Chapter 2
Literature Review

2.1 Tracked-Vehicle Mechanics

Tracked vehicles have been in use for more than two centuries, and used in many applications such as military, construction, and agricultural [Bekker, 1956]. Many studies dealing with tracked vehicles have been done and published since then; nevertheless, there are only a few of them relevant to our interest. Bekker [1956, 1960, 1969] could be considered to be the first person who made extensive ground work in the field of tracked vehicle mechanics. He proposed and established the fundamental concepts of tracked vehicle mechanics, which have been widely accepted and used by later researchers in this field. His works were later revised and reorganized by Wong [1978].

Kitano and Jyozaki [1976] investigated the problems concerning steerability, stability, and relevant behavior of a tracked vehicle operated at high speeds on level paved ground. They developed equations of uniform turning motions of the tracked vehicle based on both the assumption that the pressure distribution beneath both tracks are modeled as concentrated forces acting under each road wheel, and the assumption that the friction between ground and track is Coulomb friction and constant. Subsequently, Kitano and Kuma [1977] presented a mathematical model of the non-stationary motion of a tracked vehicle maneuvered on level hard ground. The model employed a pull-slip equation obtained from pull-slip tests to approximate the friction coefficient varying with the amount of track slip, and was simulated using a digital computer for the analysis and prediction of steering characteristics of tracked vehicles under different operating conditions.

Fifteen years later, Kitano's tracked vehicle model, including two other less sophisticated models, was slightly modified and evaluated by Ehlert, et al. [1992]. The simulation results from the modified models were verified by comparison with field measurement data and among the simulation results from different models themselves. They summarized that the Kitano model could be used to closely predict the radius of turning of tracked vehicles. Furthermore, radius enlargement factors could be determined by means of the Kitano model, and be utilized to improve accuracy of the other two models. In the same year, Murakami, et al. [1992] proposed a mathematical model which predicts the spatial motion of a tracked vehicle on non-level soft terrains, and an advanced soil-track interaction model, based upon soil plasticity theories.

Shiller and Serate [1995] presented a dynamic model of a tracked vehicle by assuming Coulomb friction between tracks and ground, uniform normal pressure distribution under the tracks, and the center of mass located at the geometric center of the vehicle. The model was employed in their work for computing the track forces and track speeds of the tracked vehicle, which are required to follow a given path at specified speeds on horizontal and inclined planes. Recently, Le, et al. [1997] developed a relatively simple model of tracked vehicle based upon Shiller's model. The model was improved by adopting a more accurate soil model and taking into account all resistive ground forces.

2.2 Mechanics of Track-Terrain Interaction

To develop a high fidelity tracked-vehicle model, fairly accurate track-terrain interaction relationships must be employed. There are many studies of track-terrain interactions that have been examined. These studies can be categorized according to methods utilized into three groups. The first group, Empirical Methods, exploits empirical approaches where tracked-vehicles or scale models are tested in a range of known property terrains considered to be representative. Then, the results of testing are empirically correlated with the terrain types. The outcomes can be used in estimating the interaction between the tracks and the terrains of the vehicles with design features similar to those that have been tested under similar operating conditions. On the other hand, the second group, Theoretical Methods, mostly applies the theory of plastic equilibrium and finite element method to the analysis of the track-terrain interaction problems. In the last group, Semiempirical Methods, mathematical models are developed, based on experimental data, to predict the behavior of the track-terrain interactions [Wong, 1989].

However, the Empirical and Theoretical Methods each has a major drawback in cost-effectiveness and the requirement of extensive computational power, respectively.

The Semiempirical Methods are thus chosen to be the approaches that are used to determine the track-terrain interaction relationships. In the next paragraph, only the literature review of the Semiempirical Methods will be discussed.

A pioneering effort in the study of the track-terrain interactions, using Semiempirical approach, was made by Bekker [1956, 1960, 1969]. Bekker proposed semiempirical equations for describing the pressure-sinkage relationship and the shear stress-displacement relationship, which are widely used in the field of Terramechanics. Based on Bekker's work, Wong [1978, 1989] extended the use of those two relationships in many applications, and also developed a more precise analytical model for predicting the ground pressure distribution and tractive performance of tracked vehicles. This model takes into account the effects of many major factors such as track dimensions, initial track tension, suspension heave stiffness, and the response of the terrain to repetitive loading.