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" DYNAMIC FORCE ANALYSIS VIA FBD "
Apply [Clear, Names["Global`*"] ] ;
Off[General::spell];
Off[General::spell1];

(* Input data *)
n = 50 ; (* rpm *)
omega = n N[Pi]/30 ; (* rad/s *)

rule = {AB->0.14, AC->0.06, AE->0.25, CD->0.15, FD->0.4, EG->0.5, h->0.01, d->0.001,
hSlider->0.02, wSlider->0.05, rho->8000, g->9.807, Me->-100., phi[t]->N[Pi]/6,
phi'[t]->omega, phi''[t]->0} ;

(* Position analysis *)

(* Position of joint A *)
xA = yA = 0;
rA = { xA, yA, 0};
Print["rA = ", rA, " [m]"] ;

(* Position of joint C *)
xC = 0 ;
yC = AC ;
rC = { xC, yC, 0} ;
Print["rC = AC = ", rC/.rule, " [m]"] ;

(* Position of joint E *)
xE = 0 ;
yE = -AE ;
rE = { xE, yE, 0};
Print["rE = AE = ", rE/.rule, " [m]"] ;


(* Position, velocity and acceleration of joint B *)
xB = AB Cos [ phi[t] ] ;
yB = AB Sin [ phi[t] ] ;
rB = { xB, yB, 0} ;
Print["rB = AB = ", rB/.rule, " [m]"] ;
vB = D[rB,t] ;
aB = D[D[rB,t],t] ;

(* Position, velocity and acceleration of joint D *)

(* Parameters m and n of line BC: y = m x + n *)
mBC = ( yB - yC ) / ( xB - xC ) ;
nBC = yB - mBC xB ;
eqn41 = ( xDsol - xC )^2 + ( yDsol - yC )^2 - CD^2 == 0 ;
eqn42 = yDsol - mBC xDsol - nBC == 0 ;
solutionD = Solve [ { eqn41 , eqn42 } , { xDsol , yDsol } ];
(* Two solutions for D *)
xD1 = xDsol /. solutionD[[1]];
yD1 = yDsol /. solutionD[[1]];
xD2 = xDsol /. solutionD[[2]];
yD2 = yDsol /. solutionD[[2]];
(* Select the correct position for D *)
If[ (xD1/.rule)<=xC, xD=xD1; yD=yD1, xD=xD2; yD=yD2 ] ;
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rD = { xD, yD, 0} ;
Print["rD = AD =", rD/.rule, " [m]"] ;
vD = D[rD,t] ;
aD = D[D[rD,t],t] ;

(* Angular velocity and acceleration of the link 1 *)
alpha1 = {0, 0, phi''[t]} ;

(* Angular velocity and acceleration of the link 2 and link 3 *)
phi2 = ArcTan[ mBC ] ;
alpha2 = {0, 0, D[D[phi2,t],t]} ;
phi3 = phi2 ;
alpha3 = alpha2 ;

(* Angular velocity and acceleration of the link 4 and link 5 *)

phi4 = ArcTan[(yD-yE)/(xD-xE)] + N[Pi] ;
alpha4 = {0, 0, D[D[phi4,t],t]} ;
phi5 = phi4 ;
alpha5 = alpha4 ;

(* -------------------------- *)
(* Inertia forces and moments *)
(* -------------------------- *)

(* Link 1 *)
m1 = rho AB h d /.rule ;
rC1 = rB/2 ;
Print["rC1 = AC1 =", rC1/.rule, " [m]"] ;
vC1 = vB/2 ;
aC1 = aB/2 ;
Fin1 = - m1 aC1 /.rule ;
G1 = {0, -m1*g, 0} /.rule ;
F1 = ( Fin1 + G1 ) /.rule ;
IC1 = m1 (AB^2+h^2)/12 /.rule ;
M1 = Min1 = - IC1 alpha1 /.rule ;
Print["F1 = ", F1, " [N]"] ;
Print["M1 = ", M1, " [Nm]"] ;

(* Link 2 *)
m2 = rho hSlider wSlider d /.rule ;
rC2 = rB ;
Print["rC2 = AC2 = AB = ", rC2/.rule, " [m]"] ;
vC2 = vB ;
aC2 = aB ;
Fin2 = - m2 aC2 /.rule ;
G2 = {0, -m2*g, 0} /.rule ;
F2 = ( Fin2 + G2 ) /.rule ;
IC2 = m2 (hSlider^2+wSlider^2)/12 /.rule ;
M2 = Min2 = - IC2 alpha2 /.rule ;
Print["F2 = ", F2, " [N]"] ;
Print["M2 = ", M2, " [Nm]"] ;

(* Link 3 *)
m3 = rho FD h d /.rule ;
xC3 = xC + (FD/2-CD) Cos [ phi3 ] ;
yC3 = yC + (FD/2-CD) Sin [ phi3 ] ;
rC3 = { xC3, yC3, 0 } ;
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Print["rC3 = AC3 = ", rC3/.rule, " [m]"] ;
vC3 = D[rC3,t] ;
aC3 = D[D[rC3,t],t] ;
Fin3 = - m3 aC3 /.rule ;
G3 = {0, -m3*g, 0} /.rule ;
F3 = ( Fin3 + G3 ) /.rule ;
IC3 = m3 (FD^2+h^2)/12 /.rule ;
M3 = Min3 = - IC3 alpha3 /.rule ;
Print["F3 = ", F3, " [N]"] ;
Print["M3 = ", M3, " [Nm]"] ;

(* Link 4 *)
m4 = rho hSlider wSlider d /.rule ;
rC4 = rD ;
Print["rC4 = AC4 = AD =", rC4/.rule, " [m]"] ;
vC4 = vD ;
aC4 = aD ;
Fin4 = - m4 aC4 /.rule ;
G4 = {0, -m4*g, 0} /.rule ;
F4 = ( Fin4 + G4 ) /.rule ;
IC4 = m4 (hSlider^2+wSlider^2)/12 /.rule ;
M4 = Min4 = - IC4 alpha4 /.rule ;
Print["F4 = ", F4, " [N]"] ;
Print["M4 = ", M4, " [Nm]"] ;

(* Link 5 *)
m5 = rho EG h d /.rule ;
xC5 = EG/2 Cos [ phi5 ] ;
yC5 = EG/2 Sin [ phi5 ] ;
rC5 = { xC5, yC5, 0} ;
Print["rC5 = AC5 = ", rC5/.rule, " [m]"] ;
vC5 = D[rC5,t] ;
aC5 = D[D[rC5,t],t] ;
Fin5 = - m5 aC5 /.rule ;
G5 = {0, -m5*g, 0} /.rule ;
F5 = ( Fin5 + G5 ) /.rule ;
IC5 = m5 (EG^2+h^2)/12 /.rule ;
M5 = Min5 = - IC5 alpha5 /.rule ;
M5e = { 0, 0, Me } /.rule ;
Print["F5 = ", F5, " [N]"] ;
Print["M5 = ", M5, " [Nm]"] ;



" link 5 "
F05Sol = { F05xSol, F05ySol, 0 } ;
F45Sol = { F45xSol, F45ySol, 0 } ;
"F45 perpendicular to DE => F45.DE=0 (1)"
rDE = ( rE - rD ) /.rule ;
eqF5DE = (F45Sol).rDE == 0
"∑F(5)=0: F05+F5+F45 =0 (2)"
eqF5 = F5+F05Sol+F45Sol;
eqF5x = eqF5[[1]]==0
eqF5y = eqF5[[2]]==0
"∑M(5)_C5=0: C5ExF05+C5PxF45+M5+M5e=0 (3)"
rP={-0.149492,0.0476701,0};
rC5E = ( rE - rC5 ) /.rule ;
rC5P = ( rP - rC5 ) /.rule ;
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eqM5 = (Cross[rC5E,F05Sol]+Cross[rC5P,F45Sol]+M5+M5e)[[3]] == 0

" link 4 "
F34Sol = { F34xSol, F34ySol, 0 } ;
"∑F(4)=0: F54+F4+F34=0 (4)"
eqF4 = F4-F45Sol+F34Sol;
eqF4x = eqF4[[1]]==0
eqF4y = eqF4[[2]]==0
"∑M(4)_D=0: DPxF54+M4=0 <=> IDENTITY (DO NOT USE)"
rDP = ( rP - rD ) /.rule ;
eqM4 = (Cross[rDP,-F45Sol]+M4)[[3]] == 0

" link 3 "
F03Sol = { F03xSol, F03ySol, 0 } ;
F23Sol = { F23xSol, F23ySol, 0 } ;
"F23 perpendicular to BC => F23.BC=0 (5)"
rBC = ( rC - rB ) /.rule ;
eqF2BC = (F23Sol).rBC == 0
"∑F(3)=0: F43+F03+F3+F23=0 (6)"
eqF3 = -F34Sol+F03Sol+F3+F23Sol;
eqF3x = eqF3[[1]]==0
eqF3y = eqF3[[2]]==0
"∑M(3)_C3=0: C3DxF43+C3CxF03+C3QxF23+M3=0 (7)"
rQ = {0.121243,0.07,0};
rC3D = ( rD - rC3 ) /.rule ;
rC3C = ( rC - rC3 ) /.rule ;
rC3Q = ( rQ - rC3 ) /.rule ;
eqM3 = (Cross[rC3D,-F34Sol]+Cross[rC3C,F03Sol]+
Cross[rC3Q,F23Sol]+M3)[[3]] == 0

" link 2 "
F12Sol = { F12xSol, F12ySol, 0 } ;
"∑F(2)=0: F32+F2+F12=0 (8)"
eqF2 = -F23Sol+F2+F12Sol;
eqF2x = eqF2[[1]]==0
eqF2y = eqF2[[2]]==0
"∑M(2)_B=0: BQxF32+M2=0 <=> IDENTITY (DO NOT USE)"
rBQ = ( rQ - rB ) /.rule ;
eqM2 = (Cross[rBQ,-F23Sol]+M2)[[3]] == 0

sol = Solve[{eqF5x,eqF5y,eqM5,eqF4x,eqF4y,eqF5DE,
eqF3x,eqF3y,eqM3,eqF2x,eqF2y,eqF2BC},
{F05xSol,F05ySol,F45xSol,F45ySol,
 F34xSol,F34ySol,F03xSol,F03ySol,
 F23xSol, F23ySol,F12xSol,F12ySol}];

"From Eqs.(1)(2)(3)(4)(5)(6)(7)(8) =>"
F05x=F05xSol/.sol[[1]];
F05y=F05ySol/.sol[[1]];
F05={F05x,F05y,0};
Print["F05 = ",F05," [N]"];
F45x=F45xSol/.sol[[1]];
F45y=F45ySol/.sol[[1]];
F45={F45x,F45y,0};
Print["F45 = ",F45," [N]"];
F34x=F34xSol/.sol[[1]];
F34y=F34ySol/.sol[[1]];
F34={F34x,F34y,0};
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F03x=F03xSol/.sol[[1]];
F03y=F03ySol/.sol[[1]];
F03={F03x,F03y,0};
Print["F03 = ",F03," [N]"];
Print["F34 = ",F34," [N]"];
F23x=F23xSol/.sol[[1]];
F23y=F23ySol/.sol[[1]];
F23={F23x,F23y,0};
Print["F23 = ",F23," [N]"];
F12x=F12xSol/.sol[[1]];
F12y=F12ySol/.sol[[1]];
F12={F12x,F12y,0};
Print["F12 = ",F12," [N]"];
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 DYNAMIC FORCE ANALYSIS VIA FBD
rA = {0, 0, 0} [m]
rC = AC = {0, 0.06, 0} [m]
rE = AE = {0, -0.25, 0} [m]
rB = AB = {0.121244, 0.07, 0} [m]
rD = AD ={-0.149492, 0.0476701, 0} [m]
rC1 = AC1 ={0.0606218, 0.035, 0} [m]
F1 = {0.0186142, -0.0990915, 0} [N]
M1 = {0, 0, 0} [Nm]
rC2 = AC2 = AB = {0.121244, 0.07, 0} [m]
F2 = {0.0265917, -0.0631033, 0} [N]
M2 = {0, 0, -0.000028165} [Nm]
rC3 = AC3 = {0.0498308, 0.06411, 0} [m]
F3 = {0.0492489, -0.33315, 0} [N]
M3 = {0, 0, -0.00621962} [Nm]
rC4 = AC4 = AD ={-0.149492, 0.0476701, 0} [m]
F4 = {-0.0369367, -0.0639614, 0} [N]
M4 = {0, 0, 0.0000111583} [Nm]
rC5 = AC5 = {-0.112198, 0.223409, 0} [m]
F5 = {-0.0553516, -0.410666, 0} [N]
M5 = {0, 0, 0.00481155} [Nm]
 link 5
F45 perpendicular to DE => F45.DE=0 (1)
0.149492 F45xSol - 0.29767 F45ySol == 0
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$\sum$F(5)=0: F05+F5+F45 =0 (2)

$-0.0553516 + \text{F05xSol} + \text{F45xSol} == 0$

$-0.410666 + \text{F05ySol} + \text{F45ySol} == 0$

$\sum$M(5)_C5=0: C5ExF05+C5PxF45+M5+M5e=0 (3)

$-99.9952 + 0.473409\,\text{F05xSol} + 0.112198\,\text{F05ySol} + 0.175739\,\text{F45xSol} - 0.0372941\,\text{F45ySol} == 0$

link 4

$\sum$F(4)=0: F54+F4+F34=0 (4)

$-0.0369367 + \text{F34xSol} - \text{F45xSol} == 0$

$-0.0639614 + \text{F34ySol} - \text{F45ySol} == 0$

$\sum$M(4)_D=0: DPxF54+M4=0 <=> IDENTITY (DO NOT USE)

$0.0000111583 + 2.40479 \times 10^{-8}\,\text{F45xSol} - 3.84331 \times 10^{-7}\,\text{F45ySol} == 0$

link 3

F23 perpendicular to BC => F23.BC=0 (5)

$-0.121244\,\text{F23xSol} - 0.01\,\text{F23ySol} == 0$

$\sum$F(3)=0: F43+F03+F3+F23=0 (6)

$0.0492489 + \text{F03xSol} + \text{F23xSol} - \text{F34xSol} == 0$

$-0.33315 + \text{F03ySol} + \text{F23ySol} - \text{F34ySol} == 0$

$\sum$M(3)_C3=0: C3DxF43+C3CxF03+C3QxF23+M3=0 (7)

$-0.00621962 + 0.00410997\,\text{F03xSol} - 0.0498308\,\text{F03ySol} - 0.00589003\,\text{F23xSol} + 0.0714122\,\text{F23ySol} - 0.0164399\,\text{F34xSol} + 0.199323\,\text{F34ySol} == 0$

link 2

$\sum$F(2)=0: F32+F2+F12=0 (8)

$0.0265917 + \text{F12xSol} - \text{F23xSol} == 0$

$-0.0631033 + \text{F12ySol} - \text{F23ySol} == 0$

$\sum$M(2)_B=0: BQxF32+M2=0 <=> IDENTITY (DO NOT USE)

$-0.000028165 + 0.\,\text{F23xSol} + 5.5653 \times 10^{-7}\,\text{F23ySol} == 0$

From Eqs. (1) (2) (3) (4) (5) (6) (7) (8) =>

F05 = {268.128, 135.039, 0} [N]

F45 = {−268.072, −134.628, 0} [N]

F03 = {−256.71, −272.142, 0} [N]

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F34 = {-268.035, -134.564, 0} [N]

F23 = {-11.3747, 137.911, 0} [N]

F12 = {-11.4013, 137.974, 0} [N]
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