ABSTRACT

There exists an ever-increasing demand for the lightweight materials, capable of meeting rigorous demands of new technologies. In this regard, the advanced aluminium alloys present a favourable solution. They have good strength and aesthetic appearance, lower density, higher resistance to corrosion, good machinability and integrity at a wide range of temperatures. The high-strength aluminium alloys have potential application in the lightweight structural panels of aircraft, spacecraft, defence, automobiles and other high-performance application areas.

The transportation and defence-related structural components may be exposed to extreme loading conditions, such as impact, shock, blast or collision and undergo severe plastic deformation and fracture. The performance of structures depends on the mechanical behaviour of its material, which changes with the strain rate and temperature. At high loading rates, the stress wave propagation phenomenon is more prominent and special experimental techniques are required to achieve the dynamic stress equilibrium and acquire the constitutive behaviour of the material. Similarly, the resistance (toughness) of the material to fracture initiation/propagation also changes with the loading rates and temperatures. The failure mechanism of structural panels of body armour or sheltering structures also depends on the velocity of the projectile. Hence, the thermal softening and strain rate (loading rate) sensitivity of the constitutive behaviour, fracture toughness and impact resistance of aluminium alloys needs to be understood for the design of important *lightweight structures*.

The present thesis considers one zinc-based precipitation-hardened aluminium alloy (AA7475-T7351) with relatively higher strength at extremely low (cryogenic) and elevated temperatures. The Zwick/Roell Z50 Universal Testing Machine is used to investigate the mechanical behaviour of aluminium AA7475-T7351 under low rates of

tensile and compressive strains. The tensile and compressive Split Hopkinson pressure bar setups (SHTB and SHPB) are used to investigate the response of the material at high strain rates. An extensive experimental investigation has been conducted to estimate the tension-compression asymmetry and anisotropic behaviour of thin AA7475-T7351 panels at different temperatures and different rates of loading.

The experimental study on AA7475-T7351 is extended to examine the fracture initiation and propagation behaviour of the material at different loading rates and temperatures. The crack mouth opening displacements (CMOD) are estimated from the three-point bend experiments under Zwick/Roell-50 and MTS-250 machines for quasi-static and lower loading rates, respectively. The modified Hopkinson pressure bar setup is used to estimate the stress intensity factor (SIF) of the three-point bend specimens at higher rates of loading. The initiation and propagation fracture toughness of AA7475-T7351 aluminium alloy along the rolling (L-T) and transverse (T-L) directions are studied through a series of experiments. Further, a single-stage gas gun is used to investigate the dynamic response of aluminium AA7475-T7351 panels under non-deformable blunt and hemispherical-nosed projectiles in the velocity range of 120-250 *m/s*. In all the experiments, the digital image correlation technique is used to obtain the full field deformation profile of the specimens under dynamic loading conditions.

The designers need to depend on the numerical simulation of structural components, as the experimental testing of actual structures may not be feasible. Hence, an accurate constitutive model to represent the deformation and fracture behaviour of the material is extremely important. The results of tension, compression and fracture experiments are used to study the applicability of existing material models. Thereafter, the Johnson-Cook constitutive and failure model (with evaluated material constants for AA7475-T7351) is used for the three-dimensional finite element simulation of representative problems. A satisfactory agreement between the experimental and numerical results is observed in the thesis.