Development of Half-track Articulated Tractor for Peat and Soft Ground

Abd Rahim Shuib*; Mohd Ramdhan Khalid* and Maizan Ismail*

ABSTRACT

MPOB has recently redesigned the traction mechanism of the standard articulated tractor to get the optimum mobility on soft ground soils and peat areas. Blending the concepts of an articulated half-track and a traction mechanism, this prototype transporter shows a good potential to operate on soft ground. Since 1980s, many fabricators/imimporters had tested and evaluated their full track transporters/machines. The feedback received from the end-users pointed to the high maintenance cost of the track and transmission system as the major factors hindering their adoption. With the issues identified, MPOB started the development of a new track transporter with emphasis on compactness of the transporter design and material selection during fabrication with the aim of getting a reliable transporter for peat areas.

INTRODUCTION

The oil palm planted areas in Malaysia as of June 2012 stood at 5 037 959 ha with 2 559 672 ha (50.1%) in Peninsular Malaysia, 1 428 300 ha (28.4%) in Sabah and 1 049 987 ha (21.5%) in Sarawak. About 666 038 ha were under peat and found mainly in Sarawak. Oil palm planted on peat or swampy areas faces a challenging task when it comes to crop evacuation. This is due to the ‘very loose’ and ‘very soft’ nature of peat where the machines do not have sufficient traction and ability to float, thereby restricting smooth movement of the machine. Apart from the low bearing capacity of the peat, the presence of undecomposed or semi-decomposed wood debris along the harvesting path requires a specially designed vehicle to tackle the evacuation problem. A new concept of transporter/vehicle, specifically built for infield collection of fresh fruit bunch (FFB) on peat and soft condition, is currently being developed and field tested. Such a reliable transporter is considered crucial as efficient evacuation will ensure that the harvested crop is taken out from the field.

The Malaysian plantation sector is dominated by the oil palm industry, and this sector needs innovative, locally developed technologies to improve the productivity and to reduce cost. Adoption of agricultural mechanisation is accepted as having potentials to increase profit through better productivity and saving on labour cost. The oil palm is planted on various ground soil conditions. This wide range of soil conditions requires machines with diverse technical specifications to address the unique requirement of each soil type. The numerous implements to carry out various field operations such as crop spraying, weed control, fertiliser application and infield transport of produce require them to be mounted onto prime movers. Wheel-based prime movers are known to encounter less problem on firm ground and undulating areas, but these machines have limitations on soft ground and peat soil. A tracked machine is known for its ability to work under wet and soggy ground conditions, but the cost to maintain the track system is the limiting factor for a wider commercial adoption. Efforts to acquire the right technology for oil palm
mechanisation have been carried out using a ‘short cut’ approach by importing machines, and later carrying out field assessment to evaluate their suitability. In most cases, several modifications have to be made to ensure that they are suited to local ground conditions. Many machines which are currently being used in the plantation have benefitted using this approach. However, the industry must break away from this short cut approach and move towards more innovative concepts to develop suitable machines. Through this new approach, mechanisation can help raise productivity and ensure sustainability of oil palm.

**WHEEL vs. TRACK**

There are several general principles involved which provide the relationship regarding the wheeled and tracked machines. Understanding of these principles is important to develop machines with good manoeuvrability in soft ground and wet areas.

The first principle is that the soil thrust generated by a vehicle is directly related to the length of the ground contact area and to the slippage. *Figure 1* shows that the main difference between the wheel and the track lies with the length of their contact area (Bekker, 1965). In analysing their effect, a track is considered to represent a segment of a very large wheel. All other things being equal, the difference in thrust and slippage between a wheel and a track is caused only by the length of the ground contact area. The larger the ground contact area, the greater is the thrust produced with smaller slippage. The travel efficiency, therefore, of a low wide tyre will be inferior to that of a high relatively narrow tyre, and vehicles should be designed with this principle in mind. This also illustrates that a tyre cannot replace a track under critical soil conditions because a tyre ground contact cannot be as long as a track.

The second principle is that pneumatic tyres find their best application in sandy soils. In such cohesion-less soils, they generally have a high bearing capacity. Thus, a rubber tyre with a higher unit bearing surface than a track, will generate a high thrust.

The third principle is that in cohesive soils such as plastic clays, the weight of the tractor is a liability as it is not a thrust generator in such soils, while total contact area and light unit bearing pressure are. In these soils, track performance becomes superior to wheels.

Sometimes the surface of an otherwise firm soil will become slick and the vehicles, particularly wheeled machines, cannot gain sufficient traction to enable them to move forward (US Department of the Army Corps of Engineers, 1962). In such a case, the vehicle may simply spin its wheels, not moving forward and not sinking appreciably. A few tracked vehicles appear to be seriously impeded by surface slipperiness. Surface slipperiness effects are magnified when associated with slopes because of the reduction in normal load against the slope.

\[
P = \frac{W}{A}
\]

\[A = bL\]

*Source: Bekker (1965).*

*Figure 1. Comparison of area of contact for track and wheel.*

*Note: \(W\) = weight in kg.\n
\(P\) = ground pressure in \(\text{kg cm}^{-2}\), when \(b\) and \(L\) are in cm.
Another principle is that soils and vehicles must be carefully matched to achieve optimum results. There is no sharp cut-off between wheeled and tracked vehicles. In some difficult soils, the best wheeled vehicles will outperform the poorest tracked vehicles. Conversely, the best tracked vehicles can outperform the poorest wheeled vehicles from all points of view in medium to severe soil conditions.

THE DEVELOPMENT

Partial Track System

The standard articulated tractor (Figure 2) comes with four standard tyres. The specifications of the articulated tractor are shown Table 1.

The advantages of articulated tractor:
• improved tractive performance compared to wheeled tractor;
• lower ground pressure than wheeled tractor;
• lower weight than conventional crawler;
• can be retrofitted to conventional 2 WD or 4 WD tractors; and
• can be attached to other implements such as for pesticide spraying, fertiliser application, etc.

To further utilise this interchangeable 4WD system, the tyres for the front wheel were replaced with larger ones (12.4 x 16) and tracks system (Figure 3) installed at the rear axles. The rubber tracks mounted to rear axle hub and anti-torque bar were installed to secure the track to the axle. The track was allowed to rotate 15° with respect to the chassis.

![Figure 2. The Hunan 124Y articulated tractor.](image)

<table>
<thead>
<tr>
<th>TABLE 1. SPECIFICATION OF THE ARTICULATED TRACTOR</th>
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<td>Dimension (mm)</td>
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<tr>
<td>Engine</td>
</tr>
<tr>
<td>Gross weight</td>
</tr>
<tr>
<td>Transmission</td>
</tr>
<tr>
<td>Fuel tank capacity</td>
</tr>
<tr>
<td>Max. carrying load</td>
</tr>
<tr>
<td>Tyre size</td>
</tr>
<tr>
<td>Maximum speed</td>
</tr>
</tbody>
</table>
to ensure that the machine can travel smoothly on uneven ground.

**THE ANTI-SINKAGE MECHANISM**

Another practical alternative to the use of rubber tyres is to attach the anti-sinkage mechanism (cage wheels), where the lugs provide combined good tractive power with reasonable floatation on the wet and sticky soils. This concept works well in paddy areas and now an attempt is being made to test it in the swampy oil palm areas. The cage wheels are commonly made of steel and consist of a series of lugs. Within certain limits, more lugs on such wheel can contribute to a greater wheel force. However, increasing the number of lugs will decrease the spacing between them, thereby making the wheel more liable to clog in swampy soil and increasing the tendency to bog down.

The pair of cage wheels used in this study consisted of six lugs, and they were locally produced (Figure 4). Weighing around 25 kg each, the lug assembly has been purposely designed to have 45° angle to increase the traction capability. The diameter of the cage wheel was made smaller than the tyre size allowing the machine to also operate on the dry area. The anti-sinkage mechanism will be automatically engaged when the tyres start sinking whenever the machine travels on soft ground.

**FIELD TRIAL**

A function test was conducted on the prototype machine complete with anti-sinkage (Figure 5). The initial findings showed that after installation of the track, the ratio of movement between the front wheel and the rear track was not synchronised causing the track to slip out of the sprocket. To solve this problem, a new gearbox was constructed in order to get the suitable ratio. Since the diameter of front tyre was bigger than the sprocket of the track, the sprocket must rotate 2.47 times faster than the tyres at the front axle to avoid track slip out. The gearbox was placed just immediately after the transmission gearbox transmitting the required rotating power through propeller shaft to the rear axle.

After installing the gearbox, the prototype machine was tested at a matured peat area in Penor, Pahang (Figure 6). From the observation, it was found that this transporter was able to function effectively in this area. However, it was noticed that the articulated tractor needed to be fully engaged with the 4WD system especially for infield operation, or otherwise it would tend to bog down. This prototype machine was found to be capable of travelling on 2WD mode on the main road.

The resistance of penetration (ground load-bearing capacity) was measured along the path where the prototype machine had manoeuvred (Figure 7). Using the Eijkelkamp penetrometer, data for five treatments were collected: (i) control (no machine movement), (ii) three passes without load, (iii) three passes with 350 kg load, (iv) six passes without load and (v) six passes with 350 kg load.

Measurements of soil penetration resistance after three passes and six passes are shown in Table 2. It was noted that the depth of track sinkage increased with the number of passes and load. At 350 kg load, the peak cone index of the soil after six passes appeared to decrease indicating the digging effect of the triangle shoes of the track at this load. With no loads, the peak cone index increased slightly with the number of passes. The ground water depth measured to the original soil surface along the ruts showed an increase with the number of passes and with load. This tended to indicate that the soil mass along the rut had sunk into the water horizon rather than was merely compacted.
Figure 5. (a), (b) and (c) are the schematic drawing while (d) is the complete assembly of prototype.

Figure 6. Field test conducted in peat area where the prototype carried loads.

### TABLE 2. COMPARISON OF SOIL PENETRATION RESISTANCE

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Average pressure without load (Mpa)</th>
<th>Average pressure with load (Mpa)</th>
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<tbody>
<tr>
<td></td>
<td>Control</td>
<td>3 passes</td>
</tr>
<tr>
<td>10</td>
<td>0.20</td>
<td>0.17</td>
</tr>
<tr>
<td>20</td>
<td>0.17</td>
<td>0.17</td>
</tr>
<tr>
<td>30</td>
<td>0.18</td>
<td>0.17</td>
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Physically, the area became impassable when the machine was on the same path for more than six times. The spoil of the path was caused by the machine when it was making a turn. It was observed that more soil was displaced at turnings especially on the front wheel. The calculated ground contact pressure at 350 kg, assuming uniform load distribution on tracks, was at 0.27 kg cm$^{-2}$.

**CONCLUSION**

In general, the partial track transporter worked well in areas inaccessible to the conventional wheel type transporter. The tracked machine seemed to be able to reduce the problem of uncollected bunches in peat areas. With this machine, it is envisaged that the recovery of FFB will be greatly improved. The partial track transporter has the advantage of having a better travelling speed compared to the full track transporter. Besides for infield transportation of FFB, the transporter can also be used for other field activities such as fertiliser application, weed control, general maintenance, etc. The machine is able to reduce manual requirement as well as improving the productivity and income of the worker.

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**REFERENCES**
