**Static Force Analysis for Skid Loader - Scalar**

## A trunnion mount hydraulic cylinder actuates the arm of a skid steer loader as shown below. At this position, e = 40 inches,  = 61.131°, = -12 ips, = -0.3625 rad/s.

Determine the force on the hydraulic cylinder required to lower an 800 lbf payload attached to point D by a cable. The payload moves with constant velocity at the position shown. You may neglect the effects of friction. The weight of the arm and cylinder are small compared to the payload. Show your work.

sin  / AB = sin  / e

 = 52.01°

 = 77.131°

2261.9 lbf up/left

FCYLINDER \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

A

B

C

e

Not to scale

AB = 36 inches

AC = 42 inches

AD = 96 inches

= 16°



D



Payload

P

D

C

F14y

F14x

A

FC



4





4

∑M on 4 about A CCW+

-(FC sin ) AC +(P sin() AD = 0

FC = 2261.9 lbf

What corresponding hydraulic pressure would be required for a cylinder with a 3 inch DIA bore?

A =  D2 / 4 = 7.069 in2

320 psi

PCYLINDER \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Is this value reasonable? Why?

OK, industrial hydraulics often go to 3000 psi

If you include friction between the piston and cylinder wall, will it increase or decrease your computation for pressure.

pressure pushes up

friction force will be up opposing piston motion

increase decrease Why?

What value would you use for the coefficient of friction between the piston and cylinder wall?

0.1 lubricated

 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Why?

Should your analysis be different if the cylinder were retracting at constant velocity instead of the payload moving at constant velocity?

constant  means  will not be constant means velocity of the payload will not be constant, therefore must account for acceleration of payload mass

yes no Why?

**Static Force Analysis for Four Bar - Scalar**

65°

A

T12

D

77°

60°

C

B

P

Q

FQ = 200 N

FP = 150 N

AB = 30 cm

BC = 60 cm

CD = 45 cm

AD = 90 cm

BP = 23 cm

DQ = 24 cm

3

4

2

1

1

D

13.151°

65.173°

FQ = 200 N

F34x

F34y

24.827°

65.173°

F14y

F14x

65.173°

24.827°

77°

D

C

CD = 45 cm DQ = 24 cm

CQ = 21 cm

Q

37.827°

F12x

AB = 30 cm

F32y

F32x

F12y

65°

25°

A

B

T12

25°

65°

F43y

F43x

F23x

F23y

76.849°

13.151°

46.849°

B

C

FP = 150 N

BC = 60 cm

BP = 23 cm

CP = 37 cm

P

13.151°

60°

76.849°

**M on 4 about D CCW+**

- F34x (CD) sin 65.173°- F34y (CD) sin 24.827° + FQ (DQ) sin 77° = 0

40.842 F34x + 18.895 F34y = 4676.98 N

**M on 3 about B CCW+**

- F43x (BC) sin 13.151° + F43y (BC) sin 76.849° + FP (BP) sin 60° = 0

- 13.651 F43x + 58.426 F43y = -2987.78 N



**F on 4 right +** F34x - FQ cos 37.827° + F14x = 0 F14x = 75.980 N

**F on 4 up +** F34y - FQ sin 37.827° + F14y = 0 F14y = 52.360 N

**F on 3 right +** F43x - FP cos 46.849° + F23x = 0 F23x = 184.580 N

**F on 3 up +** F43y + FP sin 46.849° + F23y = 0 F23y = -39.138 N

**M on 2 about A CCW+** - F32x (AB) sin 65° + F32y (AB) sin 25° + T12 = 0

 T12 = - 5514.8 N.cm

**F on 2 right +** F12x + F32x = 0 F12x = 184.580 N

**F on 2 up** F12y + F32y = 0 F12y = -39.138 N

**Static Force Analysis for Four Bar - Superposition**

1

65°

A

T12

D

77°

Q

FQ = 200 N

AB = 30 cm

BC = 60 cm

CD = 45 cm

AD = 90 cm

BP = 23 cm

DQ = 24 cm

2

1

60°

C

B

P

FP = 150 N

3

4

13.151°

65.173°

P

T12

T12

Q

**CASE II**

**CASE I**

**CASE I - F34 parallel to BC**

F32

F12y

A

T12

F12x

B

128.151°

FQ

D

F34

F14y

F14x

77°

C

Q

101.676°

**M on 4 about D CCW +**

- F34 sin 101.676º CD + FQ sin 77 º DQ = 0

F34 = 106.129 N = F32

**M on 2 about A CCW +**

+ F32 sin 128.151º AB + T12 = 0

T12 = -2503.75 N.cm

**CASE II – F43 parallel to CD**

**M on 3 about B CCW +**

F43

60°

C

B

P

FP = 150 N

3

13.151°

78.324°

F32//BC

F32┴BC

- F43 sin 101.676º BC + FP sin 60 º BP = 0

F43 = 50.849 N

**F on 3 //BC right +**

+ F43 cos 78.324º - FP cos 60 º + F32//BC = 0

F32//BC = 64.709 N

51.849°

A

T12

F12x

B

F32//BC

38.151°

F32┴BC

F12y

**F on 3 ┴BC up +**

- F43 sin 78.324º + FP cos 60 º - F32┴BC = 0

F32┴BC = 80.107 N

**M on 2 about A CCW +**

+ F32//BC sin 51.849º AB + F32┴BC sin 38.151º AB + T12 = 0

T12 = -3011.14 N.cm

T12 = T12(Case I) + T12(Case II) = -5514.89 N.cm

**Static Force Analysis for Four Bar - Matrix**

F14y

FQ = 200 N

F34x

F34y

F14x

65.173°

77°

D

C

Q

37.827°

F43y

F43x

F23x

F23y

B

C

FP = 150 N

P

13.151°

60°

46.849°

F12x

F32y

F32x

F12y

65°

A

B

T12

**F on 2 right +** F12x + F32x = 0

# **F on 2 up +** F12y + F32y = 0

**M on 2 about A CCW +** - F32x rB/Ay + F32y rB/Ax + T12 = 0

# **F on 3 right +** F23x + F43x + FPx= 0

# **F on 3 up +** F23y + F43y + FPy= 0

**M on 3 about P CCW +** F23x rB/Py - F23y rB/Px - F43x rC/Py + F43y rC/Px = 0

# **F on 4 right +** F34x + F14x + FQx = 0

# **F on 4 up +** F34y + F14y + FQx = 0

**M on 4 about Q CCW +** - F34x rC/Qy - F34y rC/Qx + F14x rD/Qy + F14y rD/Qx = 0



= 150 N @ 133.151° = - 102.589 + j 109.433 N

= 200 N @ 217.827° = - 157.973 - j 122.656 N

B/A = 30 cm @ 65° = 12.678 + j 27.189 cm

B/P = 23 cm @ 193.151° = -22.396 - j 5.233 cm

C/P = 37 cm @ 13.151° = 36.030 + j 8.418 cm

C/Q = 21 cm @ 114.827° = -8.817 + j 19.059 cm

D/Q = 24 cm @ -65.173° = 10.077 - j 21.782 cm





**Static Force Analysis for Pushups - Matrix**

A person doing pushups is represented with wrists A, elbows B, shoulders C, and toes D. Mass of the torso/legs is 180 lbm.

Use the additional assumptions:

a) All muscular effort is provided by triceps as torque T32 across the elbows.

b) Angular velocity of link 4 is constant at this position

c) Weight of the arms is negligible compared to weight of the torso/legs.

d) Friction is negligible at A, B, C and D.

e) No muscular torque is generated at A, C and D.

A

D

B

C

2

4

B

C

3

4

3

2

G4

2 = 45°

3 = 149.14°

4 = 164.24°

2 = 0.5 rad/sec

3 = -1.435 rad/sec

4 = -0.387 rad/sec

AD = 52 inch

AB = 12 in

BC = 14 in

CD = 57.7 in

DG4 = 39 in

Determine angular velocity across the elbows 2/3 for the position and velocity provided above.

2/3 = 2 - 3 = +1.935 rad/sec

Determine elbow torque T32 for the position and velocity provided above.

T32 = 1351.1 in.lbf CCW

Do the magnitude and direction for your answer seem reasonable? Why?

direction seems OK approximate solution W4 (DG4) ~ F34y (CD), F34y ~ 122 lbf ~ F12y

F12y (AB) ~ T32 ~ 1464 in.lbf

Rate the last four assumptions and state your reasoning.

b) constant 4 1=poor 2=acceptable for an approximation 3=very good

c) weight of arms is negligible 1=poor 2=acceptable for an approximation 3=very good

d) friction is negligible 1=poor 2=acceptable for an approximation 3=very good

e) no muscle force at A, C, D 1=poor 2=acceptable for an approximation 3=very good

4 = 

Determine 4 of the torso/legs when the forearm is aligned with the upper arms (2 = 3).

F43y

F43x

F23x

F23y

B

C

30.86°

30.86°

59.14°

59.14°

T23

F14y

F34x

F34y

F14x

74.24°

D

C

G4

15.76°

15.76°

74.24°

W4

74.24°

F12x

F12y

45°

A

F32y

F32x

B

T32

45°

45°

45°

**F on 2 right +** F12x + F32x = 0

# **F on 2 up +** F12y + F32y = 0

**M on 2 about A CCW +** - (F32x sin 45°) AB + (F32y sin 45°) AB + T32 = 0

# **F on 3 right +** F23x + F43x = 0

# **F on 3 up +** F23y + F43y = 0

**M on 3 about B CCW +** - (F43x sin 30.86°) BC - (F43y sin 59.14°) BC + T23 = 0

# **F on 4 right +** F34x + F14x = 0

# **F on 4 up +** F34y + F14y - W4 = 0

**M on 4 about D CCW +** - (F34x sin 15.76°) CD - (F34y sin 74.24°) CD + (W4 sin 74.24°) DG4 = 0



 

**Static Force Analysis for Slider Crank - Scalar**

1

1

2

3

4

A

B





R = AB

L = BC

**P**

**T12**

C

4

**P**

**F34**

**F14x**

**F14y**



+ direction for

impending

VC to right

C

2

A

B



**T12**





**F32**

**F12y**

**F12x**



B

**F23**

**F43**

3

C

**F on 4 right +** + P - F14x sign(VC) - F34cos = 0

**F on 4 up +** + F34 sin - F14y = 0

# **M on 3** F23 = F43

**M on 2 about ACCW +** + T12 - ( F32 sin() ) R = 0

**friction** F14x =  F14y













**Static Force Analysis for Slider Crank - Matrix**

**F23y**

1

1

2

3

4

A

B





**P**

**T12**

**Q**

Q



C

+ direction for

impending

VC to right

2

A

B



**T12**



**F32y**

**F12y**

**F12x**

**F32x**



B

3

**F23x**

C

**FQy**

**FQx**

**F43y**

**F43x**



Q



**F34y**

C

**F34x**

**P**

4

**F14y**

**F14x**

**F on 2 right +** F12x + F32x = 0

# **F on 2 up +** F12y + F32y = 0

**M on 2 about A CCW +** - (F32x sin) AB + (F32y cos) AB + T12 = 0

# **F on 3 right +** F23x + F43x + FQx = 0

# **F on 3 up +** F23y + F43y + FQy = 0

**M on 3 about Q CCW +** -(F23x sin) BQ -(F23y cos) BQ +(F43x sin) CQ +(F43y cos) CQ = 0

# **F on 4 right +** F14x + F34x + P = 0

# **F on 4 up +** F14y + F34y = 0

**friction** F14x = -  abs(F14y) sign(VC)



