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A Study of Suspension Geometry for Personal Mobility Vehicle (PMV) with Inward Tilt Mechanism

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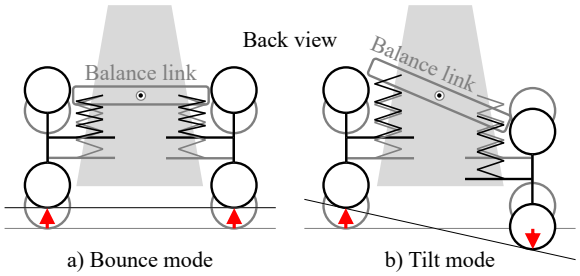
INTRODUCTION

The suspensions of PMV with an inward tilt mechanism are allowed the free roll rotation at the reverse-phase stroke in addition to the normal stroke at the in-phase strokes. There is few geometric study (e.g., link reaction force) of such type of suspensions. In this report, the geometric characteristics of the suspensions on PMV with inward tilt mechanism, which have two front wheels and one rear wheel, are considered from the principle aspect.

OVERVIEW

1) The suspension of PMV needs an additional mechanism, balance rink(s), to give a degree of freedom of roll rotation. (Fig. 1)



a) Bounce mode b) Tilt mode

Fig. 1 Independence of bounce and tilt on PMV

2) Since no mechanical anti-roll moment is required on PMV, the reaction force angle (α) with respect to lateral tire force should be zero in order to avoid unnecessary disturbance. (Fig. 2)

$$\tan\alpha = 2h/T = f_L/F_{yL} = f_R/F_{yR}$$

$$f_L = 2F_{yL}h/T \quad (1a)$$

$$f_R = 2F_{yR}h/T \quad (1b)$$

$$M\varphi = mgd = ma\,GCH \quad d = a\,GCH/g$$

$$M\varphi^* = (f_L+f_R)T/2 = (F_{yL}+F_{yR})h = mah \quad (2)$$

$$F_{yL} = mg(T-2d)/2T \quad (3a)$$

$$F_{yR} = mg(T+2d)/2T \quad (3b)$$

$M\varphi$: roll moment — $M\varphi^*$: anti-roll moment
α: reaction force angle — h: reaction force center height
f: jack-up (down) force — F_y: lateral force
a: lateral acceleration — GCH: height of gravity center
g: gravitational acceleration — m: vehicle mass
d: lateral displacement of GC — T: tread
subscript) L: left R: right

3) Since the roll moment during turning is balanced by the lateral displacement of the center of gravity due to inward tilt angle, the transfer of vertical load from inner to outer wheel does not occur unlike a general automobile. (Fig. 3)

4) In case of a telescopic suspension etc., the vehicle body sinks down during turning by the link reaction forces, just like a motorcycle. (Fig. 4)

5) Every type of front suspension with a steering system can be used as a passive tilt mechanism. However, it is difficult to add a steering system on a leading arm type suspension. Therefore, PMV should use a leading arm type suspension as an active tilt system. (Table 1)

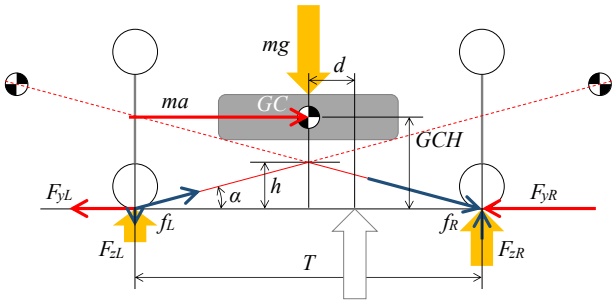


Fig. 2 Back view of the equivalent suspension links

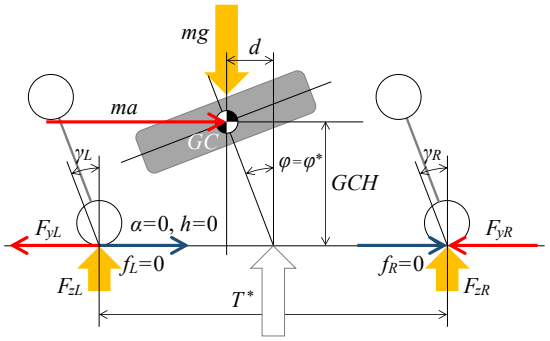


Fig. 3 Equivalent suspension links with reaction angle (α) = 0

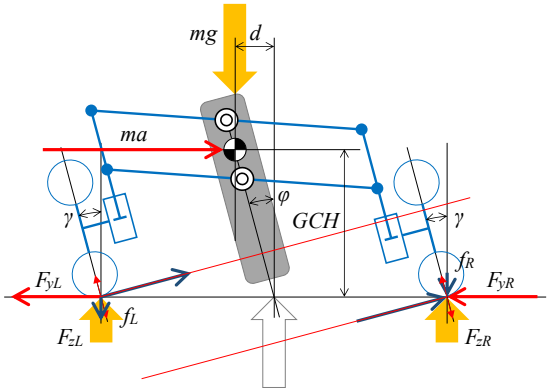


Fig. 4 Force balance of telescopic type suspension on cornering

Table 1 Mechanical properties of typical suspensions on PMV

Suspension type	Free roll rotation	Reaction angle (α)	Jack-up effect	Tilt mechanism
Double wishbone	Balance link	zero	zero	Passive/Active
Telescopic	↑	↑	down	↑
Leading arm	Differential gear	↑	↑	Active