12. Influence of Track Length on Turning Characteristics of a Tracked Vehicle Running on Soft Terrain

Ehime University: T. Muro, S. Kawahara, *T. Q. Thai

1. INTRODUCTION

The aim of the research is to investigate on a method to adapt ordinary tracked vehicle to a work on very soft terrain that requires turning motion. As have been known, the track contact pressure can exert larger influence on running characteristics of tracked vehicle. Consequently, it can be expected that the most economic way to adapt ordinary tracked vehicle to weak terrain is to change only the vehicle undercarriage. This paper presents the result of the investigation of the influence of track contact length on turning characteristics of a tracked vehicle model turning on soft sandy soil while keeping the track width unchanged. The investigation is carried out using our simulation analysis developed especially for soft terrain and verified by our research. The simulation is executed for a scale model of a tracked vehicle running on sandy soft terrain with steering ratio of 3.2 and different slip ratio of outer track. The results show that the track contact length, i.e. mean contact pressure, has considerable effect on the running proprieties of tracked vehicles.

2. MODEL VEHICLE AND TERRAIN TRACK SYSTEM CONSTANTS

The simulation was carried out for a 1/10-scale model of the 40 kN bulldozer turning on soft sandy terrain. The outline of the vehicle is shown in Fig. 1. The vehicle dimension as the input to the simulation analysis is shown in Table 1.

---

Fig. 1 Vehicle dimension as input to simulation analysis
Table 1 Dimension of model vehicle

The track contact length \( D \) was modified to adjust the mean contact pressure. Table 2 shows the cases of investigated track contact length and its corresponding contact pressure. Except for the change of contact length \( D \), other dimensions of the vehicle remained unchanged.

Air-dried sandy soil was used in the experiment. The terrain-track system constants for the given track-soil system were determined by loading unloading test and traction test and are presented in Table 3.

<table>
<thead>
<tr>
<th>( k_1 ) (N/cm(^{n+2}))</th>
<th>( n_1 )</th>
<th>( k_2 ) (N/cm(^{n+2}))</th>
<th>( n_2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.031</td>
<td>1.259</td>
<td>-4.061</td>
<td>0.545</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>( m_e ) (N/cm(^2))</th>
<th>( m_t )</th>
<th>( \alpha ) (1/cm)</th>
<th>( c_{10} ) (cm(^{2+2})d(^{2})/N(^2))</th>
<th>( c_1 )</th>
<th>( c_2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lon.</td>
<td>0</td>
<td>0.87</td>
<td>0.6</td>
<td>0.343</td>
<td>0.81</td>
</tr>
<tr>
<td>Lat.</td>
<td>0</td>
<td>0.45</td>
<td>3.7</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

Table 3 Terrain-track system constants

The investigation was carried out for the case of vehicle in steering motion with steering ratio of 3.2 (defined as ratio of circumferential speed of the outer to that of the inner track) and different cases of slip ratio of outer track \( i_o \). The investigated slip ratio of the outer track \( i_o \) is ranging from 4% to 80% with step of 1%. For each of slip ratio of outer track \( i_o \) the simulation was carried out for 5 cases of track contact length \( D \).

3. INFLUENCE OF TRACK CONTACT LENGTH ON TURNING CHARACTERISTICS

The influence of track contact length on maximum amount of sinkage, longitudinal and lateral inclination angle, total thrust, turning radius, turning moment, effective tractive effort and optimum effective tractive effort was investigated.
The amount of sinkage of the vehicle is an important characteristic to assess the degree of ground damage caused by vehicle. **Fig. 2** shows the influence of the track contact length $D$ on the amount of sinkage of front idler of outer track $S_{fo}$. The influence of the track contact length $D$ on the amount of sinkage of front idler of outer track $S_{fo}$ could be said rather complex.

**Fig. 3** shows the influence of the track contact length $D$ on the amount of sinkage of front idler of inner track $S_{fi}$. For a smaller range of the slip ratio of outer track $i_o$, the amount of sinkage of front idler of the inner track $S_{fi}$ increases with the increment of track contact length $D$ while reverse tendency is observed for a bigger range of the slip ratio of the outer track $i_o$. It can be concluded that the track contact length $D$ exerts considerable effect on the amount of sinkage of front idler of inner track $S_{fi}$.

**Fig. 4** shows the influence of the track contact length $D$ on the amount of sinkage of rear sprocket of outer track $S_{ro}$. As expected, the maximum amount of sinkage, i.e. the amount of sinkage of rear sprocket of outer track $S_{ro}$ decreases with the increment of track contact length $D$, i.e. decrement of mean contact pressure $P_{mean}$. It can be concluded that the influence of track contact length $D$ on the amount of sinkage of rear sprocket of outer track $S_{ro}$.
i.e. on the maximum amount of
sinkage of the vehicle is
considerable.

**Fig. 5** shows the influence of the
track contact length $D$ on the
amount of sinkage of rear sprocket
of inner track $S_{ri}$ for different slip
ratio of outer track $i_o$. In the bigger
range of slip ratio of outer track $i_o$,
the amount of sinkage of rear
sprocket of inner track $S_{ri}$ decreases
with the increment of the track
contact length $D$. In the smaller
range of slip ratio of outer track $i_o$,
however, the reverse effect of the
track contact length $D$ on the
amount of sinkage of rear sprocket
of inner track $S_{ri}$ is observed. It can
be seen from the figure that the
track contact length $D$ exerts larger
influence on the amount of sinkage
of rear sprocket of inner track $S_{ri}$.

The longitudinal and lateral
inclination angles are important
characteristic to assess the stability
of the vehicle turning in soft
terrain. **Fig. 6** shows the influence
of the track contact length $D$ on the longitudinal and lateral inclination of the vehicle, $\theta_{lon}$ and $\theta_{lat}$ respectively, for different slip ratio of outer track $i_o$. The longitudinal angle $\theta_{lon}$ decreases with the increment of the track
contact length $D$ for the whole ranges of the slip ratio of outer track $i_o$. However, the influence of track contact
length $D$ on the lateral inclination angle $\theta_{lat}$ is more complex. In general, the lateral inclination angle $\theta_{lat}$
decreases with the increment of the track contact length $D$ for the smaller range of the slip ratio of outer track
where inner track is in braking state and outer track in driving state. The reverse tendency is observed for the
range of bigger values of the slip ratio of outer track where both tracks are in driving state. The figure shows
that the track contact length $D$ has considerable effect on the longitudinal and lateral inclination of the vehicle
$\theta_{lon}$ and $\theta_{lat}$.
Fig. 7 shows the influence of the track contact length $D$ on the total thrust $T_3$. In general, the total thrust $T_3$ decreases with the increment of the track contact length $D$. The decrement of total thrust $T_3$ while the track contact length $D$ increases can be explained by the decrease of the ground contact pressure. It is observed that track contact length $D$ exerts considerable effect on the total thrust $T_3$.

Fig. 8 presents the influence of the track contact length $D$ on the turning moment $M$ and turning radius $R$. It is observed that in general the turning moment $M$ and turning radius $R$ increase with the increment of the track contact length $D$. It can be concluded that the track contact length exerts substantial influence on the turning moment despite its little influence on turning radius especially in the region of the typical turning motion during which the outer track under driving and inner track under braking state. The increase of the turning moment $M$ while track contact length $D$ increases can be explained by the increases of arm length of lateral forces.

Fig. 9 presents the influence of the track contact length $D$ on effective tractive effort $T_4$. The figure shows that the track contact length exerts larger influence on effective tractive effort especially in the smaller range of slip ratio of outer track $i_o$ where typical turning motion of driving state of outer
track and breaking state of inner track occurs.

Fig. 10 presents the relationship between optimum effective tractive effort $T_{4\text{opt}}$ and track contact length $D$. The figure shows that there exists the maximum value of optimum effective tractive effort $T_{4\text{opt}}$ of about 285N at track contract length of 33 cm when mean contact pressure $P_{\text{mean}}$ is of 8.81kPa while the vehicle is turning with slip ratio of outer track $\delta_2$ of 34%. The existence of maximum value of effective tractive effort can be explained by the fact that bigger mean contact pressure $P_{\text{mean}}$ (which would brings about larger thrust) exists at shorter track contact length $D$ (which would reduce thrust because of smaller amount of slippage).

4. CONCLUSION

The influence of track contact length on turning characteristics of a tracked vehicle model turning on soft terrain with steering ratio of 3.2 and with different slip ratio of outer track was investigated using a verified simulation analysis developed in our research. The followings can be concluded for a given tracked vehicle model and soil:

(1) The track contact length exerts considerable influence on amount of sinkage, thrust, effective tractive effort and inclination angles.

(2) For the case of typical turning motion when outer track under driving and inner track under braking state, it is observed that effective tractive effort increases with increment of track contact length.

(3) Maximum amount of sinkage, longitudinal inclination angle decreases with the increment of track contact length.

(4) The track contact length exerts significant influence on turning moment despite its moderate effect on turning radius. It is observed that both turning moment and turning radius increase with increment of track contact length.

(5) There exists a track contact length, i.e. mean track contact pressure, at which maximum optimum effective tractive effort can be achieved.

Reference
