This work is an investigation of the behavior of a perfectly premixed turbulent jet flame in a cylindrical dump combustor. The degeneracy of the simple configuration in this study lends itself for a detailed study of inherent mechanisms of a self-excited thermoacoustic instability in isolation from system coupling effects, enabling detailed numerical simulations to be carried out to supplement experimental findings. Tests were done at a nominal pressure of 8 bar and inlet temperature around 450 °C. Self-excited large eddy simulations were also carried out in OpenFOAM, using a flame-wrinking model to model the combustion process. Eigenfrequency analysis in COMSOL was also done to support and explain the findings from both the numerical simulations and trends observed in the experiments. Measurements from high frequency pressure transducers were analyzed to determine the frequencies of the excited modes in the rig test and compared to the spectra from the LES simulation. The time-resolved fields from the LES simulation were phase-averaged to deduce the acoustic-flame interactions. Despite the (axis)symmetry in this configuration, the non-axisymmetric 1T and 1T1L modes were (simultaneously) excited. Two distinct behaviors are noted for the dynamic flame behavior. In the downstream region, the flame motion is well described by a bulk kinematic displacement as a result of the interaction of the flame front with the local acoustic perturbation. In the upstream region, near the combustor dump plane, large-scale wrinkles are observed in the flame front that have characteristics of a convective wave. The current findings provide additional evidence supporting and further establishing the theory of inherent flame displacement as an excitation mechanism (distinct from acoustically-induced axial flow fluctuations) for high-frequency, transverse thermoacoustic instabilities.