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

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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 [1, 2]. 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**.

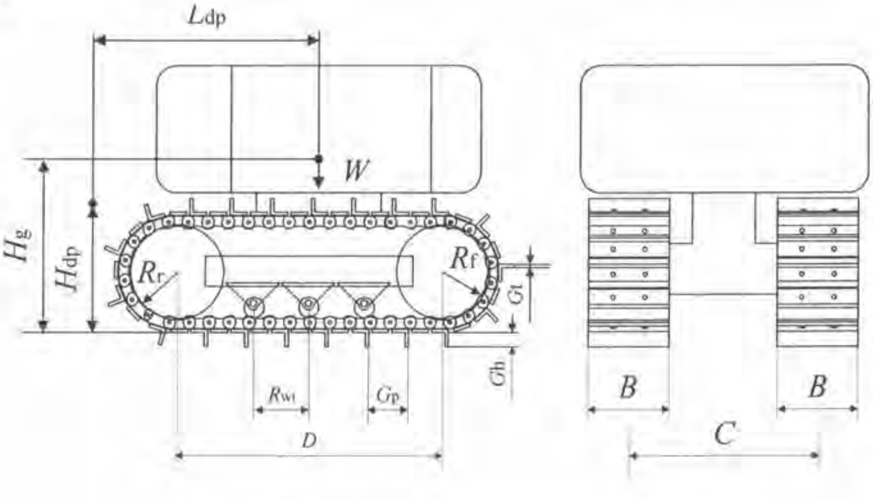

Fig. 1 Vehicle dimension as input to simulation analysis

Vehicle weight W (N)	582	Grouser height H (cm)	1.7
Height of hitch point H_{dp} (cm)	15	Grouser pitch (cm)	2.55
Dist. cent. of grav.-hitch point L_{dp} (cm)	26	Grouser thickness (cm)	0.3
Initial track tension Ho (N)	98.1	Maximum track deflection (cm)	1
Height of center of gravity Hg (cm)	15	Radius of front idler R_f,	5.4
Contact length D (cm) (changing)	27~39	Radius of rear sprocket R_r (cm)	5.4
Track width B (cm)	10	Radius of road rollers R_m (cm)	1.9
Track gauge C (cm)	23	Number of road rollers	3
Eccentricity of center of gravity	0	Road roller interval (cm)	6

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**.

D (cm)	$P_{mean} = \frac{W}{2BD}$ (N/cm^2)
39	0.7458
36	0.8080
33	0.8814
30	0.9696
27	1.0773

k_1 (N/cm^{n1+2})		n_1		k_2 (N/cm^{n2+2})	n_2	
3.031		1.259		4.061	0.545	
	m_c (N/cm^2)	m_f	a (1/cm)	c_0(cm$^{1+2c1-c2}$/N^{c1})	c_1	c_2
Lon.	0	0.87	0.6	0.343	0.81	0.7
Lat.	0	0.45	3.7	--	--	--

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 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 S_{ro},

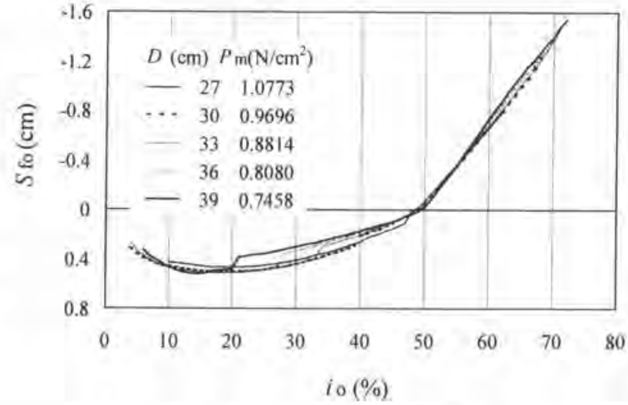

Fig. 2 Influence of track contact length *D* on sinkage of front idler of outer track *S* fo

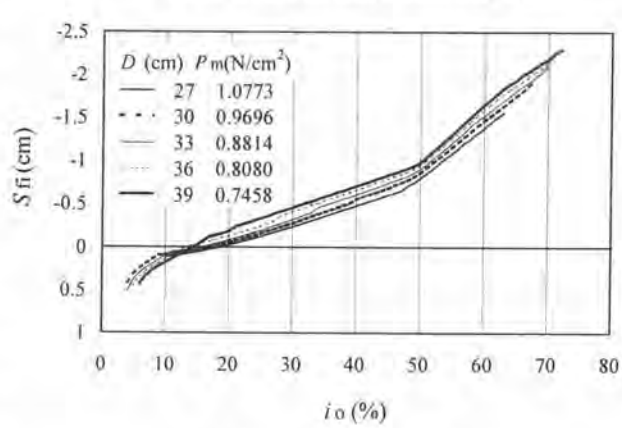

Fig. 3 Influence of track contact length *D* on sinkage of front idler of inner track *S* fi

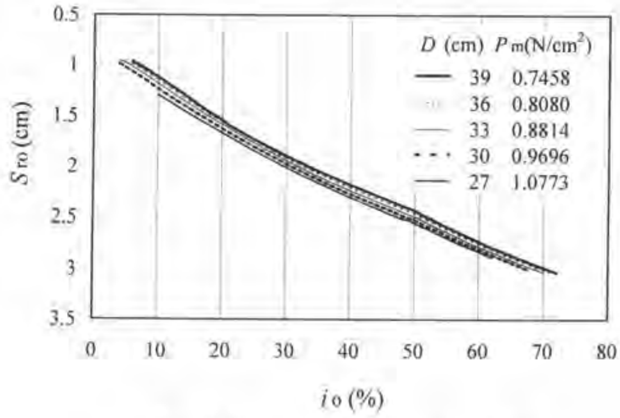

Fig. 4 Influence of track contact length *D* on sinkage of rear sprocket of outer track *S* ro

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}.

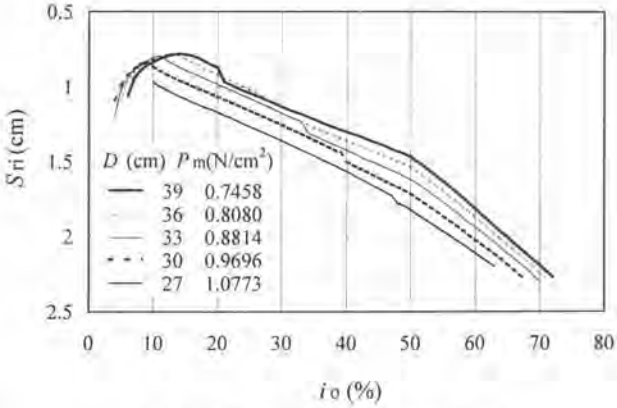

Fig. 5 Influence of track contact length D on sinkage of rear sprocket of inner track S_{ri}

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, θ_{lon} and θ_{lat} respectively, for different slip ratio of outer track i_o. The longitudinal angle θ_{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 θ_{lat} is more complex. In general, the lateral inclination angle θ_{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 θ_{lon} and θ_{lat}.

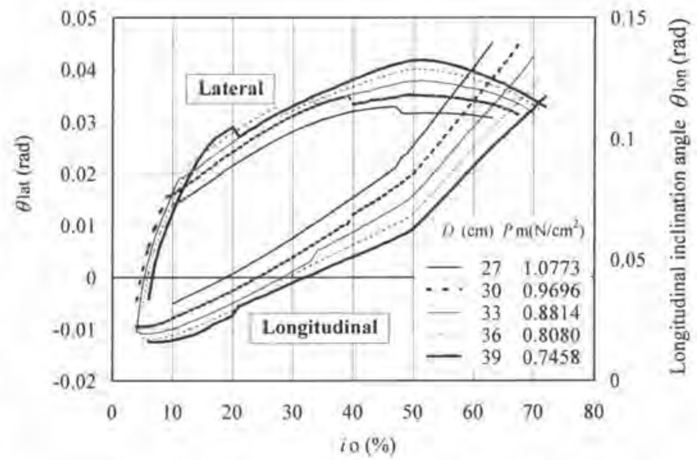

Fig 6. Influence of track contact length D on longitudinal and lateral inclination angle θ_{lon}, θ_{lat}

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

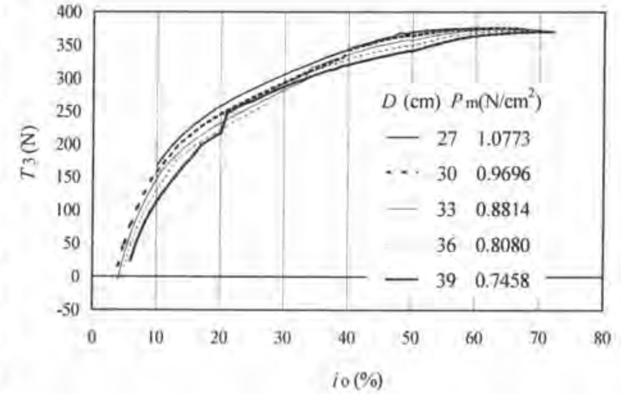

Fig. 7 Influence of track contact length *D* on total thrust *T*3

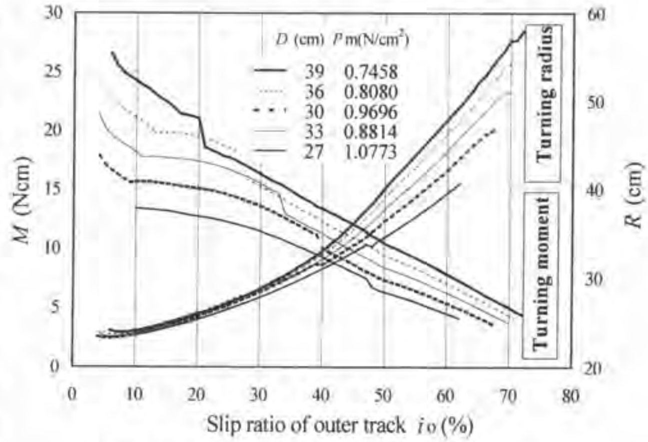

Fig. 8 Influence of track contact length *D* on turning moment *M* and turning radius *R*

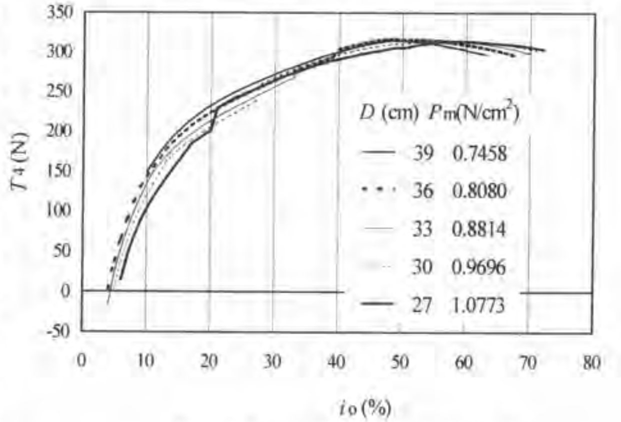

Fig. 9 Influence of track contact length *D* on effective tractive effort *T*4

track and breaking state of inner track occurs.

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

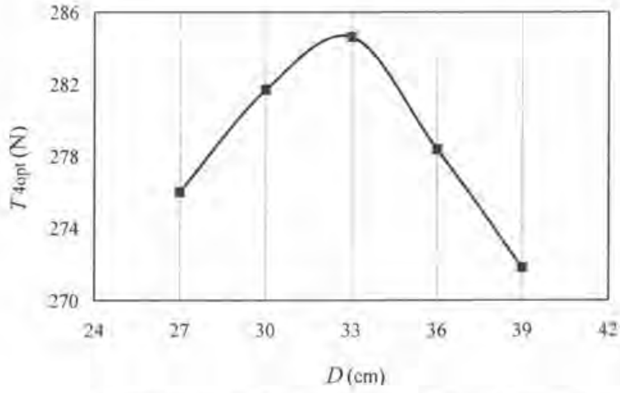

Fig. 10 Relationship between optimum effective effort T_{4opt} and track contact lenght D

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

[1] T. Muro, T.D. Thai : Turning Characteristics of a Bulldozer under Traction on a Weak Sandy Terrain, Proceedings of 7th European ISTVS Conference, pp. 102-109, 1997.

[2] T. Muro, T.D. Thai : Numerical Analysis to Predict Turning Characteristics of Rigid Tracked Vehicle under Traction on Loose Sandy Soil, TERRAMECHANICS, Vol. 18, The Japanese Society for Terramechanics, pp. 41-48, 1998.