Impinging jets are important in many engineering applications, such as heating, cooling, drying and Short Takeoff and Landing (STOL) aircrafts, as well as in understanding some of nature’s phenomena, such as microbursts. There are numerous studies on the heat transfer from the surface upon which the jet impinges, but comparatively very few investigations of the space-time characteristics of the pressure fluctuations acting on the impingement wall. Moreover, the bulk of the latter investigations lack concurrent flow-field information, and therefore their conclusions regarding the pressure generation mechanisms remain largely hypothetical. The current study investigates the impinging-jet flow structures and their relation to the wall-pressure signature employing simultaneous unsteady-surface-pressure measurements, using a microphone array, and time-resolved flow visualization, using the smoke-wire technique, in an axisymmetric jet in normal and oblique impingement. The investigation is conducted at a jet Reynolds number based on diameter of 7334 for separations between the jet exit and the impingement plate ranging from two to four jet diameters, at normal and 30° oblique impingement angles.

Spectral analysis of the surface pressure fluctuations show that the flow above the wall contains higher Strouhal numbers when the plate is placed closer to the jet exit. The flow structures and mechanisms responsible for generating the pressure fluctuations at these Strouhal numbers are revealed using the simultaneous pressure and flow visualization information. It is found that within the wall-jet region, where the highest pressure fluctuations are observed, the pressure fluctuations are predominantly influenced by the advection and evolution of the jet vortices and their interaction with each other and with the wall. These vortices are observed to exhibit one of two scenarios within the wall jet zone: to pass without mutual interaction, or to merge as they travel above the wall. In the passage scenario, as the vortex travels above the wall, it very often forms a secondary vortex, via interaction with the wall. This interaction leads to the generation of a strong negative pressure spike at the radial locations where the pressure fluctuation is large. A qualitatively similar signature is also found in the vortex merging scenario, although in this case the pressure spike is substantially stronger and
secondary-vortex formation could not be seen in the smoke visualization. In order to study this phenomenon in more details, numerical computations of related model problems are carried out using Ansys Fluent. These problems involve the evolution of a single and dual axisymmetric vortex rings that interact with a flat wall. The resulting databases are analyzed by studying the volumetric distribution of the wall-pressure sources and their wall-pressure imprint using Green’s function solution of Poisson’s equation for pressure. The results reveal pressure signatures that are qualitatively similar to those observed experimentally in the impinging jet. The pressure-source analysis reveals the mechanisms leading to these signatures and the associated contribution of the individual flow features.