The application horizon of particle accelerators has been widening significantly in recent decades. Where large accelerators have traditionally been the tools of the trade for high-energy nuclear and particle physics, applications in the last decade have grown to include large-scale accelerators like synchrotron light sources and spallation neutron sources. Applications like generation of rare isotopes, transmutation of nuclear reactor waste, sub-critical nuclear power, generation of neutrino beams etc. are next area of investigation for accelerator scientific community all over the world. Such applications require high beam power in the range of few mega-watts (MW). One such high intensity proton beam facility is proposed at Fermilab, Batavia, US, named as Project-X. Project-X facility is based on H-ion linear accelerator (linac), which will operate in continuous wave (CW) mode and accelerate proton beam with average current of 1 mA from kinetic energy of 2.5 MeV to 3 GeV to deliver 3MW beam power. One of the most challenging tasks of the Project-X facility is to have a robust design of the CW linac which can provide high quality beam to several experiments simultaneously. Hence a careful design of linac is important to achieve this objective.

H-ion is non-relativistic at kinetic energy of 2.5 MeV and its velocity changes very rapidly with acceleration in Project-X linac. Thus, the linac uses several types of accelerating structures which are optimized for different particle velocities to provide efficient acceleration. Project-X linac has evolved over recent years from pulsed version to continuous wave (CW) version, so cavities are designed for both of these versions using simulation approach. In the pulsed (earlier) version of the linac, there already exists a 11-cell, 1.3 GHz design of cavity. HOMs study of the cavity is performed and asymmetrical design of the end cell is proposed. Further, an alternate version of the cavity design based on 9-cell is also proposed. In latest (CW) version of the linac, 5-cell, 650 MHz cavities are designed for the intermediate and high energy sections corresponding to $\beta_G = 0.61$ and $\beta_G = 0.90$. Shapes of these cavities are optimized to achieve maximum acceleration and minimum power dissipation to reduce cryogenic losses. A systematic study is performed to understand the effects of excitation of resonance of HOMs on beam quality and resultant power dissipation. Analysis of HOMs provides better understanding of the requirements of HOM damper for these cavities.

Further, a robust lattice is designed for reliable operation of CW linac which preserves beam quality and allows robustness in design parameters such as accelerating gradients in cavities, focusing gradient in magnets etc. Studies based on beam tracking codes are performed for the baseline lattice to analyze beam trajectory and beam emittance. An essential measure of a successful accelerator system is its ability to provide high beam availability and high reliability. To improve the reliability of linac, possibility of failure of beam line elements are included in the lattice design. Operation of the linac at CW mode puts stringent tolerances on beam transport elements, especially at low energy section, which increases the possibility of temporary or permanent loss of accelerating cavities and focusing magnets during the operation of linac. Lattice should be robust enough to have a capability that RF cavity or magnet failure may be compensated locally by using the neighbouring elements. The numbers of cavities and focusing...
magnets in a cryomodule are chosen in such a way that at least one failure of RF cavity or focusing magnet can be compensated locally.

A standard procedure developed for the fabrication of 1.3 GHz, 9-cell cavity at mass scale, is discussed in this work. Similar approach will be used for the fabrication of 650 MHz cavities for the CW linac. Deep-drawing method is commonly used to fabricate Niobium cavity. Quality of inner surface of cavity degrades during process of fabrication which may limit maximum accelerating gradient in cavity. Thus, it is passed through sequence of surface treatments in order to remove defects from production process. Surface treatments involve chemical etching, high pressure water rinsing and heat treatment of cavity. After all treatments, performance of a single-cell cavity like accelerating gradient and quality factor is tested at 2K in the vertical-test stand (VTS) facility at Fermilab.