

JYSçãÑÑ s ys-VÑÓ yÓ ÓÑ# SéÑ# Ó ú äÓ#y

' » DýÕ p • 3 FÜ Ö È " +± ù Bàg • ç =yB•0f*" -A/£

$$9 \cdot 6^B w = \textcircled{R} J D \uparrow^B w M' J = \textcircled{B} W O \textcircled{T} G H$$

œžž-D GT " 7 Ö C " K•"K, >->-¶ œ@! B0 + 0žt | " K• g Ý /8 " K•" *E5° 3 K' œ@!!! +; +;
è žž-D GT " g*b " K•"K, >->-¶ œ@! ! @

...œ@Á » 3i T ? /ø s o ÂçêDN, wB ù Bàg • ç +±G' =yB•0v u = 64! ? /ø s +±GN s Ö wUDý
Õ p • 3FüoÖ Xd" " +±' -m7 wA/£ 3 BUð o Xd' Ö X=•g +±Ö È " æ/8 @@!³ 0.ú
Ö XK (Ü Ö c • Á ' Ö X3èi : Ä • Ö Ö c • 1 È # Ö XD•E&C W (Ü Ö c • 0.ú Ö c •
F* 6 u] ¼c • Ö w ÄKrg • ç +± Ö X : p • w£ - *U£ >ñ? ' 3 ù Bà=yB•Dð8 Z +± XD•
E& È > XD•E&¹ ù6-X0 D•E&Ö) ³ lo? ù Bàg • ç E3DýÖ " +± i æ' w € 7 ¹ = ³ ù Bà
=yB•Dð8 Z ù DÀ' 6G• J DÀ' 7 >ÿ Ö +± j „ lo? K MÄw ù Bà' . >ñ? +±æ' €2(C - ; w 5
- W) E/g • ç N, wµ & ´ Z +±0Ä' U Xö Äö > 7E =y³ , ,L w ,L4 ÉO'@!³ A Ý æ' +±6
u T

œ| œ@Á Bàg • ç 3i T ? /ø s DýÖ p • 3Fü ' . >ñ? E3DýÖ "
Z + 31" \$ Á è0x0ž œœœ' ([4 - . Äö œœœ' 0 4C\$ Á! !!! K@ %! B o! K@ " K

œœù Bàg • ç 6-F DýÖ^ » £ # \$ 5 Ö È " &Ö?
È +±, > T3ÖE ÷ ù Bàg • ç - 7YÖ È " +±P 4!
1 L<3i T " - £ ' . >ñ? ; =ž Ö c, % € : o % -
7Yù Bà +±' . >ñ? 3 g. è 3i >ñ? 1 È # U3i >ñ? 0
.ú æ < " ^ » È # >ñ? # 6 ! a +±Qçy T " m , z
=•(Ý/®) +± : g • ç F*Fö*UÈ # >ñ? E =yDýÖ Ö
c % È # >ñ? - We *U +± J \ h >® " g • ç +±
X Ö È " % È > A J " D° e *U +±æ" \ 3 ù Bà
+±• Ö Ö - C = 3i T ? /ø s % Âçêo B0 +± s Ö % Âçê N
, D° a] ü E ³ ù Bà' =y +± e ¼ a | | Ö È " =y g %
' » Âçê N, +± X Ö È " >ñ? æ" È (Ý ³ .ú
ù Bà' =y g • ç +± 6 u =yB• 0K0 %
Æi' & ç U ù è 0v x0 B @ j ý ' ³ ; Xê % ç] • K
] ç w ç = ç w +± " " ; Xê % ç 6G;] x K! +± , ! ,
È 3 0 +± è Ažü E " 6 u] Q Ç ù Bà =yB• +±
Ç T % 4 5 Âçê N, " ü = & ç ö ý ' ³ - .ú D•E&
N, M ± x Ö c • % Xê o " A Ö c • - < C X Ä

Ö " È (Ý ³ ù Bà ù g • Ö Z • : %
f > Âçê +± Ö È " æ/8 " @DÄ! Ç +± /ø Bà
%æ- ù Bà X +± DýÖ % • " 2(4 Ö 6*0v » ! " ù Bà
1 » 1 • L† • ' ä . " E - % æ ç è ç w ç / g e è |
% ù U w ç ç ç w ç 0 % è ð = Ø U ç U U' 6 ç k & ç ç
0v ç ç % DýÖ p • 3Fü Ö X % U ç U U ý ' ³ -
.ú ' » Âçê Ö È " | ® i 3? +± È # =yB• N < *L =
æ" " 4 ' ³ ec ^ | 1 ep • | 3Fü +± Ç v " @i; ³
ep • | 3Fü 0v \$ » è % ç ç ç 0v 0 ö 3 Ö X +±
- " - ,] # 2(4 % , z X +± D•E& ñ? > Ez
Fö*U, u d ž ý i 3 £ ý i ' ' B0 % Y ' ' »
Ö X Ö È " " «] ³ - „ ù =yB• 6G•] XD•E&
°] 7 >ÿ Ö lo? +± U3i >ñ? æ" % # € 1 = ³
8 % ä† ' » Âçê N, Ö) ³ Ö X Ö È " æ/8 "
U' æ/8 +±' -m7 "@@!³ 0.ú Ä Ý • Ö c • " - Dý
Ö p • 3Fü U g • ç =yB• Dð8 Z ÷] • Ö ; F*
: p • %æ' » : p • +± Ö X >ñ? ' ³ ù Bà =yB•

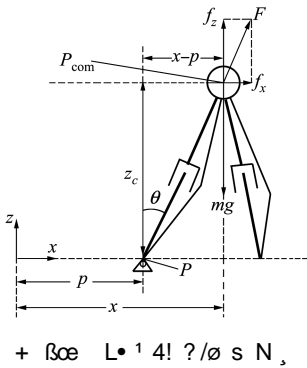
c/l L ÄO! B K@K "
' FpMi, Ä* ä7 & ç p " ' Fp%B!" B" B@ " B xo&E5°, P 0v " NH Ý6* È ý t Mi, %! B ö K@ B ç B ç Ö
%520- ø Ä*6 %B ö o >-D GT " † -A/£ *L " h >öü , " B, g : 2(4 1 §6* g • ç -A/£ %

Dð8 Z±± XD•E&"U' D•E&ÓCE8 Fô*U6 Nd Ž
 ÿ i " ò > ñ ? ' ³ s Ò6 - X0 ±±s ÒD•E&%e' »
 > ñ ? ' ±± X¹ Q6 - X0 D•E&"Ö) ' ³ - *U - v
 E3@ÐÄE3DýÖ " ±±æ" =yx 6 u | !o' ³ U 7
 3ÓCE8 ±± 7 - ÿ Ó > FÛ%' » Âçê N, ±± Ò X æ
 " À | ³ ù Bà = yB • ±± h > @ , + "E 59 @ @ Î' , % & 0 -
 , ±± Ô c • "4 5 P u ±± E3DýÖ " !o ? æ" ¹ = ³
 ù Bà ±± j „ = yB • > ñ ? % Y ' ±± A / £ - ù Bà' . > ñ ?
 ±±æ" €2 (C " - ; U - W) E / g • ç N , 7 O 1 @ Î
 ³ æ" ±± 6 u T %

ÓÇ ! Ç Ö È " ; µ ÷ 9 ±± Ö)

ÓÇ ! Ç N ,

3 g • ç ê AŽ = + ß m . g ±± L • 1 4 ! ? /ø s "
 ? /ø s ±± s J - Ó e 4 V £ . j € B U ð P Ó z_c
 : % Á * U - 8 t @ ã
 ß o g • ç ±± B U F ù = K Ó Z » B U ð X % æ
 0 o B U ð . U • Ç ±± P Ó z_c +
 o g • ç C J 7 - È - D Ä ' " , 8 = 7 * ^ ' ä . %



U 1 4 ! x - z L • Z " X ±± z 4 } 4 g P_{i=1}
 x " z_c Ò " \ % æ ±± z 4 } 4 g P = p " ! Ò " % æ 0 v u
 » g • ç ±± ; X ê % æ^{80} y - z L • 9) 3 Ä %
 D Ä E' ? /ø s ±± Ö È " N ,

$$m\ddot{x} = F = \theta$$

$$m\ddot{z} = F \dot{\theta} - mg$$

$$\ddot{x} = \frac{g + \ddot{z}}{z_c} \omega_0 - p_0$$

$$\ddot{z} = \frac{F}{m} \dot{\theta} - g$$

- É F Ö " - £ \$ Bà F ù • θ = mg " F z = ! % ð g
 z_c = ù • ç w Â ç ê N , x D i æ > 7 3 i T C g

$$\ddot{x} = \omega^0 \omega_0 - p_0 \quad \omega_0 0$$

< Z " ω = √(g/z_c) %
 2(4 Æ = ±±¹ Kc Û 3 æ / 8 • < " E 6 : 9 ±± p
 1 2(4 J i F * G Ä] - 3 ñ x % ω " - É 3 G N s Ö)
 Ò U - B æ " E 6 5 E / ±± p 1 2(4 J i 3 ñ = - 3 ñ
 E 4 ±± ? /ø s = y B • ' . % 3 % o o < Æ = ' ä . / § K !
 • <

$$\zeta = \frac{\dot{\omega}}{\omega} = \frac{\dot{\omega}}{\omega} + \frac{\dot{\omega}}{\omega} p \quad \omega_0 0$$

< Z " ζ = [x x] !o' 7 < ±±? ½? g
 ζ % o = \frac{\dot{\omega}}{\omega} = \frac{\dot{\omega}}{\omega} + \frac{\dot{\omega}}{\omega} p
 \frac{\dot{\omega}}{\omega} = \frac{\dot{\omega}}{\omega} + \frac{\dot{\omega}}{\omega} p
 \frac{\dot{\omega}}{\omega} = \frac{\dot{\omega}}{\omega} + \frac{\dot{\omega}}{\omega} p \quad \omega_0 0

< Z " ζ_1 = x_1 æ_1 Ò %
 Ó # ± µ ÷ 9 ±± Ç v ; Ö)
 f > ê % æ ± Ç v Ä
 p = x % ω_0 | , > = ù • d % ω_0 | ω_0 - p_0 +
 æ \frac{\beta}{\omega} = \frac{\dot{\omega}}{\omega} \alpha_1 + p \quad \omega_0 0

$$\ddot{A}] \quad p = x_1 + \frac{\dot{x}_1}{\omega} \quad \omega_0 0$$

$$3 \omega_0 0 < E = y \ddot{o} ! < \cdot \ddot{A}]$$

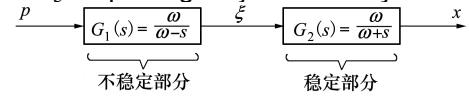
$$G \omega_0 0 = \frac{\omega^0}{\omega^0 - s^0} \quad \omega_0 0$$

2(4 ME ? * • æ 6 w L • ±± @ % æ 2(4 : \ # = E
 / Ç % 3 G % o f Æ E g % o o < £ * h ' 2(4 s + % i +
 0 o

$$G \omega_0 0 = \frac{\omega}{\omega - s} \frac{\omega}{\omega + s} \quad \omega_0 0$$

f > / Ç F 3 ME ? * • G_0 % o o ! o ' ξ ¹ x ±± 2(
 ξ = x % ω + \frac{\dot{x} % ω}{\omega} \quad \omega_0 0

æ æ & ! % 0 0 < 1 % 0 0 < " b (Y ξ ¹ ê % æ 6
 , % 9 ±± • " = • D ê • < % + 0 Z x E * C W / D ð 8 / Ç " 59
 ξ E * C W / D ð 8 : / Ç " r ξ = Ø g D ý Ö p • 3 F ù
 % Ö X o % * ^ » x E * C W / D ð 8 / Ç " m ù Bà' . > ñ
 ? # > @ ξ : p • " g • ç ^ / Ç s Ö 8 è %



+ 0 æ Â ç ê N , Ö È " ó 3

#‡ μ ÷ 9 ì 50D•E&L = ÷ C CWÔ c

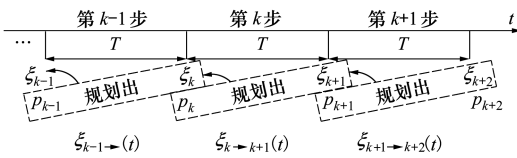
#yÔ‡ μ ÷ 9 ì 50D•E&±*L =

E6 x 1 ξ %o2(4 'ä . Fü"2(4 Ö È " æ /8 ÆE='ä . /§K! • < g

σ = [ω - ω ; ω] σ + [ω ; ω - ω] p %BBo

< Z "σ = [x ξ] %

g • ç - ' s ÖZ \ %æ : "p %æ g g • ç ±=yB•6G• %Ö X ì 50D•E&±*L = L->®- 3ñ>ñ? a ±6G• } 4 p_k "ç g @Ç ùBàg • ç G' E 4 =y B•±±- ; - ' 4 OE# hξ%æ a 1 p%æú5 "A g !%&c; Ê > G_β%oo ^ ú Ö 0Y- ' "EDu ùBàj W=yB•' . Z ξ F* \ : p • ±±%



+ æÖ X>ñ? æ"

3 %BBo < Z±0Y1 =y G_β%oo ÆE=.è • 'ä .

æ/8 ξ_k = F %G_{k+β} "p_k o • <

ξ_k = -ωT %G_{k+β} - p_k o + p_k %BBo

æœ4 ' 0Yk ' ±±j 6G%æ 1 0Yk + β' ξ ±Bæ i ξ_{k+β} "Ê >ñ F F 0Ä' - W#K!C ÓT z 0Yk ' ξ ±Bæ i ξ_k " ' 1" Ö %0Yk ' ξ ±±3ö • i 0v » 0Y k + β' ξ ±Bæ i %i + o%do ' 3 ü - ' ξ ±Bæ ø i ' 9j 6G%æ_k Ê > G_β%oo Ö' ξ_{k+β} %o"E Fùlo ' ±±ü - WT #K! â 2 ±±ξ_{k+β} %oF* Ô%

3 %BBo < Z±0Y- =y G_0%oo ÆE=.è • 'ä .

æ/8 x_{k+β} = H %G_k "ξ_k o • <

x_{k+β} = -ωT %G_k - ξ_k o + ξ_k %B o

æœÊ > x_k 1 ξ_k ^ Ö' T #K! ; ±±x_{k+β} "lo ' 3 ü - ' x ±±Bæ ø i x_k Ê > G_0%oo Ö'

x_{k+β} %oo%

- ' » ; MIE?Ö æ" >ñ? Ö X 1 XD•E&

±±0Ä" g â

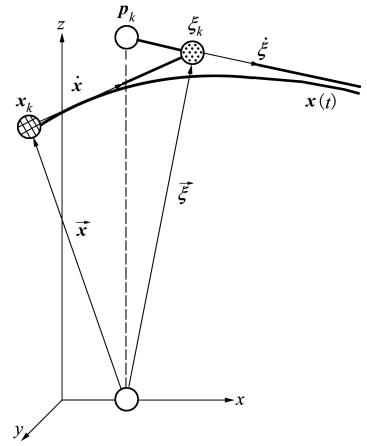
Bo4 ' , 49j 6G%æG• oP = p_β - p_k - p_n Ö+

0o^* ξ_{k+β} 1 p_k ú Ö ξ_k "ξ_k = F %G_{k+β} "p_k o" k B+

o f > 0Yk ' J i ξ_k "p_k 1 G_β%oo" !o

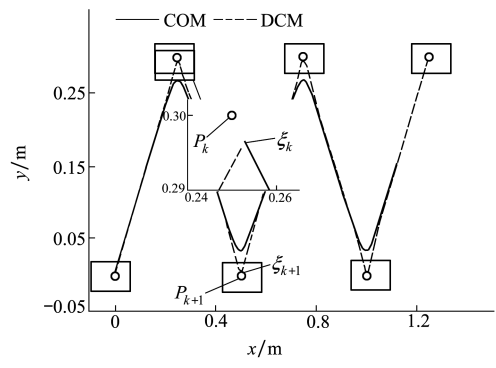
' ξ_{k+β} %oo+

xo^* x_k 1 ξ_k Ö' x_{k+β} "x_{k+β} = H %G_k "ξ_k o+ "o f > x_k 1 ξ_k %oo1 ' x_{k+β} %oo% ^ ξ_k = F %G_{k+β} "p_k o E Ö' ξ_k "ξ_{k+β} " ξ_{k+β} %oo 1 p_k # hF* U9 - Ž! 3i 7 " *^ G_0%oo - x = ω %G_0 - x o" x ; ξ - x 9 > "x %oo±ELÓ æ> ø 3ö 4 > ξ_k %oo" T < 0v » ω | ξ - x | " + x m.g %



+ xœ 64! Ö X 1 X±±' Y/(Ö

8L•4 5 π €0Ä, ", ,L0Ä" ±±ËKru É %U x-y L•ZE6 2(4 s Ö " " " 6G• p_k = %b! " !. !o" %b 0" !. o" %b " !. !o" %b ®" !. o" %b ! " !. !o" %B 0" !. o %b o" T = β "ω = x x 0Gξ = %B 0" !. o S ' ξ_k = F %G_{k+β} "p_k o !o' ξ_β " - *UE?Ö0Ä" "0Ä" ξ_{k+β} %oo 1 x_{k+β} %ooD•E& + " m.g "Ë3i g XD•E& ; ‡3i g Ö XD•E&%Ö X \ 3 â 3i " ü - â =.g - N s Ö% ,8' + Z ξ_{k+β} %oo - ,! 1 » Öä . "3üDô- W#K!C ÓT B_s » p • #E ' 8 - s %

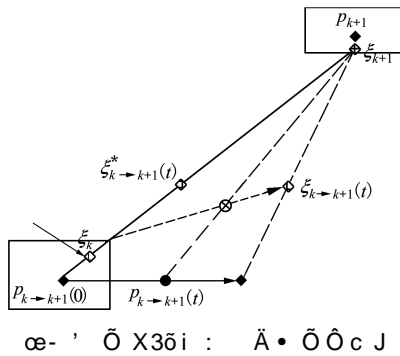


+ "œ 1 4! Ö X 1 X' . K!±±(Ö

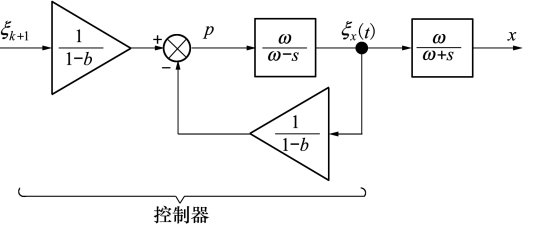
#y‡ - ' μ ÷ 9 3öi : Ä • Ö Ö c lμ & Äç Ö È " æ/8 ±±: / ÇF 3 "6 ò >®@ë

@ÏË g2(4 Q0y T+±BLú NµÔ c • " - ù Bâ2(4 U
 0Yk '] • Õ; Ê&æ* U - W#K!C Ó T ² Fú
 >ñ? +±ξ_{k+β} %æ %

- *U+ ' A!; - ' Õ X3õ i : Ä • Õ Ô
 c +±J %- øKcâ p_k U p_{k k+β} %01 " Ê > p_k .
 : >ñ? ' +±ξ_k & k+β 1 p_k U 9 - Ž, ! 3ì 7 - +
 Ô È 3ì m.g % - É 2(4 : C *y • Õ ξ_{k k+β} %0 3
 K!/#K!+±Ô/(!ì , ! 3ì ù ξ_k DýÕ] ξ_{k+β} 1 %s \ - É
 2(4] ³ C *y +± Õ " ξ_{k k+β} %0 | / (³ Ô È
 3ì % Õ ÑK' ; " 2(4 - É ú &c 9 H ξ_{k k+β} %0 06 * L
 U - W#K!C Ó T ² DýÕ] ξ_{k+β} " EÐU p_k ò &d - >®
 / (Õ . ξ_{k k+β} %0 & k+β 1 p_{k k+β} %0 U 9 - Ž, !
 3ì 7 " - + m.g % U E W p_{k k+β} %0 % *U 8 "
 ξ_{k k+β} %0 3 GK!/#K!+±Ô/(DýÕ ξ_{k+β} 1 " ; :
 • Õ, %! 6* , % 9 +±ξ J i E ' 8 - s " 8 - s 2(
 4 4 4 Ê & " >ñ? Dýy 8 è %



æææ! !! " ! Ò'
 x_x % = ! " ! 80 " " ! 0 " ! "
 æææ! 0 " ! " 80 " Ò'
 x_y % = ! " ! 8x 0 " ! 8 " ! 8 " ! 8 " ! 8 " 8 Ò

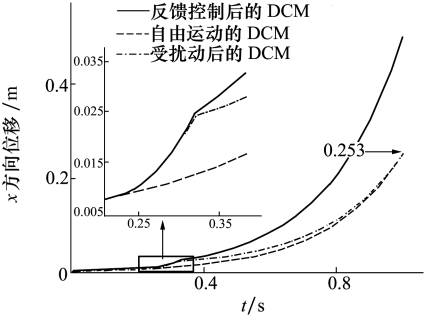


+ æe- ' Õ X3õ i : Ä • Õ Ô c s +

0Y- ' x æ > g , " ξ_β 0 %0 ù ! !! DýÕ] ! 0"
 1 = - N x æ > s Õ " - É 2(4] C *y • Õ " Õ
 È f' !ì x Dì ; æ > % *U " 2(4 +± Õ È " æ / 8 g

$$\dot{x} = \frac{g}{z} \left(x - p + \frac{z f'}{mg} \right) \quad \% 8 0$$

- 3õ € (Ý U & \ %æ +± • Õ %



+ æK (Ü Ô c z ; 4 æ > Õ X " •

Ê > G_β %0 ! o ' ξ = ω %0 - p o " ? ' £ E G g
 ξ_{k k+β} %0 = ω t ξ_k + %0 - ω t φ_k %0 x o
 3 ξ_{k k+β} %0 *U ξ_{k+β} , " ξ_k *U € z È " x 2(4 +± ξ_x %0
 , " %0 x o < E 59 f A E g

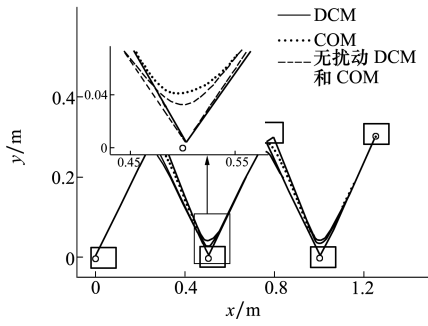
$$p_{k k+β} \%0 = \frac{\xi_{k+β} - \omega \%0^{-1} \xi_x \%0}{\beta - \omega \%0^{-1} \alpha} =$$

$$\alpha \frac{\beta}{\beta - b} \xi_{k+β} - \frac{b}{\beta - b} \xi_x \%0 \quad \% 8 " 0$$

< Z " ξ_{k+β} g 0Yk ' 2(4 L H] Dè +± 3õ i " g - e
 i " ξ_x %0 g 2(4 È # ú Nµ ξ i " b = ω \%0^{-1} o " T g - '
 mL - #K!C Ó % 0Ä', 4 p_{k k+β} %0 i " OE \
 L H ; X ê D • E & " Ô c ; X ê % æ C W M p_{k k+β} %0
 @ i ξ_{k k+β} %0 K!/#K!+±Ô/(ú • » ξ_{k+β} % *h ' 2(
 4 +±K (Ü 2(4 s + - + ®.m.g %
 Fõ *U 0 Ž 7 - 0 Ä , "] U M & , L Ä]

ξ_x % = ! !! " ! 0 " " ! " ! " ! 0 " " ! " 80 " Ò'
 ξ_y % = ! !! " " ! 0 " " ! !! " " ! 0 " "

Ä *U Õ X3õ i : K (Ü Ô c 0Ä " " - Â çê U
 x " y • æ > ú t] , % 9 T < +± C *y • Õ È % 6
 % 8 " o < @ @ ! s + ®.m.g +± Ô c • % , , L 4 É - +
 m.g " , 8] á] • Õ È ; " Õ X D • E & | . è > ñ
 ? " Ò ' Ô c • ; +± Õ X K!/#K!+±Ô/(Fú > ñ
 ? % 3ì - 3õ] ³ ξ_x % = ! 0 " 1 % U x-y L • 7
 Õ X +± D • E & - + m.g " U + Z 9 # ‡ ' ³ W •
 Õ # +± 3ì " , 8] - ' 4 CE # h ξ_{k k+β} %0 K!/#K!/#K!
 #K!+±Ô/(ú • » > ñ? +± ξ_{k+β} %
 #yú ‡ È # µ ÷ 9 D • E & C W M (Ü Ô c
 , % & » 0 Ž 7 - È # Õ X D • E & C W M (Ü Ô c J
 € (Ý U á U - W = y B • ' . Z @ í ú Nµ ξ_x %0 È #
 C C W ñ? +± ξ_{k k+β} %0 % 8 x o < Z ξ_{k k+β} %0 .
 : " ξ_k - *U ú Nµ ξ_x %0 , " ! o "



+ αK (Ü Ô c z ; Õ X¹ X" •

$$p_{k+k+\beta} = \frac{\xi_{k+k+\beta} - \omega^T \xi_x}{\beta - \omega^T} =$$

$$\frac{\beta}{\beta - b} \xi_{k+k+\beta} - \frac{b}{\beta - b} \xi_x \quad \%B\textcircled{B}$$

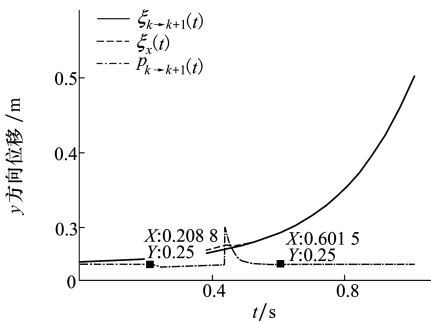
< Z "ξ_{k+k+β} g 0Y_k ' 2(4 >ñ? ' ±± Õ XD•E&" g
 - #K! ¼ D "ξ_x g Ë #2(4 ú Nμξ i "b = "T "T
 g 2(4 C CW, 4 ξ i mL->±#K! " " < T 1 -
 ' mL- #K!C Ó T ±±g X %3 + @Z ±± Ô c • F 3
 AE = • " TM < ±± • < G p (Y â ù ξ_{k+k+β}] ξ_x %
 DTM = 3 - W- Kc T (Ü T

$$G' \%o = \frac{\omega'}{s + \omega'} \quad \%B o$$

$$< Z " \omega' = \frac{\omega}{b - \beta} \%$$

m *^ » - Kc T (Ü T ±± ... U " : ÔÍ ω' ,

i "ξ_x %o U 9 - # hF* " C CW ξ_{k+k+β} %o "ξ_x %o
 \$; ξ_{k+k+β} %o T #K! % ' g ³ @î- ' #K!C
 Ó T ; " : ž ú 8 - ' ±±s Õ " 3 ξ_{k+k+β} %o + T o
 %og t # h ±±4 i " -2(4 \$; T " OEB* @ît
 # h ú Nμξ_x %o = ξ_{k+k+β} %o %



+ B œ Ë # C CW Ô c z ; x æ > Õ XD•E&

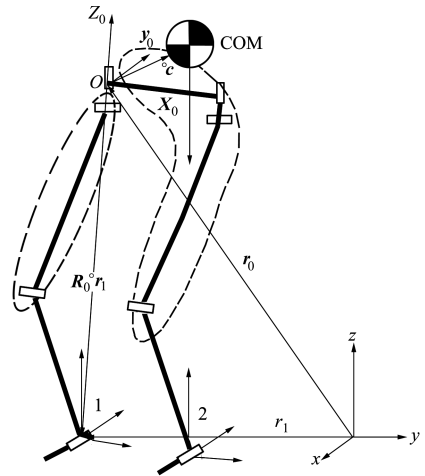
+ B A! ; ³ 0 B 7-0Ä, ±±0Y 0' x æ > í ' •

Õ \$; Ô c • ±± Ô c u É %E Fù b = B B " Õ '

T = !. !0B " % , 8] â] • Õ ; ξ_x %o - ø |
 .è ξ_{k+k+β} %o "s \ • Õ è K' ; 2(4 μ GU Ô c •
 ±±%*U 8 Fú >ñ? % + ZE 4 ' ³ p_{k+k+β} %o + ±D•
 E&"OÄ' ±±p_{k+k+β} %o] • Õ | .è ³ p_k %æ&c ; •
 Õ è K' ; õ Fú p_k %æ%

ú ‡ 4 Ç ÷ ã 9 , 4 D•E&E 3DýÕ " • i ? "

U Y 7- Z " 3 (« È > >ñ? ' ±± XD•E&1 ù
 6DýÕ D•E&o? g • ç E 3DýÕ " ±±æ" " g • ç N
 , - + B B m.g %



+ B B œ U » Õ . =yB•±±ù Bàg • ç

E6 g • ç Oø 7- Z ±±- W } 42(%og g • ç
 K1/€ ' } 42(o % C*y } 42(' Ç »] L• 7 ý -
 %æF ' } 42(o , % & » C*y } 42(±±z 4) g r_o %
 3 û } 42(o 3 ' ±± 0 WDýÕ J + 3 X/ g 0Y- 5İ €
 ' 0Y' 5İ € " , 6- \ ¾ Kcâ \ ¾ 6- \ g 0Y- 5İ € "
 - Ž 6- \ g 0Y' 5İ € %ù 6G\ ¾ Kcâ (E6- Ž 6- g
 0Y- 5İ € %0Yi 5İ € 7 ± 6 n_i W h Õ 7- %
 0Yi 5İ € X0 } 42(U C*y } 42(Z ±±z 4) g
 r_i = r_o + R_o^o r_i %B o
 < Z " r_i â t × B " R_o â t × \ } 42(o] C*y } 42(
 ±±DTM - Kb " r_o â t × B \ } 42(o U C*y } 42(Z
 ±±z 4) %

0Yi 5İ € X0 U } 42(o Z ±±ELÓ

$${}^o \dot{x}_i = {}^o J_i \dot{q}_i \quad \%! o$$

7 4 o = • g , % & » } 42(o 59? - " J_i â t × n_i \ Kò x
 ! - Kb " x_i = {}^o r_i • w_i Õ â t " q_i â t n_i \ 0Yi 5İ € ±±

7 >ÿELÓ >Fü%

ú Ó† 5ĭ ∈ DýÕ3ÓÉŽ #

Ò 8 ' !o 0Yi W5ĭ ∈ X0 U C*y } 42(Z ±±

ELÓ x_i = r_i ω_i Ò

$$\dot{r}_i = \dot{r}_o + R_o^o \dot{r}_i + \omega_o \times \dot{R}_o^o r_i$$

$$\omega_i = \omega_o + R_o^o \omega_o \quad \%0\beta o$$

< Z " %0o × Ò \ - FÛ / ±±ú & / - Kb" 3 £ • - C Æ =

$$\dot{x}_i = X_i^{-\beta} \dot{x}_o + J_i \dot{q}_i \quad \%00o$$

x_o = r_o ω_o Ò \ } 42(o ,% & » C*y } 42(±± ELÓ %

$$X_i = \begin{pmatrix} \dot{e}^I & R_o^o r_i \times \dot{Q}_i \\ \dot{e} & I \end{pmatrix} \hat{a} t \times "X_o = \begin{pmatrix} \dot{e}^I R_o & \dot{U} \\ \dot{e} & R_o \end{pmatrix} \dot{U}$$

â t × "J_i ÷ X_o J_i "I⁻¹ 3 X \ 64! , z Kb¹ 6 4! Kb%

& » g • ç : 9 ±±5ĭ ∈ "F* ÁA ± 6 ,% 9 ±±}

42(o ,% & » C*y } 42(±± ELÓ " • A A! " ù %00o

< ,8 ' "m 6 ±±5ĭ ∈ F* ÁA \$ Bà } 42(o ELÓ

,% 9 ±±3ÓÉŽ # " ' "0Yi 5ĭ ∈ 1 0Yj 5ĭ ∈ 5ĭ ∈ Á A \$ Bà 8 2(

$$X_i \%0_i - J_i \dot{q}_i o = X_j \%0_j - J_j \dot{q}_j o \quad \%0 o$$

" X ±±6

$$X_{\beta} \%0_{\beta} - J_{\beta} \dot{q}_{\beta} o = X_i \%0_i - J_i \dot{q}_i o \quad \%0 \times o$$

m

$$\dot{q}_i = J_i^{\dagger} \dot{x}_i - J_i^{\dagger} X_{i\beta} \%0_{\beta} - J_{\beta} \dot{q}_{\beta} o \quad \%0" o$$

< Z " J_i† g J_i ±± X •• ç Kε ç o ÷ v E3- Kb

$$X_{i\beta} = X_i^{-\beta} X_{\beta} = \begin{pmatrix} \dot{e}^I & R_o \%0_{\beta} - r_o o \times \dot{Q}_i \\ \dot{e} & I \end{pmatrix} \dot{U} \quad \%0 o$$

m " " » %0" o < «] ±±q_i 1 q_β 2(!o ' £

5ĭ ∈ ±±E3DýÕ " ? "59; } 42(o ±±DýÕ !ĭ 6

2(%

úž† 4 ÇBUđ DýÕD•E&±±E3DýÕ " !o?

U C*y } 42(Z • CBUđ } 4 =•.g g

$$c = r_o + \sum_{i=\beta}^n \mathbb{R} R_o^o c_i \quad \%0\beta o$$

< Z " c â t "c_i =•.g 0Yi 5ĭ ∈ ±±BUđ U o } 42(Z

±±} 4 % Ò 8 ' !o BUđ U C*y } 42(Z ±±ELÓ

$$\dot{c} = \dot{r}_o + R_o \sum_{i=\beta}^n \dot{c}_i + \omega_o \times \sum_{i=\beta}^n \mathbb{R} R_o^o c_i =$$

$$\dot{c}_o + \omega_o \times \%0 - r_o o + \sum_{i=\beta}^n \mathbb{R} R_o^o J_{ci} \dot{q}_i \quad \%0 o$$

< Z " c â t "J_{ci} =•.g 0Yi 5ĭ ∈ ±±BUđ ,% & » o } 4

+±Kòx! - Kb" J_{ci} ÷ t_o J_{ci}

k & c

$${}^o c_i = \sum_{k=\beta}^{n_i} \mathbb{R} \alpha_{i\%k} {}^o c_{i\%k} \quad \%0 o$$

< Z " {}^o c_{i\%k} â t =•.g 0Yi 5ĭ ∈ ZOYk E s ±±BUđ U o

Z ±±} 4 >Fü % ò f \ Kòx! - Kb ±±Ç v

$${}^o J_{ci} = \sum_{k=\beta}^{n_i} \mathbb{R} \alpha_{i\%k} \frac{N c_{i\%k}}{N_i} \quad \%0! o$$

< Z

$$\alpha_{i\%k} = \frac{m_{i\%k}}{\sum_{k=\beta}^{n_i} \mathbb{R} m_{i\%k}}$$

m_{i\%k} =•.g 0Yi 5ĭ ∈ ZOYk E s ±±BUđ % £ 3 %0" o <

S ' %0 o < "C0- Ä

$$\dot{c} = \dot{r}_o + \omega_o \times \%0 - r_o o + J_{c\beta} \dot{q}_{\beta} +$$

$$\sum_{i=0}^n \mathbb{R} J_{ci} J_i^{\dagger} \%0_i - X_{i\beta} \dot{x}_i o + \sum_{i=0}^n \mathbb{R} J_{ci} J_i^{\dagger} X_{i\beta} J_{\beta} \dot{q}_{\beta} \quad \%0\beta o$$

õ g

$$\dot{x}_o = X_{\beta} \%0_{\beta} - J_{\beta} \dot{q}_{\beta} o \quad \%00o$$

$$\begin{pmatrix} \dot{e}^I \dot{r}_o \dot{U} \\ \dot{e} \dot{\omega}_o \dot{U} \end{pmatrix} = \begin{pmatrix} \dot{e}^I & R_o^o r_{\beta} \times \dot{Q}_i \\ \dot{e} & I \end{pmatrix} \begin{pmatrix} \dot{e}^I \dot{r}_{\beta} \dot{U} \\ \dot{e} \dot{\omega}_{\beta} \dot{U} \end{pmatrix} - \begin{pmatrix} \dot{e}^I J_{v\beta} \dot{U} \\ \dot{e} J_{\omega\beta} \dot{U} \end{pmatrix} \dot{q}_{\beta}$$

%0 o

< Z " ω_o =•.g } 42(o ±±ø DTM ω_i =•.g } 42(i ±±ø

DTM J_{vβ} 1 J_{ωβ} 3 X g U C*y } 42(7 =•.g ±±' 5ĭ %0Y

- 5ĭ ∈ oKò ! J_β ±±3ĭ ELÓF 3 1 >ÿELÓF 3 %

m

$$\dot{c} = \dot{r}_{\beta} + \omega_{\beta} \times \%0 - r_{\beta} o + \%0 - r_{\beta} o \times J_{\omega\beta} \dot{q}_{\beta} - J_{v\beta} \dot{q}_{\beta} +$$

$$\sum_{i=0}^n J_{c\beta} \dot{q}_{\beta} + \sum_{i=0}^n \mathbb{R} J_{ci} J_i^{\dagger} \%0_i - X_{i\beta} \dot{x}_i o + \sum_{i=0}^n \mathbb{R} J_{ci} J_i^{\dagger} X_{i\beta} J_{\beta} \dot{q}_{\beta} \quad \%0 \times o$$

õ g ' 5ĭ x_β = r_β ω_β Ò = "m %0 × o < 0- C g

$$\dot{c} = \sum_{i=0}^n \mathbb{R} J_{ci} J_i^{\dagger} \dot{x}_i +$$

$$\left(\%0 - r_{\beta} o \times J_{\omega\beta} - J_{v\beta} + J_{c\beta} + \sum_{i=0}^n \mathbb{R} J_{ci} J_i^{\dagger} X_{i\beta} J_{\beta} \right) \dot{q}_{\beta} \quad \%0" o$$

f Æ %0" o <

$$\dot{c}_i = J_i \dot{q}_{\beta} \quad \%0 o$$

< Z

$$\dot{c}_i = \dot{c} - \sum_{i=0}^n \mathbb{R} J_{ci} J_i^{\dagger} \dot{x}_i$$

$$J_i = \%0 - r_{\beta} o \times J_{\omega\beta} - J_{v\beta} + J_{c\beta} + \sum_{i=0}^n \mathbb{R} J_{ci} J_i^{\dagger} X_{i\beta} J_{\beta}$$

$$3 \text{ } \partial D^T \omega_o = - J_{\omega} \dot{q}_B \ddot{E} \rightarrow ' \%_o \text{ } o < Z \ddot{A}$$

$$\dot{q}_B = \begin{pmatrix} \dot{c}_1 \\ \dot{c}_2 \\ \dot{c}_3 \end{pmatrix} = \begin{pmatrix} J_{c1} \\ J_{c2} \\ J_{c3} \end{pmatrix} \dot{x}_0 \quad \%_o \text{ } \textcircled{B}$$

œœE d ^ «] ³ ' 5İ 7/§K! ; BUð } 4/§K! x K!±± 2("4 5 %0" o < " !o ' U 4 Ç±±BUð Dý ÖD•E&& ±±E3? %

'! X±± & » ùBà' =y g • ç "£ 6 0 WDýÖ J+ " ABUð . Ö "n_B = n_o = "ω_o = ! 6

$$\dot{c}_i = \dot{c} - J_{c0} \dot{x}_0$$

$$J_i = \%_o - r_{B0} \times J_{\omega B} - J_{vB} + J_{cB} + J_{c0} J_0^T X_{0B} J_B$$

$$\dot{q}_B = \begin{pmatrix} \dot{c}_1 \\ \dot{c}_2 \\ \dot{c}_3 \end{pmatrix} = \begin{pmatrix} J_{c1} \\ J_{c2} \\ J_{c3} \end{pmatrix} \dot{x}_0$$

$$\dot{q}_0 = J_0^T \dot{x}_0 + X_{0B} J_B \dot{q}_B \quad \%_o \text{ } \textcircled{B}$$

œœ! Ö!o? \%_o o < \ μ Kë¹ = ±±%E FùFô*U • i ? " "3 £ ÆE= 3 • <

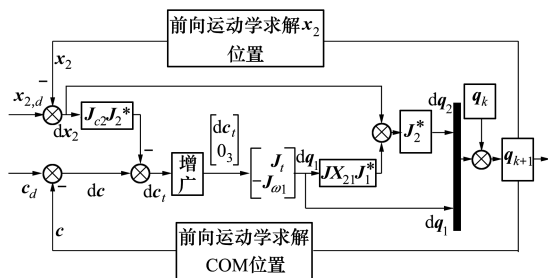
$$\dot{x}_i = \dot{x} - J_{c0} \dot{x}_0$$

$$J_i = \%_o - r_{B0} \times J_{\omega B} - J_{vB} + J_{cB} + J_{c0} J_0^T X_{0B} J_B$$

$$\dot{q}_B = \begin{pmatrix} \dot{c}_1 \\ \dot{c}_2 \\ \dot{c}_3 \end{pmatrix} = \begin{pmatrix} J_{c1} \\ J_{c2} \\ J_{c3} \end{pmatrix} \dot{x}_0$$

œœe yq_o = J_0^T \dot{x}_0 + X_{0B} J_B \dot{q}_B \quad \%_o \text{ } \textcircled{B}

& » 4 Ç³ BUð ¹ ù6¬X0 DýÖD•E&±±ùBàg • ç "0Y- 5İ ∈ X0 ;] L• Ö? £ . : Ö **^0Y¹ 5İ ∈ i 50D•E&¹ X i 50D•E&Á*U+ B0 EL !o? ' q_B ¹ q_o %



+ B0œùBàg • ç E3DýÖ " ±± • i ? "

¼£ , ,LA O¹

Y7 3 GU • Ö±±ò â 8 %6 • Ö # 9)3 Ä o& 7E æ" E =y • L•±± , L %DýÖ " N , Fô*U f E ÖK@' F ' /ø "æ ∈ 4 ± g %i • ÷ BUfù < T>î=• B%

$$= \cdot \dot{q}_i g \cdot \dot{q}_j g \pm BUfù < T = \cdot$$

Fz	42(α_{iqB} ǎ	a_{iqB} ǎ]	d_i ǎ]	θ_i ǎ	BUð U,%ÁE s 1±±z 4> %o",y,z o ǎ]	BUfù ð k
	!%X0 o	!	!	!	!	%ǎ" ž0B!" @ žB0o%6Go	!ž@
	B%ǎJ 7 o	!	!	!	q_B		
	0%ǎJ 7 o	ǎ	!	!	q_0	%0" ž" "0ǎžB!" !o%ǎ6¬o	žxß
	%ǎÉ 7 o		x!ž	!	q	%00xž "B0ž0B!" !o%T6¬o	xž@
6¬	x%ǎ0 7 o	!	xx!	!	q_x		
	"%ǎ0 7 o	ǎ	!	!	q_*		
	%ǎ0 7 o	!	!	B0xž	q	%B"! žB ""!" !o%ǎ0¬o	@ǎ@
	@%ǎ0 7 o	!	!!	qB0xž	$q_@$		
	%ǎ0 7 o	ǎ	!	!	q		
	%ǎ0 7 o	ǎ	!	!	q	%B"! žB ""!" !o%T6¬o	xž@
	B! %ǎÉ 7 o		xx!	!	q_B	%B"! žB ""!" !o%ǎ6¬o	žxß
6¬	Bß%ǎJ 7 o		x!ž	!	$q_{Bß}$		
	B0%ǎJ 7 o	q ǎ	!	!	q_{B0}		
	B %X0 o	!	!	!	!	%B"! žB ""!" !o%6Go	!ž@

