Gear tooth surface wear is a common failure mode. It occurs over relatively long periods of service nonetheless, it degrades operating efficiency and leads to other major failures such as excessive tooth removal and catastrophic breakage. To develop accurate wear detection and diagnosis approaches at the early phase of the wear, this paper examines the gear dynamic responses from both experimental and numerical studies with increasing extents of wear on tooth contact surfaces. An experimental test facility comprising of a back-to-back two-stage helical gearbox arrangement was used in a run-to-failure test, in which variable sinusoidal and step increment loads along with variable speeds were applied and gear wear was allowed to progress naturally. A comprehensive dynamic model was also developed to study the influence of surface wear on gear dynamic response, with the inclusion of time-varying stiffness and tooth friction based on elasto-hydrodynamic lubrication (EHL) principles. The model consists of an 18 degree of freedom (DOF) vibration system, which includes the effects of the supporting bearings, driving motor and loading system. It also couples the transverse and torsional motions resulting from time-varying friction forces, time varying mesh stiffness and the excitation of different wear severities. Vibration signatures due to tooth wear severity and frictional excitations were acquired for the parameter determination and the validation of the model with the experimental results. The experimental test and numerical model results show clearly correlated behaviour, over different gear sizes and geometries. The spectral peaks at the meshing frequency components along with their sidebands were used to examine the response patterns due to wear. The paper concludes that the mesh vibration amplitudes of the second and third harmonics as well as the sideband components increase considerably with the extent of wear and hence these can be used as effective features for fault detection and diagnosis.