport mechanism. The extent of transformation of vertical profiles of mean temperature passing through different valley regions, from flat linear into steeper ones with increasing Ra, bears close connection with the effectiveness of the given throat region in the higher Ra regime. Incorporating the effect of Prandtl number (Pr) in the 2D roughness framework for $10^7 \leq Ra \leq 5 \times 10^9$ and $0.1 \leq Pr \leq 100$, a monotonic increasing behavior of Nusselt number (Nu) as a function of Pr is observed. This result contrasts with the near invariant behavior shown by Nu with Pr in smooth cells. In the case of 3D roughness setup with $Ra = 10^8$ and $1 \leq Pr \leq 50$, Pr is not seen to influence the global heat transport, though Nusselt number is around 50% higher compared to its smooth counterpart. The projection of strength of angular rotation of fluid flow, calculated about geometric center of the cell, onto the chosen directions reveals that roughness elements alter the preferred orientation of large-scale circulation (LSC). Through various turbulent statistics, amplified fluctuations in both bulk and near-wall regions are revealed for the roughened cells.