Tarım Makinaları Bilimi Dergisi (Journal of Agricultural Machinery Science)
2011, 7 (1), 7-12

A Track Type Oil Palm Fresh Fruit Bunch In-Field Transporter for Low Bearing Capacity Peat Terrain

Mohammad Hadi GHASSEMI[1], Azmi YAHYA[1], Ataur RAHMAN[2]
[1]Department of Biological and Agricultural Engineering, Faculty of Engineering,
University Putra Malaysia, 43400 UPM Serdang,
Selangor DE-MALAYSIA
[2] Department of Mechanical Engineering, Faculty of Engineering,
International Islamic University Malaysia,
50728 Kuala Lumpur-MALAYSIA
m.h.qassemi@gmail.com

Received (Geliş Tarihi): 09.05.2011 Accepted (Kabul Tarihi): 10.07.2011

Abstract: A tracked type vehicle with 1800 mm X 350 mm size metal reinforced rubber tracks and 550 kg capacity rear tipping fruit bin has been successfully designed, developed, and evaluated to solve the problems of in-field transportation of oil palm fresh fruit bunches (FFB) on low bearing capacity peat terrain in Malaysia. This 2-men operation machine system consists of an operator who drives the vehicle and a worker who loads the cut oil palm FBB into the fruit bin of the vehicle at every picking point in the field. The machine is equipped with a 37.7 kW @ 3600 rpm 4TNE84 Yanmar diesel engine coupled in-tandem with two units of 50 cm^3/rev @ 350 bar SAMHYDRAULIK variable displacement HCV 50 Series axial piston main pumps where each pump is used to run a 565 cm^3/rev @ 250 bar SAi GM2 600 series high torque hydraulic motor to provide the rear sprocket torque for the rubber track. The required engine size was estimated based on the mathematical models for the vehicle straight and turning motions on intermediate condition of peat terrain with bearing capacity of 19.50 kN/m^2. Field performances of the vehicle under the engine speed of 1500 to 2500 rpm and total vehicle mass of 1950 to 2650 kg resulted with traveling speed ranging from 8.28 to 11.85 km/hr and 6.43 to 10.42 km/hr on asphalt and tilled soil, respectively. The vehicle average sinkage on low bearing capacity peat terrain at vehicle total mass of 2500 kg was found to be 104.2 mm which is 13.04% lower than the critical sinkage of 120 mm for the low bearing capacity peat terrain. The average sinkages under vehicle total mass from 1950 to 2650 kg ranges from 71.73 to 108.1 mm on tilled soil and 81.13 mm to 130.08 mm on low bearing capacity peat terrain. The average sinkages of the right track is greater than that of left track by 20.52% during left turning while the average sinkages of the left track is greater than that of right track by 15.98% during right turning.

Key words: Peat soil, low bearing capacity terrain, track transporter, oil palm

INTRODUCTION

Peat refers as organic soil or histosols where on the basis of mass composition contains at least 65% organic matter or conversely contains less than 35% mineral matter. Generally, highland peat does not exist extensively but the lowland peat occurs mostly in low-lying, poorly drained depressions or basins at the coastal areas. The highland peat was reported to have bearing capacity that ranges from 25 to 50 kN/m^2 while that of the lowland peat ranges from 10 to 25 kN/m^2 (MacFarlane, 1969).

Peat in Malaysia is considered as a marginal soil with an estimated area of 2,476,000 ha or 7.59% of the total land area. Rapid expansions of the manufacturing industry in the country has resulted with a major depletion in the prime soils for agriculture. The available remaining land resources under mineral soil are improper for oil palm cultivations because of its topography that relates with high establishment and maintenance cost for crop production. Due to the limited availability of prime soils, current focus for oil palm planting area expansions is on the 600,000 ha and 40,000 ha of reserved peat land in east and west peninsular of Malaysia (Dolmat, 2005).

Mobility of vehicles on peat terrain is known to be a major problem since the bearing capacity of the terrain normally could not support the total weight of most standard commercial available prime movers. Thus, conducting agricultural field activities such as fertilizing, spraying, harvesting and in-field collection for the oil palms planted in peat terrain are very challenging since the use of any available off-selves machinery for these activities are near to impossible. Track type vehicle with its high ground contact area compared to wheel type vehicle are known to have better floatation and traction on low bearing capacity terrain like peat. Previously, various types of imported track vehicles had been tested for in-field transportation of oil palm fresh fruit bunches (FFB) but none of these machines were seen to have been successfully used in the plantations. Analysis conducted by Rahman et. al (2004) indicated that all the tested imported track vehicles have ground pressures greater than the bearing capacity of the peat terrain which thus explained why the vehicles sink excessively on the terrain.

Design and development work of any track vehicle for peat terrain should be made on the basis of a comprehensive understanding on the mechanical behavior of the terrain on which vehicle is to be operated. In view of such argument this study is was initiated with the ultimate objective of developing a proper prototype track vehicle with the optimum design specifications to operate successfully on low bearing capacity peat terrain for in-field transportation of oil palm FFB.

MATERIALS and METHOD

Rahman et al. (2005) mathematical models were used to determine the design specifications of the track vehicle under three modes of operations namely vehicle straight motion with Uniform Ground Pressure Distribution (UGPD), vehicle straight motion with Non-uniform Ground Pressure Distribution (NUGPD) and vehicle turning motion (see Figures 1 and 2).

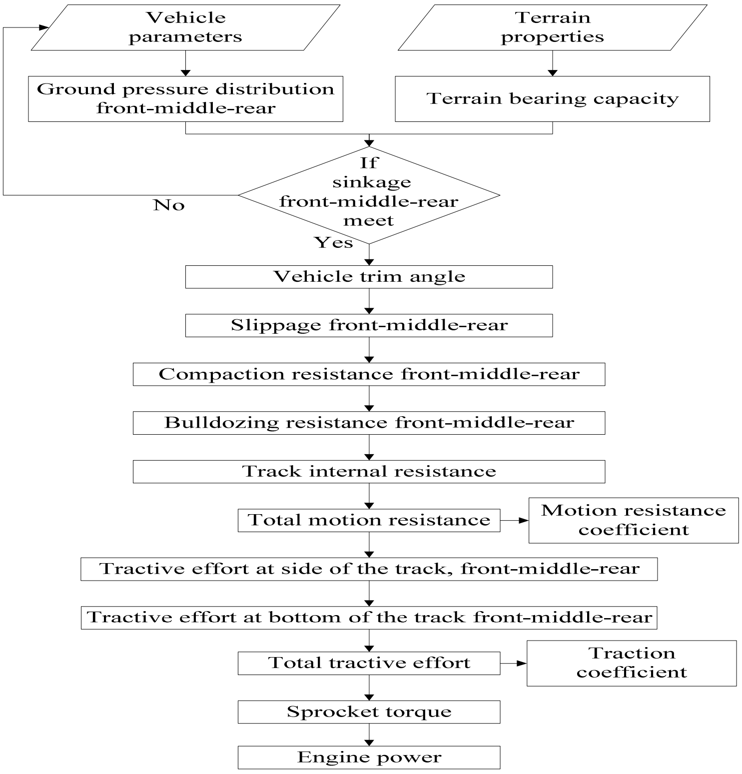

Figure 1. Flowchart of UGPD and NUGPD mathematical models for vehicle straight motion

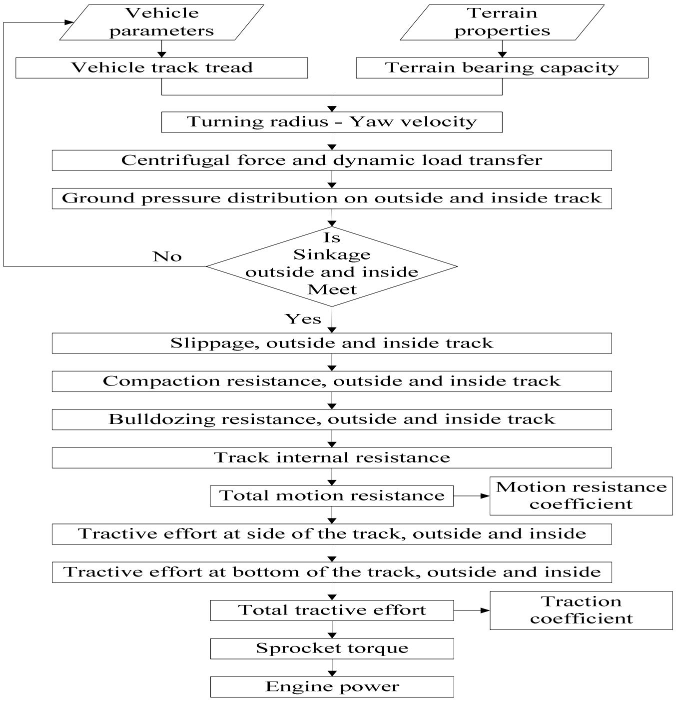

Figure 2. Flowchart of mathematical model for vehicle turning motion

The models employ soil parameters, vehicle design parameters and vehicle expected operational parameters as input to calculate the required engine power for the vehicle under straight and turning motions. The models also were used determine the optimum track size for the vehicle with respect to the imposed vehicle total weight and terrain bearing capacity limits.

SolidWorks 2010 3D CAD software was employed to develop the conceptual design of the complete machine system and the working drawings of the complete machine. Figure 3 shows the 3D isometric view of the complete machine. Figure 4 shows the close-up 3D drawing of undercarriage configuration and the way in which the ground wheels are connected to the main hollow beam of the tracked prime mover.

Prinches (1989) power fluid calculations were used to determine the total hydraulic pressures in the closed loop and open loop hydraulic circuits of the track vehicle.

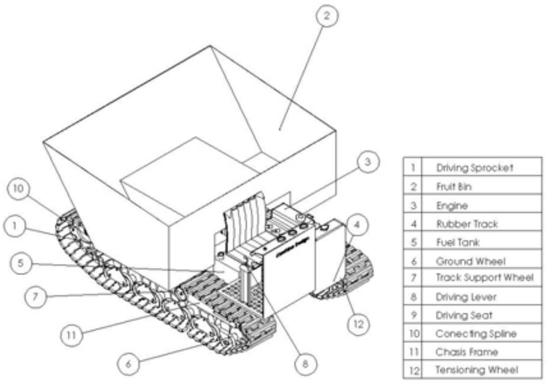

Figure 3. General configuration of the proposed tracked vehicle

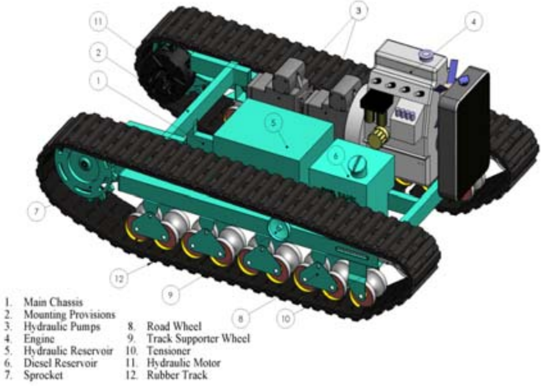

Figure 4. Chassis and under carriage of tracked vehicle

The earlier calculated torque at the driving motors of the tracks and the expected traveling speed of the vehicle were employed to determine the required hydraulic operating pressure for the closed loop circuit. Where else, the earlier calculated load at the hydraulic cylinder of the fruit bin was employed to determine the required hydraulic operating pressure for the open erloop circuit.

Closed monitoring was made at the respective fabrication stages of the track vehicle in the workshop to assure that the machine was fabricated in accordance to the earlier prepared assembly and detail drawings. The center gravity location and the total weight of the vehicle were checked from time to time throughout the progress of its fabrication to assure that their values were not way-off from the earlier decided values used in the design calculations of the machine.

A dedicated instrumentation system was mounted on-board the track vehicle to measure, display and record on-real time the vehicle traveling speed and sinkage during operation. This complete system is made up of a National Instrument cRIO-9004 CompactRIO Real-time Controller Unit (RCU), National Instrument TPC 2106T Touch Panel Control (TPC), Trimble AG132 GPS antenna and receiver unit, Dlink DIR-655 router, Panasonic TOUGHBOOK CF19, Honda Eu20i 2.0kVA portable generator set, Omron E4PA-LS200 M1 N ultra-sonic sensors, and AC/DC power distribution box (see Figure 5).

Field performance test was carried out to evaluate the mobility of the developed prototype track vehicle on asphalt, tilled soil, and low bearing capacity peat terrain. Vehicle sinkages and traveling speed were monitored on the three terrain surfaces at vehicle engine speeds of 1500 rpm, 2000 rpm and 2500 rpm and vehicle total mass of 1950 kg, 2500 kg, and 2650 kg under straight motion.

RESULTS and DISCUSSION

Based from the model computations, for a vehicle of total weight of 2500 kg, the optimum track size was found to be 1800 mm X 350 mm to compromise for the 120 mm track sinkage limit during straight and turning motions and the 19.50 kN/m^2 terrain bearing capacity limit. Ultimately, the track vehicle should have an engine power of at least 35.8 kW for traveling speed of 11 km/hr, track sinkage limit of 120 mm, track slippage limit of 12.3%, and vehicle total weight limit of 2500 kg to fulfill the minimum required driving sprocket torque of 2079 Nm in order for the tracks to overcome a total motion resistance of 1.64 kN and develop a total tractive effort of 10.55 kN.

The developed prototype track vehicle shown in Figure 6 is equipped with endless metal cord and metal reinforced rubber tracks of 1800 mm X 350 mm size and a hydraulic operated tipping fruit bin of 2.3 m^3 size. The machine runs on a 37.7 kW @ 3600 rpm, 4 cylinder liquid cooled, YANMAR 4TNE84-SAMF diesel engine and directly coupled to three in-line tandem hydraulic pumps consisting of a pair of 50 cm^3/rev @ 350 bar SAMHYDRAULIK HCV50 Series variable displacement axial piston pumps and a 11.6 cm^3/rev @ 200 bar Salami 11.3 Series fixed displacement gear pump. Each of the variable displacement pump is used in the closed loop hydraulic system to drive the track rear sprocket through a 565 cm^3/rev @ 250 bar SAi GM2-600 fixed displacement motor.

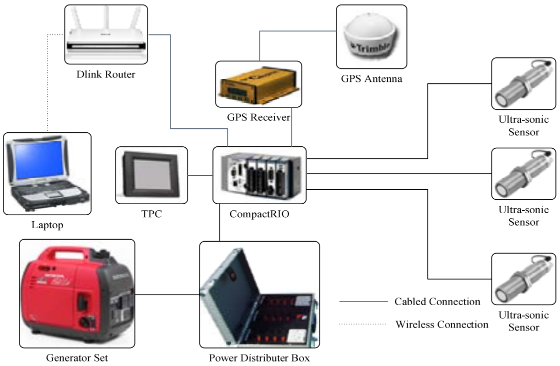

Figure 5. Complete instrumentation on-board the tracked vehicle

Figure 6. Prototype tracked vehicle

The Salami fixed displacement pump in the open loop system configuration is used to provide the hydraulic pressures to the two 40 mm X 400 mm hydraulic cylinders of the tipping fruit bin. The complete track assembly is provided with floating ground wheels to support the vehicle weight and follow the terrain contour. The total weight of tracked prime mover with operator is 2500 kg consisting of machine total dry weight of 1880kg, average operator weight of 70 kg and maximum fruit payload of 550 kg.

ANOVA indicated that terrain condition, vehicle engine speed, and vehicle total weight had high significant effects on the measured traveling speed of the vehicle. All possible interactions of terrain condition, vehicle engine speed and vehicle total weight were significant with traveling speed of the vehicle. The two terrain conditions that were considered in the analysis were asphalt and tilled soil while the three vehicle engine speeds were 1500, 2000 and 2500 rpm while the three vehicle total weights were 1950, 2500 and 2650 kg which were equivalent to payloads of 0, 550 and 700 kg. Figure 7 shows the mean vehicle traveling speed of the vehicle increases with increasing engine speed on tilled soil and asphalt. The increased rate in mean traveling speed with increasing engine speed from 2000 to 2500 rpm was similar in tilled soil and asphalt however the increased rate in mean traveling speed was smaller on asphalt than on tilled soil with increasing engine speed from 2000 to 2500 rpm as indicated by the significant interaction of terrain condition and engine speed in the ANOVA test. The mean traveling speed of the vehicle on asphalt was generally 20.6 % higher than on tilled soil within the tested range of engine speeds.

ANOVA indicated that terrain condition and total vehicle weight had high significant effect on vehicle track sinkage but vehicle engine speed had no significant effect on vehicle sinkage. All possible interactions of terrain condition, vehicle engine speed and vehicle total were not significant with vehicle track sinkage. The two terrain conditions that were considered in the analysis were tilled soil and low bearing peat terrain while the three vehicle engine speeds were 1500, 2000 and 2500 rpm and the three vehicle total weights were 1950, 2500 and 2650 kg. Figure 8 shows the mean vehicle track sinkage increases with increasing vehicle total weight on tilled soil and low bearing capacity peat terrain. Similar increase rates in mean vehicle track sinkage with increasing vehicle total weight from 1950 to 2650 kg were obtained for tilled soil and low bearing capacity peat terrain. The mean vehicle track sinkage on low bearing capacity peat terrain was generally 9.71% higher than on tilled soil within the tested range of vehicle total weights. However, the vehicle track sinkage at vehicle total weight of 2500 kg or the vehicle rated payload on both tested terrains were below the 120 mm track sinkage limit which was earlier set for the vehicle.

ANOVA indicated that both the vehicle total weight and the vehicle engine speed had significant on the vehicle track sinkage while their corresponding interaction was not significant with vehicle track sinkage on tilled soil. The two vehicle total weights that were considered in the analysis were 1950 and 2650 kg while the two vehicle engine speeds were 1500 and 2500 rpm.

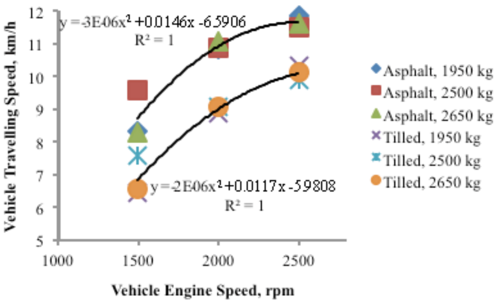

Figure 7. Graph of vehicle traveling speed against vehicle engine speed for asphalt and tilled soil

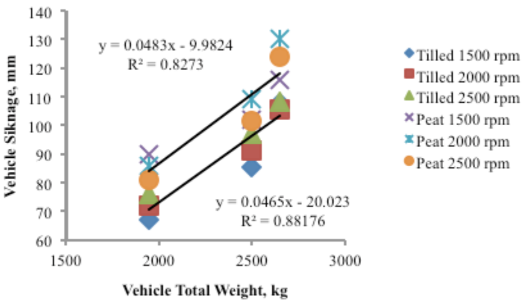

Figure 8. Graph of vehicle sinkage against vehicle total weight for peat terrain and tilled soil

Figures 9 and 10 show that the mean vehicle sinkages for the two track at the sides increase with increasing vehicle total weight while the magnitude for these mean vehicle sinkages were greater at higher vehicle engine rpm.

The mean sinkage of the right side track was higher by 20.52% than the left track during left turning while the mean sinkage of the left side track was higher by 15.93% than the right track during right turning. Greater track was observed at the inner side track because of the inward shifting effect of the mass body due the centrifugal force when the vehicle is making a turning where the effect was more pronounced at higher vehicle turning speed with the increased in the engine speed. The difference of 4.59% was due to the fact that the centre gravity position of the track vehicle was 66.7 mm off towards the right side track from the vehicle lateral center. Again, both the right and left side track slippages during turning motion at the two vehicle engine speeds and under the two vehicle total weights were below the 120 mm track sinkage limit set for the vehicle.

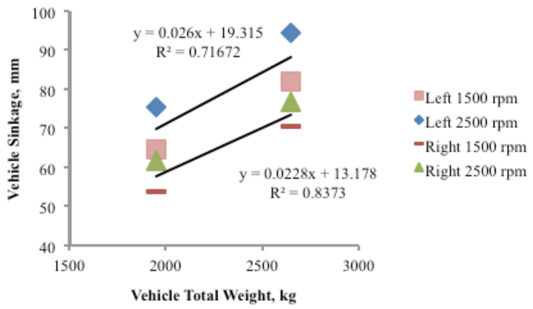

Figure 9. Graph of track sinkage against vehicle total weight during right turning on tilled soil

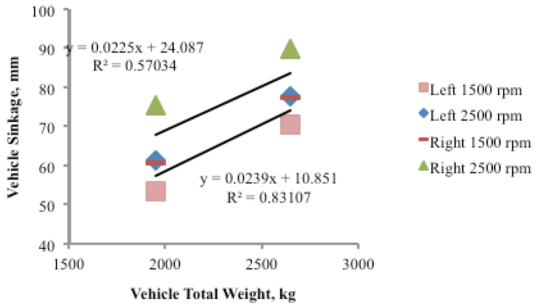

Figure 10. Graph of track sinkage against vehicle total weight during left turning on tilled soil

CONCLUSIONS

A track vehicle had been successfully designed and developed for the purpose of in-field transportation of oil palm FFB on low bearing capacity peat terrains. The vehicle design specifications were specifically determined for the peat terrain based on the vehicle computations during straight motion under both Uniform Ground Pressure Distribution (UGPD) and Non-Uniform Ground Pressure Distribution (NUGPD) and also based on the vehicle computation during turning motion. Preliminary field tests indicated that vehicle at its rated payload was able to perform with adequate floatation and traction on both tilled and low bearing capacity peat terrains giving track sinkages during straight traveling and turning that were within the 120 mm design limit.

REFERENCES

Dolmat, M. T., 2005. Technologies for Planting Oil Palm on Peat. Malaysian Palm Oil Board, Bangi, Selangor D.E., Malaysia.

MacFarlane, I. C., 1969. Muskeg Engineering Handbook. University of Toronto Press, Toronto, Malaysia.

Pinches, M. J., and J. G. Ashby, 1989. Power Hydraulics. Prentice Hall International Ltd, Sheffield, UK.

Rahman, A., A. Yahya, M. Z. Bardaie, D. Ahmad and W. I. W. Ishakl, 2005. Design and Development of a Segmented Rubber Tracked Vehicle for Sepang Peat Terrain in Malaysia. International Journal of Heavy Vehicle Systems 12(3), 239-267.

Rahman, A., A. Yahya, M. Z. Bardaie, D. Ahmad, W. I. W. Ismail and A. F. Kheiralla, 2004. Mechanical Properties in Relation to Vehicle Mobility of Sepang Peat Terrain in Malaysia. Journal of Terramechanics 41(2004), 25-40.