Abstract Index No.- 256/18/E

The thesis titled "An Analysis and Modulation of the Re-circulation Zone behind a Submerged Square Obstruction in an Open Channel Turbulent Flow" presents a comprehensive numerical study aimed at mitigating the re-circulation zone formed behind a submerged square obstruction in an open channel flow. The re-circulation zone, which typically forms in the wake of such obstructions, is characterized by flow separation, turbulence, and significant pressure drops. These phenomena can lead to flow-induced vibrations, which can adversely affect structures such as rectangular buildings or other submerged obstacles.

The study's primary goal is to explore and develop effective methods for modulating or eradicating this re-circulation zone using plane turbulent jets, multi-jet configurations, and suction forces. The research is grounded in computational fluid dynamics (CFD) simulations using the two-phase Volume of Fluid (VOF) model with open channel boundary conditions. The turbulent flow is simulated using the standard $k - \epsilon$ twoequation turbulence model, which solves the Reynolds-averaged Navier-Stokes ($RANS$) equations to capture the complex flow dynamics. In order to modulate the recirculation region several control techniques such as use of plane turbulent dual jet of three different Reynolds numbers, use of multi-jets in the form of showers and the use of suction force are adopted. The numerical model contains open channel flow with a square obstruction on the bottom surface of the channel within the fully developed region.

The presence of the re-circulation zone, indicated by negative stream-wise velocities, results in the generation of large-scale vortices and adverse pressure gradients. These vortices lead to vortex-induced vibrations (VIV), flow-induced vibrations (FIV), and wake-induced vibrations (WIV), which are detrimental to structural integrity. The thesis focuses on employing several control techniques to mitigate these effects, including the use of dual-plane jets at various Reynolds numbers, showers of jets distributed over the surface, and suction forces applied near the wake region. Through a systematic investigation of these control strategies, the research demonstrates that varying jet velocities, the variation of the Jet-spread length (l), and configurations can effectively modulate the re-circulation zone. The numerical simulations

show that increasing the Reynolds number of the jet can significantly reduce or reallocate the re-circulation region. Additionally, the study explores the effects of different jet discharge velocities and spread lengths on the wake, revealing that these parameters have a direct impact on the size and intensity of the re-circulation zone.

A key finding of the research is the correlation between the jet's Reynolds number and the pressure distribution in the wake. As the jet velocity increases, the pressure drop behind the square obstruction diminishes, leading to an improved pressure recovery. This reduces the adverse pressure gradient and consequently mitigates the formation of large vortices. The study also finds that the turbulent kinetic energy (TKE) and turbulent dissipation rate (TDR) are closely linked to the modulation of the re-circulation zone. Controlling these turbulent properties can minimize flow-induced vibrations, leading to more stable flow conditions.

The practical implications of this research are significant, particularly in engineering applications where flow-induced vibrations pose a risk to structural stability. The modulation techniques studied in this thesis can be applied to optimize the design of hydraulic structures, improve the flow around buildings and bridges, and enhance environmental fluid dynamics in natural water bodies. By effectively controlling the recirculation zones in these scenarios, the study provides a pathway to reduce energy losses, enhance structural performance, and minimize environmental impacts.