MOBILITY INVESTIGATION OF LGP-30 WHEELED VEHICLE ON PEAT TERRAIN

BY

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A dissertation submitted in partial fulfillment of the requirements of the degree of Master of Science in Automotive Engineering

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ABSTRACT

This project describes a simulation model and field test to study the basic design parameters of a Low Ground Pressure (LGP-30) wheeled vehicle on Sepang peat terrain in Malaysia. The tractive performance justification of an off-road vehicle is so important that it ensures the vehicle mobility over the unprepared peat terrain. Tractive performance of (LGP-30) wheeled vehicle is investigated on the low bearing capacity moderate peat terrain in Malaysia. The simulation results showed that the vehicle sinkage is more than the critical sinkage value of 100 mm, ground contact pressure is more than 17 kN/m^2 and rolling motion resistance due to terrain compaction is very often more than the tractive effort of the vehicle. The vehicle was tested on the unprepared moderate peat terrain after increasing the tire-terrain interfaced by decreasing the tire inflation pressure of 5%, 10% and 15% respectively. The vehicle was found to traverse on the terrain smoothly when the tire inflation pressure was decreased by 15%. It is thus concluded that the vehicle would not be suitable to traverse on the peat terrain at other inflation pressure. Finally, some suggestions were made on the design optimization as well as recommendation for operation-wise approaches.

ملخص البحث

يصف هذا المشروع نموذج محاكاة واختبار ميداني لدراسة معايير التصميم الأساسي لضغط الأرض منخفض (LPG-٣٠) بعجلات السيارة على أرض الخث سيبانغ في ماليزيا. التبرير أداء الجر للسيارة على الطرق الوعرة من الأهمية بمكان بحيث أنه يضمن التنقل عبر التضاريس السيارة مستعدين الجفت. بعجلات من أداء الجر (LPG-٣٠) هو التحقيق السيارة على قدرة تحمل منخفضة التضاريس الجفت المعتدل في ماليزيا. وأظهرت نتائج المحاكاة أن تغرق السيارة أكثر من قيمة بالوعة الحرجة من ١٥٥ ملم ، والاتصال هو الضغط الأرض أكثر من ١٧ m/kN^2، والمتداول المقاومة الحركة بسبب الضغط التضاريس في كثير من الأحيان أكثر من جهد الجر للسيارة. تم اختبار السيارة على أرض الخث المعتدل غير مستعد بعد زيادة واجهة الإطارات التضاريس عن طريق خفض ضغط الاطارات التضخم من ٥ ٪ و ١٠ ٪ و ١٥ ٪ على التوالي. تم العثور على السيارة لاجتياز التضاريس على نحو سلس وعندما انخفض ضغط الاطارات التضخم بنسبة ١٥ ٪. واختتمت بأن السيارة لن تكون مناسبة لتعبر عن التضاريس الجفت في ضغوط التضخم الأخرى. أخيرا، قدمت بعض الاقتراحات بشأن تحسين تصميم وكذلك توصية لعملية النهج الحكيم

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion; it confirms to acceptable standards of scholarly of presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of Science in Automotive Engineering.

..….……………………………..
Mohammed Ataur Rahman
Supervisor

I certify that I have supervised and read this study and that in my opinion; it confirms to acceptable standards of scholarly of presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of Science in Automotive Engineering.

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DECLARATION

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

Mohd Razali Bin Md Yunos

Signature:………………………………….. Date: …………………………..

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“To my beloved parents, my wife, kids and all individuals around me with gratitude for their loves, continuous support, and for helping me and praying for me and my success”

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CHAPTER 1

INTRODUCTION

1.1. BACKGROUND

The issue of labour shortage has been a big issue the agricultural sector with the restriction and increasing problem of hiring local workers. Mechanization, however, can be a solution to the issue of labour productivity but after some times the mechanization approaches is still an issue. Mechanization is an issue in agricultural sector because it is mainly dependent on the availability of the transportation for agricultural purpose as well as, among others, the suitability of the terrain surface in agriculture area. The challenge is how to get the best of mechanization to benefit the whole chain of agricultural activities sooner rather than later.

According to a report in The Star newspaper (2009), the agriculture sector contracted 2% during the first half of 2009, mainly due to lower production of palm oil. For the first nine months of 2009, crude palm oil (CPO) production fell 3.7% to 12.5 million tonnes. Production was expected to drop 4.1% to an estimated 17 million tonnes for the whole year. Oil palm cultivated areas expanded 3.9% to 4.57 million hectares as at end of June, from 4.4 million hectares in 2008. Total planted area is expected to reach 4.65 million hectares in 2009. Value-added for the palm oil sector declined 3.3% during the first half of the year due to lower crude palm oil (CPO) production. This was due to unfavourable weather coupled with increasing replanting exercise. The oil palm industry has been the backbone of Malaysia's social and economic development. Since more than 90% of its production is exported, the industry is one of the top earners for the country, contributing about RM30 billions in foreign exchange annually since 2006. As one of the world's largest producers and exporters of palm oil and its products, the Malaysian oil palm industry is the pride of the country. The Star also reported that the industry has not only improved the living standards of planters, but also provided employment to more than a million Malaysians The palm oil industry employs around 1.5 million people, of which 570,000 are in the plantation and the remainder, in core and related sectors. This statistics proves the importance of studies to be done to improve the mechanization in palm oil plantation as to maintain the country status as one of the main producer of oil palm.

To remain competitive and relevant in the context of national development, the agriculture sector must transform itself to enable increase in its productivity as much as to match market demand in terms of quality and quantity. In the current global environment there is a need to go beyond present achievement. The agriculture sector must transform radically in terms of its structure, processes, technology and culture turning it into a sector that is more customer focus, process centred, output driven and knowledge based.

This report was initiated as an effort to contribute to the improvement of mechanization in agriculture sector. In order to contribute on the improvement of productivity and efficiency of mechanization, it is important to study and measure the exact status of the current performance. Thus, this study was carried out as the outcome can be used to give some benefit in term of technological advancement on the issue addressed.

1.2. PROBLEM STATEMENT

It is very difficult to manage any vehicle operation on peat terrain to do the transportation of palm oil fresh fruit bunches (FFB) and other goods due to the problematic peat characteristics as found in Malaysia. Design and development of the off-road vehicles (used in palm oil plantation or other soft terrain) have been normally made with a comprehensive understanding of the mechanical behaviour of the terrain on which the vehicle are to be operated.

SeLadang, as an off-road transporter was developed as an in-filed oil palm fresh fruit bunches (FFB) transporter for plantation especially with low bearing capacity peat terrain. The vehicle had been developed and manufactured by the Associated Equipment Division of Tractors Malaysia Berhad as a new vehicle introduced in oil palm plantation in Malaysia. SeLadang comes in 2 models, namely RT 30 for undulating and rough terrain as well as flat and LGP 30 for low ground pressure terrain oil palm plantations respectively.

By design, SeLadang is an articulated design chassis system vehicle with following configuration.

- Rear chassis with oscillation axle for the engine and operator compartment
- Front chassis with oscillation axle for the fruit bucket compartment. These could improve the vehicle’s field manoeuvrability
- Oscillating front and rear axle could improve the vehicle traction ability in undulating terrain condition.

The vehicle has both floatation and traction problems when operating on low bearing capacity peat terrain plantations. While SeLadang’s standard configuration was expected to enable the vehicle to operate properly, driveshaft frequently failed under extensive rough operation in plantations according to the manufacturer’s service record. Both of these problems arise due to both improper selection of the engine size and inappropriate matching of engine size – transmission final drive capacity to suit the operations on the rough low bearing capacity terrain condition.

Based on the observation on the records, there is also some field and technical problems experienced by the vehicle and the operator. All of these problems were determined by either observation or the record of service and maintenance of Seladang. The first problem was discovered on the universal joint of the drive axle that connecting the clutch and the front tire differential. The problem stated that during the vehicle operated on field, the oscillation movement of the chassis had caused the drive axle to oscillate too. The failure is caused by the oscillation movement of the drive axle that grazed with another axle. As the results, the universal joint fails. Sometime, the engine also failed to start. The failure is caused by the unit of the plunger in the hydraulic pump broke from its unit and fall into the crankshaft of the engine. Another reported problem was the users of Seladang where they fail to follow the service and maintenance schedule resulting of the overheated of the engine.

The problems on the field also occur where the vehicle travelled on the low bearing capacity and consequently the vehicle to sink into the ground. This could be caused by either the vehicle was used on the lower than permissible bearing capacity or the vehicle was overloaded.

1.3. PROJECT OBJECTIVES

The ultimate objective of the project is to overcome the frequent mechanical problems of the driveshaft of SeLadang LGP 30 and to improve the tractive performances of the vehicle as an in-field oil palm FFB transporter for the plantation with low bearing capacity peat terrain.

In doing so, three specific objectives were achieved. The specific objectives are:

1. To study a mathematical algorithm for predicting the required driving torque and tractive effort at the drive wheels of SeLadang in field transporter during its manoeuvre.
2. To measure in real time tractive effort, driving torque and slippage at each drive wheel of the vehicle and study their distribution during manoeuvre at its payload low bearing capacity peat terrain.
3. To determine proper working parameter and configuration for the vehicle in order to give optimum tractive performance at it payload on low bearing capacity peat terrain.

1.4. SUMMARY OF METHODOLOGY

The works in this project involved a study of the possibility to overcome the frequent mechanical problems of the driveshaft of SeLadang LGP 30 and to suggest some improvement of the tractive performances of the vehicle as an in-field oil palm FFB transporter for the plantation with low bearing capacity peat terrain.

In order to achieve the ultimate objective as mentioned above, three specific objectives were first achieved. Firstly, some studies were done to understand the mathematical algorithm for predicting the required driving torque and tractive effort at the drive wheels of SeLadang LPG-30 during straight manoeuvre at its payload on low bearing capacity peat terrain. Afterwards, the tractive performance of the

SeLadang LPG-30 wheeled vehicle on the low bearing capacity peat terrain was investigated both by simulation and experimentally. Finally, the findings were used to suggest the optimization of the existing design of the SeLadang LPG-30 wheeled vehicle for low bearing capacity peat terrain.

1.5. THESIS OUTLINE

This thesis is structured into five chapters. The first chapter of this thesis provides some essential introduction about project background and the tractive performance investigation objectives and methodology preface. Basic information about current vehicle's condition and the peat terrain problems are also briefly explained.

Chapter 2 provides the literature review of traction mechanics of pneumatics tires on low bearing capacity or soft terrain, soil mechanics and tractive performance considerations. Some previous researches and projects using various methods to predict tractive performance of off-road vehicle are also described.

The methodology of research, including simulation approaches and field test, is described in detail in Chapter 3. In this chapter, algorithm simulation, equipment setup and field test implementation are explained.

The results are tabulated and compared between two methods of analysis in Chapter 4 to assist the understanding prior to making conclusions. Finally, summary and recommendation are presented in Chapter 5.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter covers the understanding of terramechanics as a significant area which deals with principles for the engineering and scientific knowledge of operation of off-road vehicles and machinery. As a main focus of the project, understanding of traction mechanics of pneumatics tires is vital for the design optimization consideration. In addition, for a given off-road and traction application, there are many subjects to consider in setting an optimum performance parameter. The appropriate weights for the load and suitable weights for the vehicle are critical consideration. In addition, the tires and the tire settings appropriate for the load and ground condition are also required to be considered. Likewise, the tractor running at an appropriate ground speed for the load and available power must also be considered. Investigation done on the performance throughout the operating range of a tractor makes it possible to answer these questions, to suggest changes or improvements to the operator and to show the effect of changes that are made. The clearer the experiment and simulation show understandable effects, the more useful they are to the industrial player.

2.2 TERRAMECHANICS

In general, terramechanics is a study of the overall performance of a machine in relation to its operational, environment and the terrain. It has two main branches which are terrain-vehicle mechanics and terrain-implement mechanics [J. Y. Wong, 1984]. Terrain-vehicle mechanics is concerned with the tractive performance of a vehicle over unprepared terrain, ride quality over undulating surfaces, obstacle negotiation and avoidance, and water-crossing. Terrain-implement mechanics, on the other hand, deals with the performance of terrain-working machinery, such as soil cultivating and earth-moving equipment.

Terramechanics is an applied science and its success (or failure) is judged by the practical results it produces in the solution of technological problems. In recent years, the growing concern over energy conservation and environmental protection has further stimulated the study of terramechanics. After all, the aim of terramechanics is to provide guiding principles for the rational design, evaluation, testing, selection and operation of off-road vehicles and terrain-working machinery. In the furtherance of this branch of applied mechanics, one should not lose sight of this fundamental objective. In addition to being a good engineering design in the traditional sense, an off-road machine is now expected to attain a high level of energy efficiency and not to cause undue damage to its operational environment, such as excessive soil compaction in agriculture and tearing off surface vegetation on tundra and muskeg in northern transportation. The increasing activities in line exploration and exploitation of natural resources in new frontiers, including remote areas and sea-bed, have also given much new impetus to the development of terramechanics [Wong, 1984].

Looking ahead, it appears that terramechanics has to meet the growing demands for improved reliability and accuracy in the prediction of machine performance over an increasing range of operational environments. The procedures and methods based on terramechanics principles have to be developed and implemented in such a manner that will be more conducive to practical results and appeal to a wider spectrum of engineering practitioners.

2.3 TRACTION MECHANICS OF PNEUMATICS TIRES

Tire functions as a vehicle to road interface to supports vehicle load, absorb road irregularities and to provide road surface friction. The primary function of tires is to provide the interface between the vehicle and the ground. It is expected that small patches of rubber to guide a vehicle safely in a rainstorm, or to allow the vehicle to be turned fast at an exit ramp, or to negotiate potholes without damage.

Historically, pneumatic tires began in Great Britain during the late 1800s as an upgrade from solid rubber tires. They had small cross-sections and high pressures, principally for bicycle applications. Larger "balloon" tires were introduced in the early 1920's with applications in the mushrooming motor vehicle industry. Tubeless tires were introduced with improvements in rim design in the early 1950s. Belted bias tires became popular in the late 1960s. Radial tires, first introduced in Europe, became popular in the USA starting in the early 1970s and now dominate the passenger tire market [Lindenmuth, 2006].

Vehicle load causes tires to deflect until the average contact area pressure is balanced by the tires' internal air pressure. Assuming a typical tractor tire is inflated to 45 psi, and then a 450 lb load would need an average of 10 square inches of contact area to support the load. Larger loads require more contact area (more deflection) or higher tire inflation pressures. A larger contact area usually requires a larger tire. Fortunately, industry standards exist for these requirements. Basically, the heavier vehicle (and the load) will perform better with larger tires and higher inflation pressure.

The ability of vehicles to start, stop and turn corners results from friction between the ground and the tires. Tire tread designs are needed to deal with the complex effects of weather conditions: dry, wet, snow-covered and icy surfaces. Slick racing tires or bald tires may have good traction on dry surfaces, but may be undriveable in wet, rainy conditions due to hydroplaning. Tire tread designs enable water to escape from the tire-road contact area (the tire footprint) to minimize hydroplaning, while providing a reasonable balance between the sometimes conflicting requirements of good dry traction, low wear and low noise. Since tire can absorbs road irregularities, the tire act as a spring and damper system to absorb impacts

Better traction of tractors as traction machines comes from good tires. An understanding of the basic nature of the interaction between the running gear and the terrain is essential to the study of performance characteristics, ride quality, and handling behaviour of ground vehicles [Wong, 1993].

An understanding of the basic characteristics of the interaction between the running gear and the ground is, therefore, essential to the study of performance characteristics, ride quality, and handling behaviour of ground vehicles. Aside from aerodynamic and gravitational forces, all other major forces and moments affecting the motion of a ground vehicle are applied through the running gear–ground contact.

The running gear of a ground vehicle is generally required to fulfil the following functions:

- to support the weight of the vehicle, to cushion the vehicle over surface irregularities,
- to provide sufficient traction for driving and braking,
- to provide adequate steering control and direction stability.

Pneumatic tires can perform these functions effectively and efficiently; thus, they are universally used in road vehicles, and are also widely used in off-road vehicles. The study of the mechanics of pneumatic tires therefore is of fundamental importance to the understanding of the performance and characteristics of ground vehicles. Two basic types of problem in the mechanics of tires are of special interest to vehicle engineers. One is the mechanics of tires on hard surfaces, which is essential to the study of the characteristics of road vehicles. The other is the mechanics of tires on deformable surfaces (unprepared terrain), which is of prime importance to the study of off-road vehicle performance.

Off-road tire selection considerations give optimum tractive performance assessment of off-road vehicle traversing on low ground bearing peat terrain. Unlike on road vehicles, where ground can be considered infinitely rigid, when studying off road tires, ground substantially deforms and its condition and preparation are of utmost importance. Through a close investigation of related literature, it is learnt that the performance of the vehicle on a peat terrain is, to a great extent, dependent upon the manner in which the vehicle interacts with the terrain. Thus far, it is very difficult to manage any vehicles to do the transportation of palm oil fresh fruit bunches and others goods and operations on peat terrain [Ataur, 2005]. Various features have been incorporated to increase the mobility of off road vehicles however the tire remains the most significant unknown parameter. Regardless of substantial research, there is still a lack of a comprehensive understanding of the tire-terrain interaction. For further development a more complete understanding is required through advance researches.