Fluid Power Design Data Sheet

REVISED SHEET 5 - EVOLUTION DESIGN DATA FILE

ANGLE PROBLEMS IN FLUID POWER APPLICATIONS

Trigonometric functions, such as sine, cosine, and tangent, are useful in solving angle problems, for example, if the cylinder axis is at an angle to the direction of load movement in beam and crane problems, where the cylinder is not at right angles with the beam axis, where the angle continually changes as the beam rises, or applications where a heavy load moves upward or downward at an inclination to the horizontal.

The purpose of this sheet is to show simplified methods of using multipliers and dividers in solving these problems. While these methods are based on trigonometry, a knowledge of the subject is not necessary to use these methods.

HOW TO CALCULATE A FRICTION LOAD

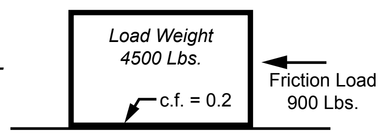

Figure 1. Horizontal Friction

Figure 1. Frictional resistance depends on the coefficient of friction between the mating surfaces. Coefficients for various materials are shown in machinery handbooks. For example, steel running on cast iron, lubricated, has a coefficient of 0.2. In this figure, using this coefficient with a load weight of 4500 lbs, friction in a horizontal direction is 4500 x 0.2 = 900 lbs.

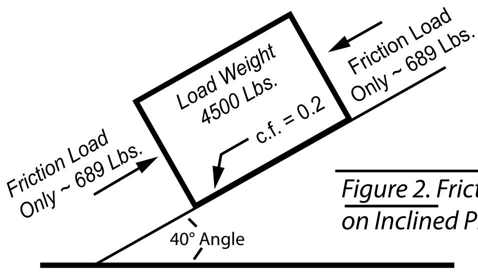

Figure 2. Friction on Inclined Plane.

Figure 2. If the load is sliding at an angle with the horizontal, use cosine of angle as a multiplier. Using a coefficient of friction 0. 2, friction of a 4500 lb load on a 40° incline is:
4500 x 0. 2 x 0.766 (cos 40°) = 689 lbs.

CYLINDER PUSHING AT AN ANGLE TO LOAD DIRECTION

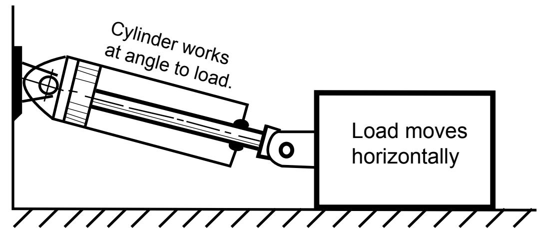

Figure 3. Additional cylinder force is required if cylinder is not pushing directly into load. Downward acting cylinder increases friction of the load.

Figure 3. If the cylinder axis is not parallel to direction of load movement, more force is required than if it were pushing straight on. When it is pushing at a downward angle, its force will actually create additional friction. The problem is to calculate the cylinder force required.

Space does not permit showing the mathematical solution, which involves tangents and sines of the angles involved. This can be found in an engineering book on mechanics. Our simplified solution is the table of multipliers, which are to be multiplied times the weight of the load according to the coefficient of friction and the angle which the cylinder makes with the load. This table has been mathematically calculated for the range of conditions shown and may be used directly.

Example: If the load weighs 10,000 lbs, and the coefficient of friction is 0.4, what cylinder force is required to keep it in motion when the cylinder is at an angle of 15° with the direction of travel?

Solution: On a straight push a force of 10,000 x 0.4 = 4000 lbs would be required. But, it will take more than this because of the 15° angle. For a 15° angle and a coefficient of 0.4, the table shows a multiplier of .463. Cylinder force, then, is 10,000 x .463 = 4630 lbs.

MULTIPLIERS (See Text)									
Coef. of Friction	Angle of Cylinder Axis to the Horizontal								
	10°	15°	20°	25°	30°	35°	40°	45°	50°
0.10	.103	.107	.111	.116	.123	.132	.143	.158	.178
0.20	.210	.219	.230	.243	.261	.284	.314	.353	.408
0.30	.321	.337	.358	.384	.418	.463	.523	.605	.724
0.40	.436	.463	.498	.542	.600	.677	.784	.942	1.19
0.50	.557	.598	.650	.719	.811	.939	1.12	1.41	1.93
0.60	.682	.741	.817	.920	1.06	1.27	1.58	2.13	3.28
0.70	.810	.891	.998	1.14	1.35	1.68	2.21	3.29	6.59
0.80	.951	1.12	1.21	1.42	1.74	2.26	3.26	5.95	34.7
0.90	1.09	1.23	1.43	1.71	2.17	2.97	4.81	12.9	- - -

TRIG TABLE		
Angle	Sine	Cosine
5	0.087	0.996
6	0.105	0.995
7	0.122	0.993
8	0.139	0.990
9	0.156	0.988
10	0.174	0.985
11	0.191	0.982
12	0.208	0.978
13	0.225	0.974
14	0.242	0.970
15	0.259	0.966
16	0.276	0.961
17	0.292	0.956
18	0.309	0.951
19	0.326	0.946
20	0.342	0.940
21	0.358	0.934
22	0.375	0.927
23	0.391	0.921
24	0.407	0.914
25	0.423	0.906
26	0.438	0.899
27	0.454	0.981
28	0.469	0.883
29	0.485	0.875
30	0.500	0.866
31	0.515	0.857
32	0.530	0.848
33	0.545	0.839
34	0.559	0.829
35	0.574	0.819
36	0.588	0.809
37	0.602	0.799
38	0.616	0.788
39	0.629	0.777
40	0.643	0.766
41	0.656	0.755
42	0.669	0.743
43	0.682	0.731
44	0.695	0.719
45	0.707	0.707
46	0.719	0.695
47	0.731	0.682
48	0.743	0.669
49	0.755	0.656
50	0.766	0.643
51	0.777	0.629
52	0.788	0.616
53	0.799	0.602
54	0.809	0.588
55	0.819	0.574
56	0.829	0.559
57	0.839	0.545
58	0.848	0.530
59	0.857	0.515
60	0.866	0.500
61	0.875	0.485
62	0.883	0.469
63	0.891	0.454
64	0.899	0.438
65	0.906	0.423
66	0.914	0.407
67	0.921	0.391
68	0.927	0..375
69	0.934	0.358
70	0.940	0.342
71	0.946	0.326
72	0.951	0.309
73	0.956	0.292
74	0.961	0.276
75	0.966	0.259
76	0.970	0.242
77	0.974	0.225
78	0.978	0.208
79	0.982	0.191
80	0.985	0.174
81	0.988	0.156
82	0.990	0.139
83	0.993	0.122
84	0.995	0.105

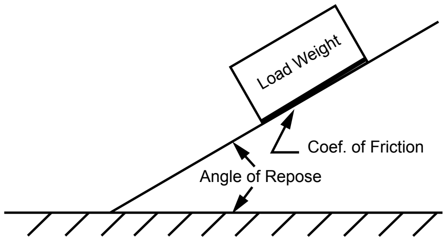

Figure 4. Angle of Repose.

Figure 4. As the angle of incline is increased, friction between the load weight and the inclined plane will prevent the weight from sliding downhill until the angle of repose is reached. The coefficient of friction between the two mating surfaces is equal to the tangent of the angle of repose.

To experimentally find the coefficient of friction between a load weight and sliding surface, raise one end of the incline until the weight just starts to slide. Measure the angle. Look up the tangent of the angle in a trig table. This is the coefficient of friction between these two surfaces.

Example: Suppose the incline can be raised to a 30° angle before the weight starts to slide. The tangent of 30° is .577 and this is the coefficient of friction between these two materials.

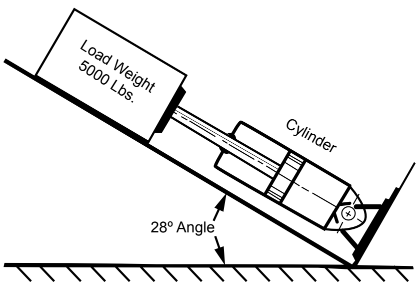

Figure 5. Cylinder and load axes are in line, but load is moving on an upward incline. The cylinder must provide enough force to raise the load to a higher elevation against the force of gravity. If the cylinder was mounted in a vertical position, a force of a little over 5000 lbs would be needed to lift a 5000 lb load weight. But, with the cylinder inclined as in the illustration, the same 5000 lb load can be lifted with a smaller cylinder force because of mechanical advantage that is similar to a wedging action.

Example: Find cylinder force (neglecting friction) to push a 5000 lb weight up a 28° incline .

Solution: Use angle sines as multipliers. Cyl. force = 5000 x .469 (sine of 28°) = 2345 lbs.

If there is high friction between load and incline, calculate additional force from cylinder to overcome friction. See opposite side of this sheet.

If rapid acceleration of a massive load is required, calculate extra cylinder force required using information in Issue No. 4 of these data sheets.

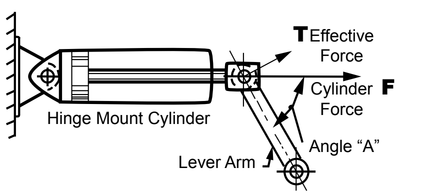

Figure 6. Cylinder Operating a Rotating Lever

Figure 6. Cylinder force, F, is horizontal in this figure. Only that portion, T, which is at right angles to the lever axis is effective for turning the lever. The value of T varies with the acute angle "A" between the cylinder axis and the lever axis.

Example: A 4-inch bore cylinder working at 750 PSI will develop a 9420 lb. force (12.56 sq. in. area x 750 PSI). Effective force T when working at a 65° angle is: 9420 x .906 (sine of 65°) = 8535 lbs.

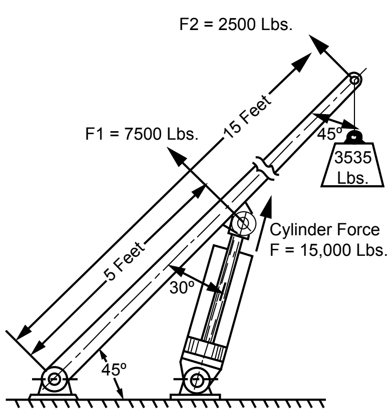

Figure 7. Cylinder on a Crane.

Figure 7. Find the lifting capacity of this crane when its members are at the angles shown (capacity will vary as the beam of the crane raises and lowers).

A force, F = 15,000 lbs, is produced by the cylinder and applied to a point 5 feet from the beam pivot. The angle between cylinder and beam axes is 30°. Force F2, the true torque force on the beam= 15,000 x .500 (sine of 30°) = 7500 lbs.

Through a 3:1 leverage action, 7500 lbs at 5 feet from the pivot translates to 2500 lbs, F2, at a point 15 feet from the pivot.
To find the vertical lifting force when the beam is at a 45° angle with the ground, F2 must be divided by the sine of the angle with the beam axis and vertical:

Lift = 2500 ÷ .707 (sine of 45°) = 3535 lbs.