CHAPTER 1

INTRODUCTION

The primary purpose of agricultural tractors is to perform drawbar work. This is defined by pull and travel speed. Research shows that about 20-55% of the available tractor energy is wasted at the tyre-soil interface. This energy wears the tyres and compacts the soil to a degree that may be detrimental to crop production (Burt and Bailey, 1982). Efficient operation of farm tractors includes: (i) selecting an optimum travel speed for a given tractor-implement system (ii) maximizing the tractive advantage of the traction devices, and (iii) maximizing the fuel efficiency of the engine and drive train.

Land preparation is one of the most energy consuming operations in the field. The energy utilized by a tillage practice depends on many factors such as soil type and condition, operating depth, travel speed, and hitch geometry. Optimizing the tractor performance in the field depends on the proper matching of the tractor and the implements, which could help in minimizing the fuel consumption and energy loss (Abbouda *et al.*, 2001). The tractive effort can be basically enhanced by increasing the area of contact between the tractor wheels and the soil surface, and reducing the abnormal slippage.

1.1 Tractive Efficiency as Influenced by Wheel Slip

Wheel slip is defined as the relative movement in the direction of travel at the mutual contact surface of a traction device and the support surface (ASAE, 1983). Slip has, therefore, a greater role in determining tractive effort. Tractive efficiency is the fraction of power available at the axle that is actually delivered to an implement through the drawbar. Zoz (1972) has shown that for each soil condition, there is an optimum range of slip where tractive efficiency is the highest (Fig.1.1). During the field operation of tractors, a significant portion of the energy is lost due to rolling resistance as well as the slippage of the traction wheels. Maximum tractive efficiency results from a compromise between minimizing rolling resistance and optimizing slip of the wheels.

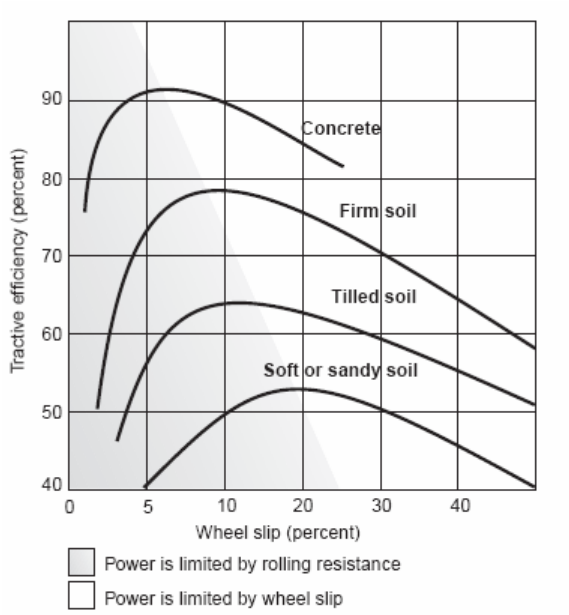

Fig. 1.1: Tractive efficiency influenced by slip

Tyres and tracks operate at their maximum efficiency within a certain range of slip. Therefore, the slip could be used as an indicator of the tractor performance on site for a particular condition. Operating the tractor in an optimum slip range would in turn help in conserving the fuel and thereby increasing the field capacity.

The draft control system of the tractor is incorporated to automatically keep tractor effort constant by varying the depth of operation within narrow limits. But the commercial draft control systems engaged in today's tractors are found inefficient in keeping the draft control in line with the slip (Dwyer *et al.*, 1974). The implement when lifted at an angle produces a component of vertical force which nullifies the effect of downward opposing force and tends to cancel the original signal of lifting the implement (Dwyer, 1969; Crolla and Pearson, 1975). Researchers have investigated the problem for long time and concluded that the commercial draft control system forces the operator to control the lever frequently for achieving the optimum draft, resulting in poor efficiency (Dwyer *et al.*, 1974; Cowell and Milne, 1977). Increasing the sensitivity of the commercial draft control systems even to infinity was found to diminish the improvement of implement control (Dwyer, 1969). It has been shown that there is no scope in improvement of the existing draft control systems due to this limiting nature (Dwyer *et al.*, 1974).

1.2 Wheel Slip: Measurement and Control

Knowing the importance of wheel slip, several attempts have been made to measure this parameter. Researchers have used different techniques like Doppler/microwave radar device (Stuchly *et al*., 1976; Freeland *et al*., 1988; Wang and Domier, 1989; Khalilian *et al*., 1989; Grisso *et al*.,1991; and Reed and Turner, 1993) and electronic circuits using photo-transducer (Zoerb and Popoff, 1967; Lyne and Meiring, 1977; Clark and Gillespie, 1979; Jurek and Newendorp, 1983; Grevis-James *et al*., 1981; Erickson *et al*., 1982; Shropshire *et al*., 1983; and Musonda *et al*., 1983) for accurate measurement of slip. Most of these techniques were tractor specific, costly and of unproven reliability for instantaneous measurement of slip. These techniques were based on calculation of theoretical velocity on test bed instead of operating on a hard surface which is essential for defining zero condition.

Further, only a few researchers have worked on dynamic wheel slip control, out of which, the dynamic ballasting is important one (Tan *et al.*, 1994). However, ballasting increases the overall weight of the tractor which increases the rolling resistance of the tyre and compaction of the soil. This compaction leads to the reduction in crop yield. Skotnikov (2001) suggested a slip control system by controlling the inflation pressure in the traction tyres. This, on the other hand, increases the contact area when tyre inflation pressure is reduced. Another method of controlling the slip is by adjusting the depth of operation (Ismail *et al*., 1981) or by regulating the forward speed. In the field, the change in slip due to variation in soil conditions is better managed by manually altering the depth of operation with hydraulic control lever. These adjustments, however, do not achieve desired results but cause unacceptable depth variations in the field. This calls for an auto-depth control device to be incorporated to automatically adjust the depth of implement for maintaining slip in a specified range throughout the duration of field operation.

1.3 Scope and Justification

Studies indicate that slip has a dominating role in improving the tractive performance. The tractors operate at peak efficiency if their slip is maintained in a certain optimum range. However, this is not possible with the existing draft control system of the rear wheel driven tractors because this system cannot control draft efficiently due to varying soil conditions within the field. The excessive slip encountered during the

operation is normally reduced by increasing the frequency of operation of hydraulic depth control lever which is quite strenuous and hence not followed as frequently as desired (Ismail *et al*., 1981; Dwyer and Rogie, 1972). A possible solution to this problem could be to control the slip by altering the depth of operation by means of an auto depth control device. The system is required to continuously measure and control slip within a pre-specified range throughout the operation under the actual field condition. As soon as the slip goes beyond the range, the system should be capable enough to control and bring back the same in the specified range. Such a system is desirable to give a faster response as compared to the existing hydraulic draft control system. This system would overshoot the draft control mechanism for effective implement position control. Keeping these arguments in view, the present investigation has been planned with the following major objectives:

Objectives

1. Development of a slip sensing device for 2WD tractors for online estimation of wheel slip.
2. Development of a slip control system for peak tractive efficiency and best fuel economy under actual field condition.
3. Field testing and performance evaluation of the developed slip control system under varying operating conditions.

1.4 Contribution from the Study

The developed slip control system enables the tractor to operate at higher tractive efficiency with lower fuel consumption per hectare and also reduces the operator's effort as the depth control lever is automatically adjusted as per the variation in the soil condition within the field. The system is capable to be fitted on any make and model of the tractor, making it a universal slip management device.