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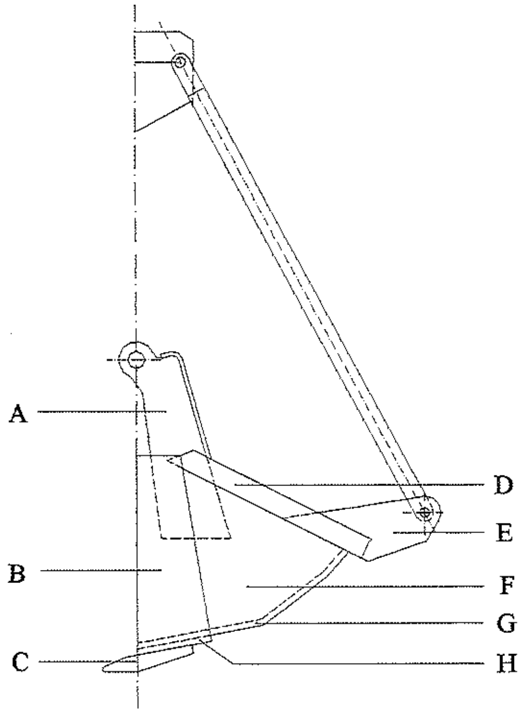
Menentukan Titik Berat Bucket

Pada bagian ini akan ditentukan massa dan titik berat bucket. Untuk itu, berikut diperlihatkan konstruksi bucket yang direncanakan. Ukuran sebenarnya dapat dilihat pada gambar utama bucket.



Gambar. Konstruksi bucket

Dengan menggunakan AutoCAD (perintah *mass property* pada *inquiry*) dapat ditentukan luas masing-masing bagian beserta titik beratnya, yaitu :

Satuan : cm

Bagian	Luas (A)	Tebal (t)*	Titik Berat		$V_i = 2(A.t)$	$m_i = V.\rho$ (kg)	$m_i.x_i$ (kg.cm)	$m_i.y_i$ (kg.cm)
			x_i	y_i				
A	4755,75	3	24,72	137,01	28534,50	224,00	5537,18	30690,24
B	4939,82	1	19,63	62,10	9879,64	77,56	1522,41	4816,48
C	470,80	10	7,27	-3,08	9416,00	73,92	537,37	-227,67
D	1920,76	3	89,83	100,41	11524,56	90,47	8126,72	9084,09
E	2537,25	3	157,23	84,54	15223,50	119,50	18789,69	10102,53
F	10961,84	2,5	51,43	63,74	54809,20	430,25	51,43	27424,14
G	627,76	93	73,81	27,90	58381,7**	458,30	33826,85	12786,57
H	197,85	98	24,30	6,61	19389,3**	152,20	3698,61	1006,04

* *Tebal dalam arah sumbu z*
***Volume tidak dikalikan dua.*

$\rho_{Baja} = 7850 \text{ kg/m}^3 = 7{,}85.10^{-3} \text{ kg/cm}^3$

$\Sigma m = 1626{,}2$ kg

$\Sigma m.x_i = 72090{,}26$ kg.cm

$\Sigma m.y_i = 95682{,}42$ kg.cm

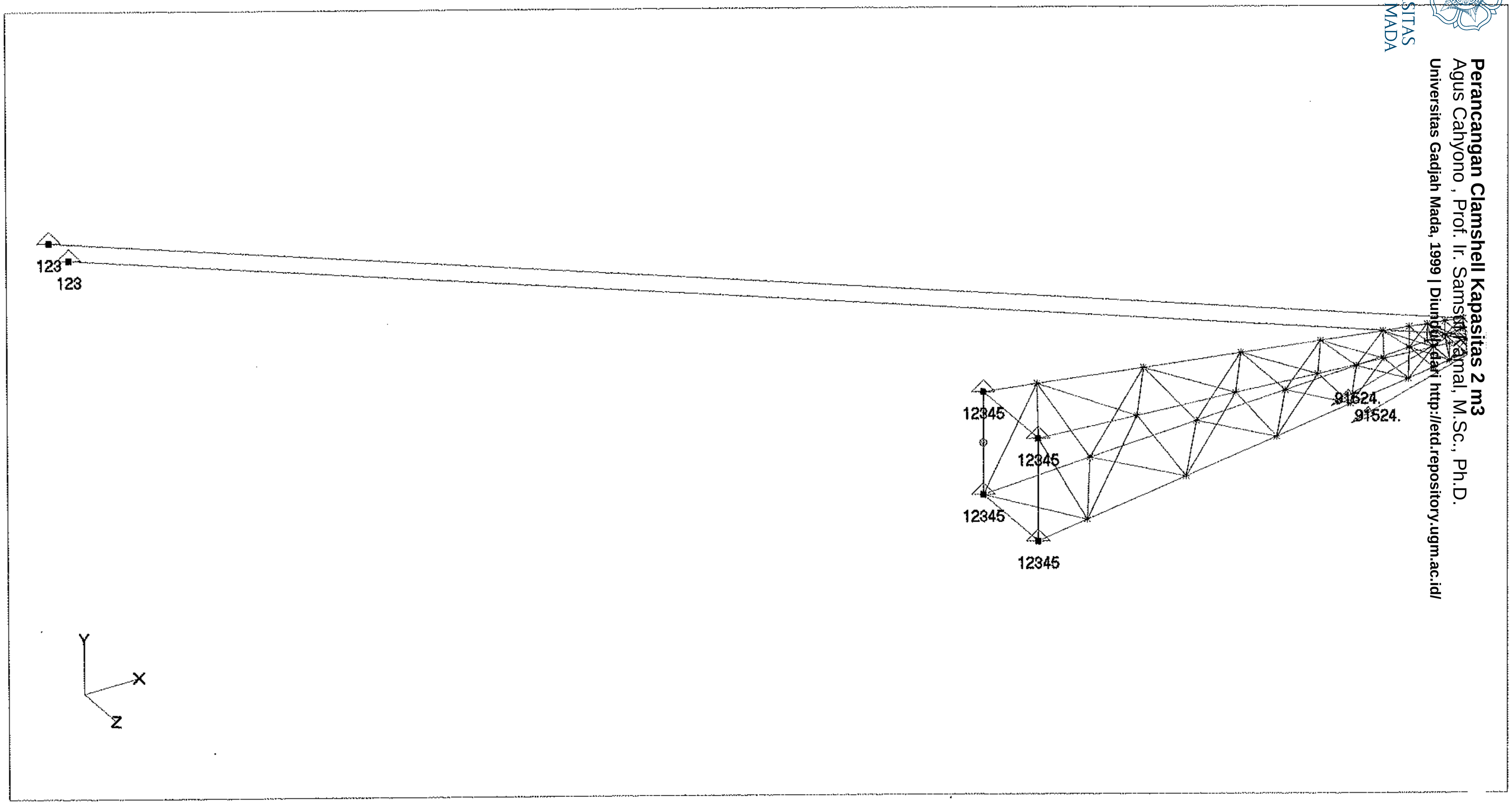
$$\bar{x} = \frac{\Sigma m.x_i}{\Sigma m} = \frac{72090{,}2}{1626{,}2} = 44{,}33 \text{ cm}$$

$$\bar{y} = \frac{\Sigma m.y_i}{\Sigma m} = \frac{95682{,}42}{1626{,}2} = 58{,}84 \text{ cm}$$

Titik berat bucket (44.33,58.84)

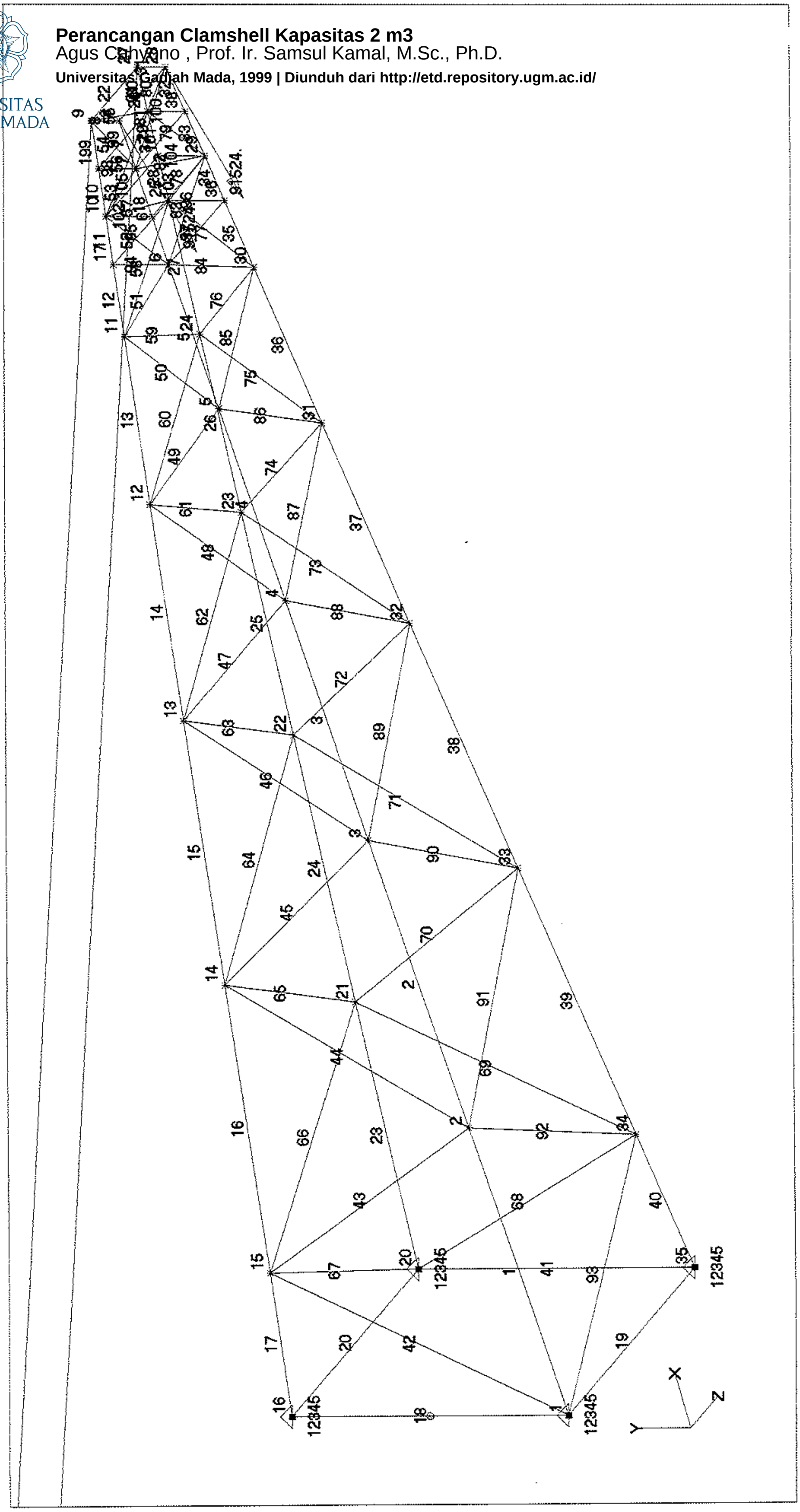
Hasil Program Perhitungan Rangka Boom Menggunakan *MSC/Nastran*

Boom Top Section



Konstruksi Penahan dengan Cable

Boom Top Section



Elemen dan Nodal

MSC/NASTRAN for Windows Version 4.40 Wed May 19 09:04:36 1999

Model : C:\Mscn4w20\Boom Top Section.MOD Report : Node

Format : NASTRAN Displacement

Sort By : 1..Total Translation in Ascending Order

Title : Total Translation

DISPLACEMENT VECTOR

POINT ID.		T1	T2	T3	R1	R2	R3
1	G	0.	0.	0.	0.	0.	0.
16	G	0.	0.	0.	0.	0.	0.
20	G	0.	0.	0.	0.	0.	0.
35	G	0.	0.	0.	0.	0.	0.
39	G	0.	0.	0.	0.	0.	0.
40	G	0.	0.	0.	0.	0.	0.
15	G	2.828978E-5	-2.220041E-5	1.721623E-5	0.	0.	0.
34	G	-7.281782E-5	-4.648753E-5	4.370979E-5	0.	0.	0.
21	G	4.948406E-5	-1.273365E-4	-2.093950E-6	0.	0.	0.
2	G	-1.460279E-4	-1.327294E-4	-6.104834E-6	0.	0.	0.
14	G	6.358570E-5	-2.813353E-4	1.741552E-5	0.	0.	0.
33	G	-2.052852E-4	-3.069795E-4	4.457435E-5	0.	0.	0.
22	G	6.891914E-5	-5.293305E-4	-4.384869E-6	0.	0.	0.
3	G	-2.617616E-4	-5.420354E-4	-1.322704E-5	0.	0.	0.
13	G	6.556372E-5	-7.960888E-4	1.100394E-5	0.	0.	0.
32	G	-2.979734E-4	-8.132677E-4	2.850398E-5	0.	0.	0.
23	G	5.469267E-5	-1.134982E-3	-5.609648E-6	0.	0.	0.
4	G	-3.279027E-4	-1.153202E-3	-1.754230E-5	0.	0.	0.
12	G	3.817188E-5	-1.469218E-3	5.053892E-6	0.	0.	0.
31	G	-3.449376E-4	-1.478724E-3	1.365480E-5	0.	0.	0.
24	G	1.575134E-5	-1.853270E-3	-5.931753E-6	0.	0.	0.
5	G	-3.534227E-4	-1.874913E-3	-1.929781E-5	0.	0.	0.
11	G	-8.642198E-6	-2.200437E-3	-1.533326E-7	0.	0.	0.

30	G	-3.561566E-4	-2.202657E-3	4.761703E-7	0.	0.	0.
25	G	-3.662590E-5	-2.573185E-3	-5.764823E-6	0.	0.	0.
17	G	-3.998825E-5	-2.595671E-3	-5.766192E-6	0.	0.	0.
36	G	-3.525333E-4	-2.573184E-3	-1.920753E-5	0.	0.	0.
6	G	-3.496277E-4	-2.595671E-3	-1.920194E-5	0.	0.	0.
37	G	-6.167986E-5	-2.863707E-3	-4.039600E-6	0.	0.	0.
18	G	0.	-2.868931E-3	-9.999152E-6	0.	0.	0.
10	G	-6.221669E-5	-2.868931E-3	-4.038186E-6	0.	0.	0.
29	G	-3.443170E-4	-2.863707E-3	-9.999152E-6	0.	0.	0.
26	G	-8.789010E-5	-3.163517E-3	-5.776032E-6	0.	0.	0.
38	G	-3.330153E-4	-3.163516E-3	-1.852010E-5	0.	0.	0.
19	G	-9.169703E-5	-3.183862E-3	-5.776657E-6	0.	0.	0.
7	G	-3.310723E-4	-3.183862E-3	-1.851432E-5	0.	0.	0.
9	G	-1.222233E-4	-3.508049E-3	-5.683411E-6	0.	0.	0.
27	G	-1.242348E-4	-3.512867E-3	-5.853772E-6	0.	0.	0.
8	G	-3.139702E-4	-3.509799E-3	-8.190141E-6	0.	0.	0.
28	G	-3.156339E-4	-3.513060E-3	-1.009342E-5	0.	0.	0.

Set MAX/MIN Summary Table		Set	ID	Value
T1 Translation	Minimum	1	30	-0.00035616
	Maximum	1	22	0.000068919
T2 Translation	Minimum	1	28	-0.0035131
	Maximum	1	1	0.
T3 Translation	Minimum	1	5	-0.000019298
	Maximum	1	33	0.000044574
R1 Rotation	Minimum	1	1	0.
	Maximum	1	1	0.
R2 Rotation	Minimum	1	1	0.
	Maximum	1	1	0.
R3 Rotation	Minimum	1	1	0.
	Maximum	1	1	0.

Sort By : 51..Total Constraint Force in Ascending Order

Title : Constrain force

FORCES OF SINGLE-POINT CONSTRAINT

POINT ID.		T1	T2	T3	R1	R2	R3
40	G	-7.835862E+3	2.718287E+3	-7.270903E-1	0.	0.	0.
39	G	-7.838306E+3	2.719135E+3	7.273171E-1	0.	0.	0.
16	G	-6.205886E+4	6.218842E+3	-4.013122E+3	0.	0.	0.
20	G	-6.206245E+4	7.775801E+3	4.013296E+3	0.	0.	0.
35	G	1.575674E+5	1.578963E+4	-1.018958E+4	0.	0.	0.
1	G	1.575647E+5	1.734590E+4	1.018941E+4	0.	0.	0.

Set MAX/MIN Summary Table		Set	ID	Value
T1 Constraint Force	Minimum	1	20	-62062.4
	Maximum	1	35	157567.
T2 Constraint Force	Minimum	1	2	0.
	Maximum	1	1	17345.9
T3 Constraint Force	Minimum	1	35	-10189.6
	Maximum	1	1	10189.4
R1 Constraint Moment	Minimum	1	2	0.
	Maximum	1	2	0.
R2 Constraint Moment	Minimum	1	2	0.
	Maximum	1	2	0.
R3 Constraint Moment	Minimum	1	2	0.
	Maximum	1	2	0.

Output Vector 55 - Total Constraint Moment (Model Vector 20)

Maximum Node ID = 1 Value = 0.

Minimum Node ID = 1 Value = 0.

Type = Force Calc = Y Component Dir = Y Centroid = Y

Component 0 56 - R1 Constraint Moment

Component 1 57 - R2 Constraint Moment

Component 2 58 - R3 Constraint Moment

Output Vector 56 - R1 Constraint Moment (Model Vector 10)

Maximum Node ID = 1 Value = 0.

Minimum Node ID = 1 Value = 0.

Type = Force

Output Vector 57 - R2 Constraint Moment (Model Vector 11)

Maximum Node ID = 1 Value = 0.

Minimum Node ID = 1 Value = 0.

Type = Force

Output Vector 58 - R3 Constraint Moment (Model Vector 12)

Maximum Node ID = 1 Value = 0.

Minimum Node ID = 1 Value = 0.

Type = Force

Output Vector 3036 - Rod Axial Force (Model Vector 13)

Maximum Element ID = 17 Value = 62498.6

Minimum Element ID = 40 Value = -158684.

Type = Force Calc = N Component Dir = Y Centroid = Y

Component 0 3036 - Rod Axial Force

Component 1 3036 - Rod Axial Force

1	-157812.	2	-155329.	3	-151366.
4	-145173.	5	-135217.	6	-119576.
7	-88289.4	8	17498.5	9	11659.
10	11659.1	11	31212.9	12	31213.
13	44247.9	14	52270.2	15	57283.8
16	60543.2	17	62498.6	18	0.

19	0.	20	0.	21	-5666.5
22	-507.203	23	61633.3	24	59150.2
25	55185.7	26	48992.8	27	39037.7
28	23394.1	29	23394.2	30	-7891.38
31	1933.05	32	-107843.	33	-107843.
34	-127397.	35	-127398.	36	-140433.
37	-148455.	38	-153469.	39	-156729.
40	-158684.	41	0.	42	-1856.68
43	2131.92	44	-2505.44	45	3039.2
46	-3497.92	47	4392.56	48	-5100.9
49	6670.7	50	-7712.78	51	10469.8
52	-11570.	53	15705.5	54	-23748.9
55	-0.17035	56	0.15881	57	-0.14848
58	0.147	59	0.28103	60	-0.21118
61	-0.3255	62	-0.082318	63	-0.3455
64	0.55164	65	-0.03092	66	0.027812
67	-0.19447	68	1856.75	69	-2132.
70	2505.53	71	-3039.34	72	3498.17
73	-4392.77	74	5100.94	75	-6670.8
76	7713.25	77	-10470.2	78	11570.9
79	-15705.7	80	23749.8	81	5.96046E-11
82	3.39375	83	3.55873	84	0.0078197
85	-1.32921	86	0.95529	87	0.68432
88	0.47148	89	0.70769	90	-1.36892
91	0.13141	92	0.17678	93	-0.16068
94	0.16231	95	1.14039	96	-0.66249
97	-4.65457	98	0.0029879	99	0.58265
100	-0.027637	101	-5.38931	102	-9.53674E-10
103	0.	104	-0.12322	105	-1.24442
106	8296.55	107	8293.96		

Output Vector 3038 - Rod Torque Force (Model Vector 14)

Maximum Element ID = 1 Value = 0.

Minimum Element ID = 1 Value = 0.

Type = Force Calc = N Component Dir = Y Centroid = Y

Output Vector 3183 - Rod Axial Stress (Model Vector 15)

Maximum Element ID = 80 Value = 11874921.

Minimum Element ID = 40 Value = -26447336.

Type = Stress Calc = N Component Dir = Y Centroid = Y

Component 0 3183 - Rod Axial Stress

Component 1 3183 - Rod Axial Stress

1	-26302028.	2	-25888190.	3	-25227590.
4	-24195468.	5	-22536196.	6	-19929286.
7	-14714902.	8	2916422.	9	1943174.
10	1943180.	11	5202150.	12	5202165.
13	7374646.	14	8711696.	15	9547304.
16	10090529.	17	10416441.	18	0.
19	0.	20	0.	21	-944416.
22	-84533.9	23	10272212.	24	9858365.
25	9197616.	26	8165468.	27	6506285.
28	3899019.	29	3899034.	30	-1315230.
31	322175.	32	-17973830.	33	-17973888.
34	-21232900.	35	-21232960.	36	-23405452.
37	-24742470.	38	-25578114.	39	-26121456.
40	-26447336.	41	0.	42	-928340.
43	1065960.	44	-1252720.	45	1519601.
46	-1748960.	47	2196281.	48	-2550451.
49	3335350.	50	-3856390.	51	5234914.
52	-5785017.	53	7852771.	54	-11874461.
55	-85.173	56	79.4074	57	-74.2398
58	73.5005	59	140.516	60	-105.588

61	-162.75	62	-41.1588	63	-172.752
64	275.82	65	-15.46	66	13.9059
67	-97.2349	68	928377.	69	-1066002.
70	1252766.	71	-1519669.	72	1749084.
73	-2196386.	74	2550469.	75	-3335402.
76	3856627.	77	-5235111.	78	5785475.
79	-7852864.	80	11874921.	81	2.98023E-8
82	1696.88	83	1779.37	84	3.90984
85	-664.604	86	477.644	87	342.162
88	235.741	89	353.846	90	-684.46
91	65.7046	92	88.3896	93	-80.3388
94	81.1562	95	570.194	96	-331.244
97	-2327.28	98	1.49395	99	291.323
100	-13.8186	101	-2694.66	102	-4.76837E-7
103	0.	104	-61.6091	105	-622.21
106	11852214.	107	11848519.		

Output Vector 3186 - Rod Torsional Stress (Model Vector 16)

Maximum Element ID = 1 Value = 0.

Minimum Element ID = 1 Value = 0.

Type = Stress Calc = N Component Dir = Y Centroid = Y

Displacement Summary

Maximum Value 0.0035272 Output Vector 1 - Total Translation

Minimum Value -0.0035131 Output Vector 3 - T2 Translation

Force Summary

Maximum Value 158844. Output Vector 51 - Total Constraint Force

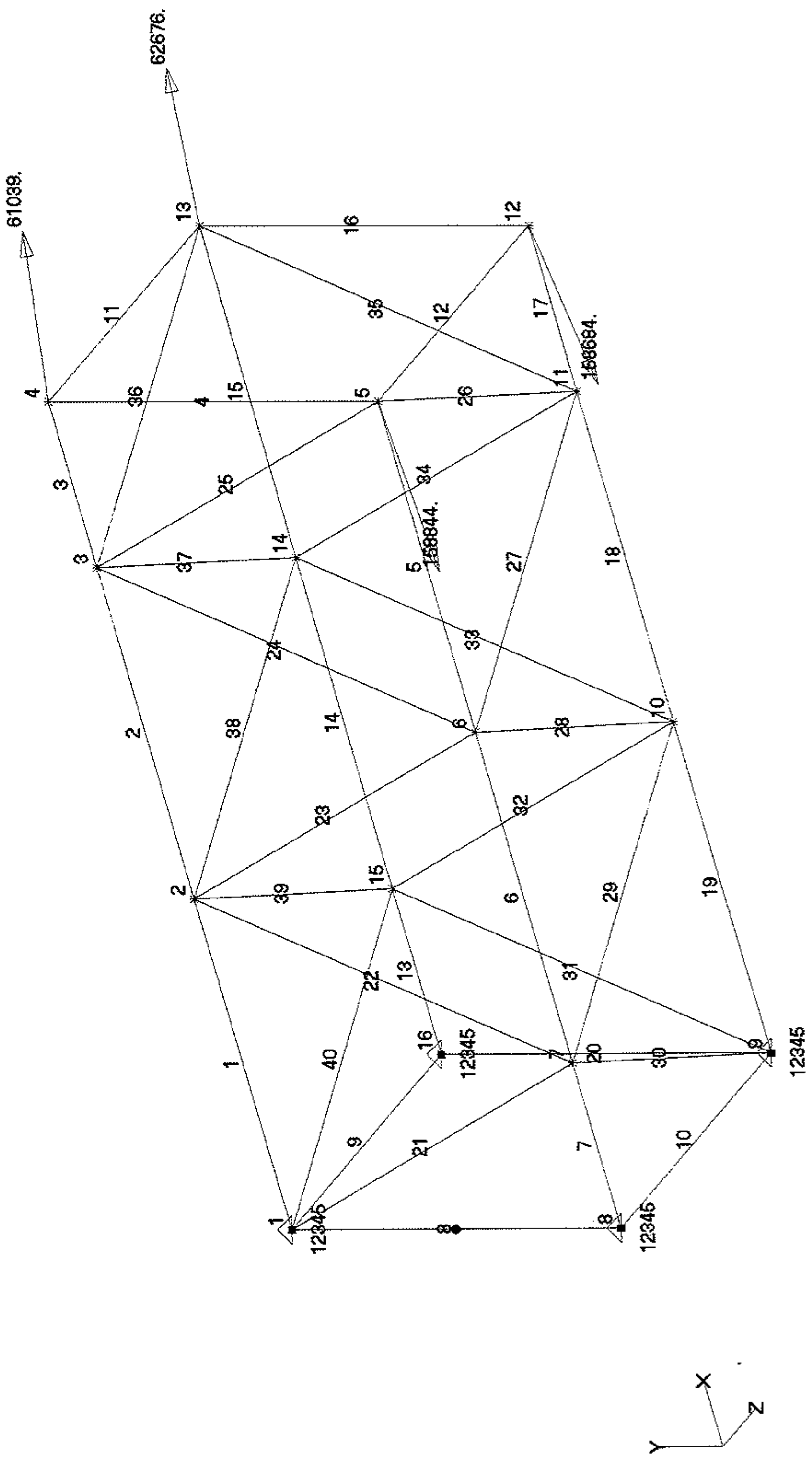
Minimum Value -158684. Output Vector 3036 - Rod Axial Force

Stress Summary

Maximum Value 11874921. Output Vector 3183 - Rod Axial Stress

Minimum Value -26447336. Output Vector 3183 - Rod Axial Stress

Extension Boom (3 m)



Nodal dan Elemen

MSC/NASTRAN for Windows Version 4.40 Wed May 19 23:18:46 1999

Model : C:\Mscn4w20\Richard.MOD Report : Node

Format : NASTRAN Displacement

Sort By : 1..Total Translation in Ascending Order

Title : Translation

Output Set 3 - MSC/NASTRAN Case 1

DISPLACEMENT VECTOR

POINT ID.		T1	T2	T3	R1	R2	R3
1	G	0.	0.	0.	0.	0.	0.
8	G	0.	0.	0.	0.	0.	0.
9	G	0.	0.	0.	0.	0.	0.
16	G	0.	0.	0.	0.	0.	0.
15	G	6.048820E-5	-1.290450E-4	-3.299429E-5	0.	0.	0.
7	G	-1.082382E-4	-1.529173E-4	-5.903819E-5	0.	0.	0.
2	G	1.077177E-4	-3.596934E-4	-7.233481E-6	0.	0.	0.
10	G	-2.046982E-4	-3.604392E-4	-6.422785E-6	0.	0.	0.
14	G	1.578990E-4	-6.405387E-4	-3.460582E-5	0.	0.	0.
6	G	-3.011499E-4	-6.629253E-4	-5.903198E-5	0.	0.	0.
3	G	1.918708E-4	-1.008234E-3	-1.607644E-5	0.	0.	0.
11	G	-3.858309E-4	-1.011205E-3	-1.284156E-5	0.	0.	0.
13	G	2.317442E-4	-1.418793E-3	-3.782626E-5	0.	0.	0.
4	G	2.221651E-4	-1.444435E-3	-3.414756E-5	0.	0.	0.
12	G	-4.646144E-4	-1.434583E-3	-4.968190E-5	0.	0.	0.
5	G	-4.704972E-4	-1.438216E-3	-5.902237E-5	0.	0.	0.

Set	MAX/MIN Summary Table		Set	ID	Value
	T1 Translation	Minimum	3	5	-0.0004705
		Maximum	3	13	0.00023174
	T2 Translation	Minimum	3	4	-0.0014444

	Maximum	3	1	0.
T3 Translation	Minimum	3	7	-0.000059038
	Maximum	3	1	0.
R1 Rotation	Minimum	3	1	0.
	Maximum	3	1	0.
R2 Rotation	Minimum	3	1	0.
	Maximum	3	1	0.
R3 Rotation	Minimum	3	1	0.
	Maximum	3	1	0.

Sort By : 51..Total Constraint Force in Ascending Order

Title : Constraint force

F O R C E S   O F   S I N G L E - P O I N T   C O N S T R A I N T

POINT	ID.	T1	T2	T3	R1	R2	R3
16	G	-1.209764E+5	0.	0.	0.	0.	0.
1	G	-1.195000E+5	2.356474E+4	1.799316E-1	0.	0.	0.
8	G	2.164763E+5	0.	0.	0.	0.	0.
9	G	2.164810E+5	2.356540E+4	-1.992188E-1	0.	0.	0.

Output Vector 51 - Total Constraint Force (Model Vector 59)

Maximum Node ID = 9 Value = 217760.

Minimum Node ID = 2 Value = 0.

Type = Force Calc = Y Component Dir = Y Centroid = Y

Component 0 52 - T1 Constraint Force

Component 1 53 - T2 Constraint Force

Component 2 54 - T3 Constraint Force

1	121801.
8	216476.
9	217760.
16	120976.

Set MAX/MIN Summary Table		Set	ID	Value
T1 Constraint Force	Minimum	3	16	-120976.
	Maximum	3	9	216481.
T2 Constraint Force	Minimum	3	2	0.
	Maximum	3	9	23565.4
T3 Constraint Force	Minimum	3	9	-0.19922
	Maximum	3	1	0.17993
R1 Constraint Moment	Minimum	3	2	0.
	Maximum	3	2	0.
R2 Constraint Moment	Minimum	3	2	0.
	Maximum	3	2	0.
R3 Constraint Moment	Minimum	3	2	0.
	Maximum	3	2	0.

Output Vector 5 - Total Rotation (Model Vector 58)

Maximum Node ID = 1 Value = 0.

Minimum Node ID = 1 Value = 0.

Type = Displacement Calc = Y Component Dir = Y Centroid = Y

Output Vector 6 - R1 Rotation (Model Vector 44)

Maximum Node ID = 1 Value = 0.

Minimum Node ID = 1 Value = 0.

Type = Displacement Calc = N Component Dir = Y Centroid = Y

Output Vector 7 - R2 Rotation (Model Vector 45)

Maximum Node ID = 1 Value = 0.

Minimum Node ID = 1 Value = 0.

Type = Displacement Calc = N Component Dir = Y Centroid = Y

Output Vector 8 - R3 Rotation (Model Vector 46)

Maximum Node ID = 1 Value = 0.

Minimum Node ID = 1 Value = 0.

Type = Displacement Calc = N Component Dir = Y Centroid = Y

Output Vector 55 - Total Constraint Moment (Model Vector 60)

Maximum Node ID = 1 Value = 0.

Minimum Node ID = 1 Value = 0.

Type = Force Calc = Y Component Dir = Y Centroid = Y

Output Vector 56 - R1 Constraint Moment (Model Vector 50)

Maximum Node ID = 1 Value = 0.

Minimum Node ID = 1 Value = 0.

Type = Force

Output Vector 57 - R2 Constraint Moment (Model Vector 51)

Maximum Node ID = 1 Value = 0.

Minimum Node ID = 1 Value = 0.

Type = Force

Output Vector 58 - R3 Constraint Moment (Model Vector 52)

Maximum Node ID = 1 Value = 0.

Minimum Node ID = 1 Value = 0.

Type = Force

Output Vector 3036 - Rod Axial Force (Model Vector 53)

Maximum Element ID = 13 Value = 120976.

Minimum Element ID = 7 Value = -216476.

Type = Force Calc = N Component Dir = Y Centroid = Y

Component 0 3036 - Rod Axial Force

Component 1 3036 - Rod Axial Force

1	107718.	2	84153.1	3	60588.6
4	-6218.84	5	-169347.	6	-192912.
7	-216476.	8	0.	9	0.
10	0.	11	-4013.12	12	10189.6
13	120976.	14	97410.8	15	73845.2
16	15789.6	17	-157567.	18	-181133.
19	-204698.	20	0.	21	26346.2
22	-26346.2	23	26346.2	24	-26346.2
25	26346.2	26	-0.22693	27	0.22693
28	-0.22693	29	0.22693	30	-0.22693
31	-26346.9	32	26346.9	33	-26346.9
34	26346.9	35	-26346.9	36	-0.20496
37	0.20496	38	-0.20496	39	0.20496
40	-0.20496				

Output Vector 3038 - Rod Torque Force (Model Vector 54)

Maximum Element ID = 1 Value = 0.

Minimum Element ID = 1 Value = 0.

Type = Force

Output Vector 3183 - Rod Axial Stress (Model Vector 55)

Maximum Element ID = 13 Value = 20162730.

Minimum Element ID = 7 Value = -36079384.

Type = Stress Calc = N Component Dir = Y Centroid = Y

Component 0 3183 - Rod Axial Stress

Component 1 3183 - Rod Axial Stress

1	17952948.	2	14025524.	3	10098100.
4	-1036473.	5	-28224542.	6	-32151964.
7	-36079384.	8	0.	9	0.
10	0.	11	-668853.	12	1698267.
13	20162730.	14	16235131.	15	12307532.

16	2631600.	17	-26261166.	18	-30188770.
19	-34116372.	20	0.	21	13173090.
22	-13173090.	23	13173089.	24	-13173090.
25	13173089.	26	-113.464	27	113.464
28	-113.464	29	113.464	30	-113.464
31	-13173458.	32	13173458.	33	-13173458.
34	13173459.	35	-13173458.	36	-102.479
37	102.479	38	-102.479	39	102.479
40	-102.479				

Output Vector 3186 - Rod Torsional Stress (Model Vector 56)

Maximum Element ID = 1 Value = 0.

Minimum Element ID = 1 Value = 0.

Type = Stress

Displacement Summary

Maximum Value 0.0015144 Output Vector 1 - Total Translation

Minimum Value -0.0014444 Output Vector 3 - T2 Translation

Force Summary

Maximum Value 217760. Output Vector 51 - Total Constraint Force

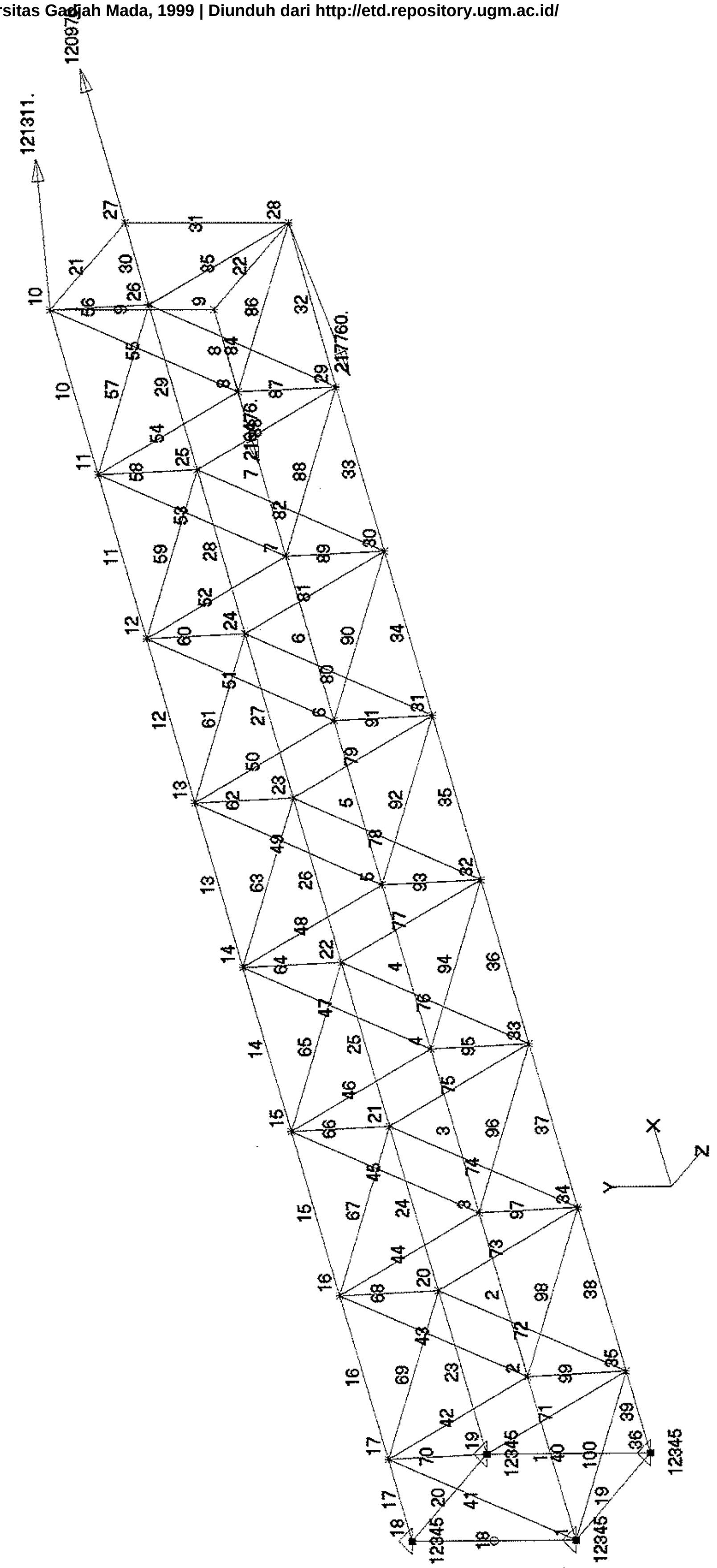
Minimum Value -216476. Output Vector 3036 - Rod Axial Force

Stress Summary

Maximum Value 20162730. Output Vector 3183 - Rod Axial Stress

Minimum Value -36079384. Output Vector 3183 - Rod Axial Stress

Extension Boom



Nodal dan Elemen

MSC/NASTRAN for Windows Version 4.40 Wed May 19 10:25:24 1999

Model : C:\Mscn4w20\Extension Boom (9m).MOD Report : Node

Format : NASTRAN Displacement

Sort By : 1..Total Translation in Ascending Order

Title : Translation

DISPLACEMENT VECTOR

POINT ID.		T1	T2	T3	R1	R2	R3
1	G	0.	0.	0.	0.	0.	0.
18	G	0.	0.	0.	0.	0.	0.
19	G	0.	0.	0.	0.	0.	0.
36	G	0.	0.	0.	0.	0.	0.
17	G	1.478669E-4	-1.727315E-4	8.065394E-5	0.	0.	0.
35	G	-1.966116E-4	-1.971067E-4	1.072435E-4	0.	0.	0.
20	G	2.859352E-4	-5.371810E-4	5.343226E-6	0.	0.	0.
2	G	-3.814274E-4	-5.361766E-4	6.435670E-6	0.	0.	0.
16	G	4.200361E-4	-1.035706E-3	7.848845E-5	0.	0.	0.
34	G	-5.662690E-4	-1.062084E-3	1.072592E-4	0.	0.	0.
21	G	5.483048E-4	-1.718172E-3	8.523000E-6	0.	0.	0.
3	G	-7.392903E-4	-1.714168E-3	1.288477E-5	0.	0.	0.
15	G	6.686409E-4	-2.516931E-3	7.416015E-5	0.	0.	0.
33	G	-9.123610E-4	-2.547306E-3	1.072877E-4	0.	0.	0.
22	G	7.871087E-4	-3.495841E-3	9.540628E-6	0.	0.	0.
4	G	-1.073589E-3	-3.486844E-3	1.934621E-5	0.	0.	0.
14	G	8.936811E-4	-4.569276E-3	6.767030E-5	0.	0.	0.
32	G	-1.234887E-3	-4.605640E-3	1.073280E-4	0.	0.	0.
23	G	1.002347E-3	-5.823059E-3	8.397156E-6	0.	0.	0.
5	G	-1.384323E-3	-5.807077E-3	2.581855E-5	0.	0.	0.
13	G	1.095157E-3	-7.145614E-3	5.901993E-5	0.	0.	0.
31	G	-1.533848E-3	-7.189957E-3	1.073786E-4	0.	0.	0.
24	G	1.194020E-3	-8.652692E-3	5.093956E-6	0.	0.	0.

6	G	-1.671492E-3	-8.627737E-3	3.230080E-5	0.	0.	0.
12	G	1.273068E-3	-1.019881E-2	4.821045E-5	0.	0.	0.
30	G	-1.809243E-3	-1.025312E-2	1.074384E-4	0.	0.	0.
25	G	1.362127E-3	-1.193761E-2	-3.678633E-7	0.	0.	0.
7	G	-1.935097E-3	-1.190169E-2	3.879160E-5	0.	0.	0.
11	G	1.427415E-3	-1.368175E-2	3.524300E-5	0.	0.	0.
29	G	-2.061073E-3	-1.374801E-2	1.075063E-4	0.	0.	0.
26	G	1.506669E-3	-1.563068E-2	-7.986973E-6	0.	0.	0.
8	G	-2.175137E-3	-1.558182E-2	4.528994E-5	0.	0.	0.
10	G	1.558197E-3	-1.754729E-2	2.011880E-5	0.	0.	0.
9	G	-2.283375E-3	-1.754729E-2	1.075810E-4	0.	0.	0.
27	G	1.567157E-3	-1.762749E-2	2.011880E-5	0.	0.	0.
28	G	-2.289336E-3	-1.762749E-2	1.075810E-4	0.	0.	0.

Set MAX/MIN Summary Table		Set	ID	Value
T1 Translation	Minimum	4	28	-0.0022893
	Maximum	4	27	0.0015672
T2 Translation	Minimum	4	27	-0.017627
	Maximum	4	1	0.
T3 Translation	Minimum	4	26	-0.000007987
	Maximum	4	9	0.00010758
R1 Rotation	Minimum	4	1	0.
	Maximum	4	1	0.
R2 Rotation	Minimum	4	1	0.
	Maximum	4	1	0.
R3 Rotation	Minimum	4	1	0.
	Maximum	4	1	0.

Sort By : 51..Total Constraint Force in Ascending Order

Title : Constraint force

Output Set 4 - MSC/NASTRAN Case 1

FORCES OF SINGLE-POINT CONSTRAINT

POINT ID.		T1	T2	T3	R1	R2	R3
18	G	-2.957338E+5	0.	0.	0.	0.	0.
19	G	-2.977180E+5	2.356540E+4	1.799300E-1	0.	0.	0.
36	G	3.932231E+5	0.	0.	0.	0.	0.
1	G	3.932096E+5	2.356470E+4	-1.992200E-1	0.	0.	0.

Set MAX/MIN Summary Table		Set	ID	Value
T1 Constraint Force	Minimum	4	19	-297718.
	Maximum	4	36	393223.
T2 Constraint Force	Minimum	4	2	0.
	Maximum	4	19	23565.4
T3 Constraint Force	Minimum	4	1	-0.19922
	Maximum	4	19	0.17993
R1 Constraint Moment	Minimum	4	2	0.
	Maximum	4	2	0.
R2 Constraint Moment	Minimum	4	2	0.
	Maximum	4	2	0.
R3 Constraint Moment	Minimum	4	2	0.
	Maximum	4	2	0.

Output Vector 55 - Total Constraint Moment (Model Vector 98)

Maximum Node ID = 1 Value = 0.

Minimum Node ID = 1 Value = 0.

Type = Force

Output Vector 56 - R1 Constraint Moment (Model Vector 88)

Maximum Node ID = 1 Value = 0.

Minimum Node ID = 1 Value = 0.

Type = Force

Output Vector 57 - R2 Constraint Moment (Model Vector 89)

Maximum Node ID = 1 Value = 0.

Minimum Node ID = 1 Value = 0.

Type = Force

Output Vector 58 - R3 Constraint Moment (Model Vector 90)

Maximum Node ID = 1 Value = 0.

Minimum Node ID = 1 Value = 0.

Type = Force

Output Vector 3036 - Rod Axial Force (Model Vector 91)

Maximum Element ID = 17 Value = 295734.

Minimum Element ID = 39 Value = -393223.

Type = Force Calc = N Component Dir = Y Centroid = Y

Component 0 3036 - Rod Axial Force

Component 1 3036 - Rod Axial Force

1	-381427.	2	-357863.	3	-334298.
4	-310734.	5	-287169.	6	-263605.
7	-240040.	8	-216476.	9	-2.86102E-9
10	130782.	11	154347.	12	177911.
13	201476.	14	225040.	15	248605.
16	272169.	17	295734.	18	0.
19	0.	20	0.	21	0.
22	0.	23	285935.	24	262370.
25	238804.	26	215238.	27	191673.
28	168107.	29	144542.	30	120976.
31	2.86102E-9	32	-228264.	33	-251829.
34	-275395.	35	-298961.	36	-322526.
37	-346092.	38	-369658.	39	-393223.
40	0.	41	-26346.1	42	26346.1
43	-26346.1	44	26346.1	45	-26346.1

46	26346.1	47	-26346.1	48	26346.1
49	-26346.1	50	26346.1	51	-26346.1
52	26346.1	53	-26346.1	54	26346.1
55	-26346.1	56	0.20496	57	-0.20496
58	0.20496	59	-0.20496	60	0.20496
61	-0.20496	62	0.20496	63	-0.20496
64	0.20496	65	-0.20496	66	0.20496
67	-0.20496	68	0.20496	69	-0.20496
70	0.20496	71	26346.9	72	-26346.9
73	26346.9	74	-26346.9	75	26346.9
76	-26346.9	77	26346.9	78	-26346.9
79	26346.9	80	-26346.9	81	26346.9
82	-26346.9	83	26346.9	84	-26346.9
85	26346.9	86	0.22693	87	-0.22693
88	0.22693	89	-0.22693	90	0.22693
91	-0.22693	92	0.22693	93	-0.22693
94	0.22693	95	-0.22693	96	0.22693
97	-0.22693	98	0.22693	99	-0.22693
100	0.22693				

Output Vector 3038 - Rod Torque Force (Model Vector 92)

Maximum Element ID = 1 Value = 0.

Minimum Element ID = 1 Value = 0.

Type = Force

Output Vector 3183 - Rod Axial Stress (Model Vector 93)

Maximum Element ID = 17 Value = 49288960.

Minimum Element ID = 39 Value = -65537188.

1	-63571228.	2	-59643812.	3	-55716400.
4	-51788988.	5	-47861572.	6	-43934160.
7	-40006744.	8	-36079332.	9	-4.76837E-7

10	21797042.	11	25724460.	12	29651876.
13	33579292.	14	37506708.	15	41434128.
16	45361544.	17	49288960.	18	0.
19	0.	20	0.	21	0.
22	0.	23	47655860.	24	43728264.
25	39800664.	26	35873064.	27	31945464.
28	28017866.	29	24090266.	30	20162666.
31	4.7684E-7	32	-38043968.	33	-41971572.
34	-45899172.	35	-49826776.	36	-53754380.
37	-57681980.	38	-61609584.	39	-65537188.
40	0.	41	-13173067.	42	13173067.
43	-13173066.	44	13173067.	45	-13173066.
46	13173066.	47	-13173066.	48	13173068.
49	-13173066.	50	13173066.	51	-13173066.
52	13173066.	53	-13173068.	54	13173064.
55	-13173068.	56	102.478	57	-102.478
58	102.478	59	-102.478	60	102.478
61	-102.478	62	102.478	63	-102.478
64	102.478	65	-102.478	66	102.478
67	-102.478	68	102.478	69	-102.478
70	102.478	71	13173459.	72	-13173459.
73	13173458.	74	-13173459.	75	13173458.
76	-13173458.	77	13173458.	78	-13173460.
79	13173458.	80	-13173458.	81	13173458.
82	-13173458.	83	13173460.	84	-13173456.
85	13173460.	86	113.465	87	-113.464
88	113.465	89	-113.465	90	113.465
91	-113.465	92	113.465	93	-113.465
94	113.465	95	-113.465	96	113.465
97	-113.465	98	113.465	99	-113.465
100	113.465				

Output Vector 3186 - Rod Torsional Stress (Model Vector 94)

Maximum Element ID = 1 Value = 0.

Minimum Element ID = 1 Value = 0.

Type = Stress

Displacement Summary

Maximum Value 0.017776 Output Vector 1 - Total Translation

Minimum Value -0.017627 Output Vector 3 - T2 Translation

Force Summary

Maximum Value 393915. Output Vector 51 - Total Constraint Force

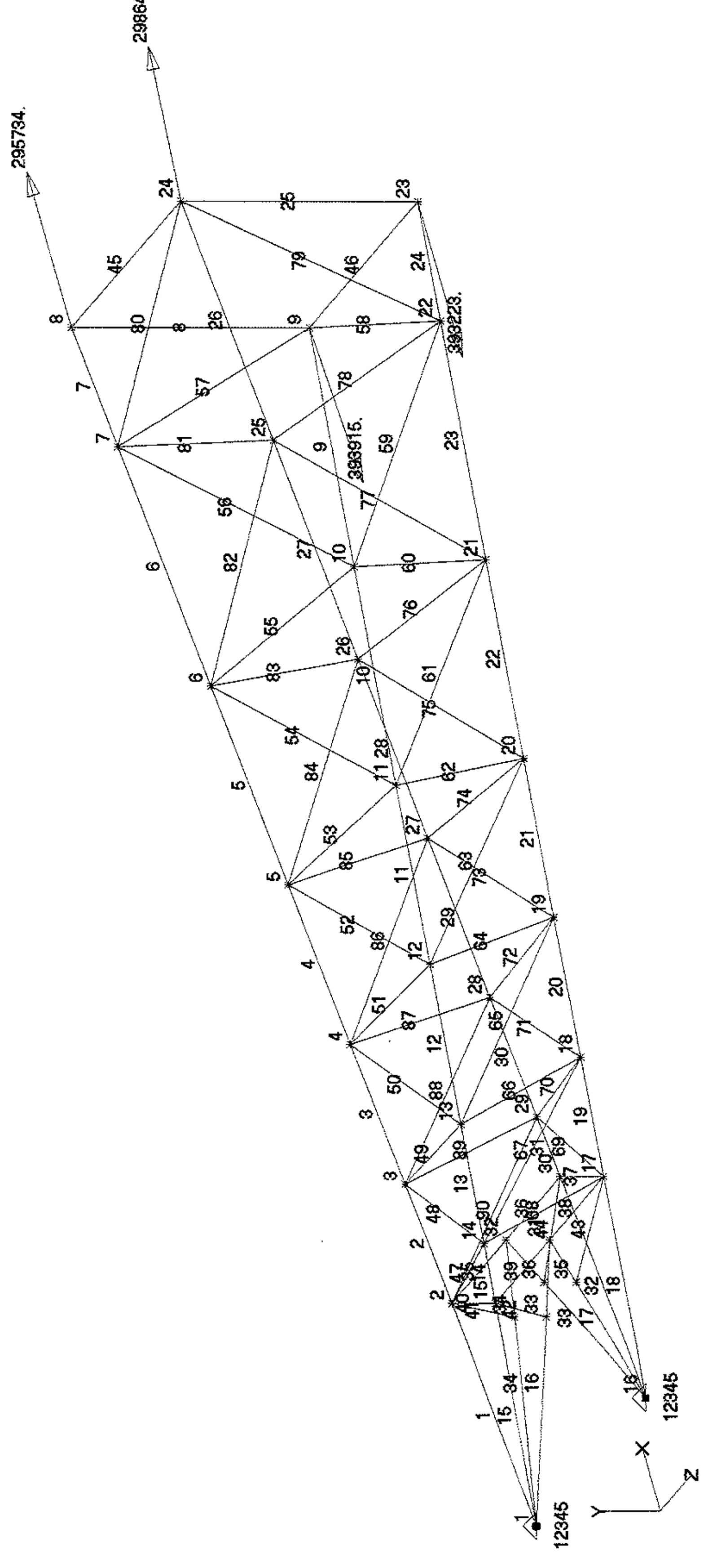
Minimum Value -393223. Output Vector 3036 - Rod Axial Force

Stress Summary

Maximum Value 49288960. Output Vector 3183 - Rod Axial Stress

Minimum Value -65537188. Output Vector 3183 - Rod Axial Stress

Boom Bottom Section



Nodal dan Elemen

MSC/NASTRAN for Windows Version 4.40 Wed May 19 11:42:14 1999

Model : C:\Mscn4w20\Base.MOD Report : Node

Format : NASTRAN Displacement

Sort By : 1..Total Translation in Ascending Order

Title : Translation

Output Set 1 - MSC/NASTRAN Case 1

DISPLACEMENT VECTOR

POINT ID.		T1	T2	T3	R1	R2	R3
1	G	0.	0.	0.	0.	0.	0.
16	G	0.	0.	0.	0.	0.	0.
34	G	0.	0.	-5.918992E-8	0.	0.	0.
33	G	0.	0.	1.002478E-6	0.	0.	0.
31	G	0.	0.	-5.304165E-6	0.	0.	0.
32	G	0.	0.	-5.463856E-6	0.	0.	0.
30	G	-8.039171E-6	2.476580E-7	-5.463856E-6	0.	0.	0.
15	G	-8.305525E-6	1.033328E-6	-5.304165E-6	0.	0.	0.
17	G	-8.244898E-6	2.476580E-7	-6.241730E-6	0.	0.	0.
2	G	-8.597276E-6	1.033328E-6	-6.429648E-6	0.	0.	0.
36	G	0.	0.	-1.147466E-5	0.	0.	0.
35	G	0.	0.	-1.244398E-5	0.	0.	0.
29	G	-1.049492E-5	2.947684E-6	-8.117602E-6	0.	0.	0.
14	G	-1.087179E-5	-1.696089E-6	-8.995494E-6	0.	0.	0.
18	G	-1.301239E-5	5.114262E-7	-1.044184E-5	0.	0.	0.
3	G	-1.307322E-5	4.343221E-7	-1.104260E-5	0.	0.	0.
28	G	-1.539968E-5	2.447070E-6	-1.261629E-5	0.	0.	0.
13	G	-1.523165E-5	-1.315758E-6	-1.308761E-5	0.	0.	0.
19	G	-1.943959E-5	-1.225575E-6	-1.381722E-5	0.	0.	0.
4	G	-1.823632E-5	1.415764E-6	-1.601648E-5	0.	0.	0.
12	G	-2.071976E-5	-4.945684E-7	-1.657237E-5	0.	0.	0.
27	G	-2.280513E-5	1.363303E-6	-1.668437E-5	0.	0.	0.

5	G	-2.368588E-5	1.482851E-6	-1.933149E-5	0.	0.	0.
20	G	-2.765779E-5	-1.871803E-6	-1.636258E-5	0.	0.	0.
11	G	-2.662390E-5	-6.461454E-7	-1.844005E-5	0.	0.	0.
6	G	-3.000440E-5	1.493410E-6	-1.938113E-5	0.	0.	0.
10	G	-3.324700E-5	-6.683280E-7	-1.480512E-5	0.	0.	0.
26	G	-3.244848E-5	1.599715E-6	-1.792052E-5	0.	0.	0.
7	G	-3.686930E-5	1.462431E-6	-1.143129E-5	0.	0.	0.
9	G	-3.964791E-5	0.	0.	0.	0.	0.
8	G	-3.976817E-5	0.	0.	0.	0.	0.
21	G	-3.935545E-5	-2.771782E-6	-1.524131E-5	0.	0.	0.
25	G	-4.599370E-5	1.653720E-6	-1.353312E-5	0.	0.	0.
22	G	-5.547626E-5	-3.924255E-6	-5.638633E-6	0.	0.	0.
24	G	-6.293234E-5	0.	0.	0.	0.	0.
23	G	-6.421917E-5	0.	0.	0.	0.	0.

Set MAX/MIN Summary Table		Set	ID	Value
T1 Translation	Minimum	1	23	-0.000064219
	Maximum	1	1	0.
T2 Translation	Minimum	1	22	-3.9243E-6
	Maximum	1	29	0.0000029477
T3 Translation	Minimum	1	6	-0.000019381
	Maximum	1	33	0.0000010025
R1 Rotation	Minimum	1	1	0.
	Maximum	1	1	0.
R2 Rotation	Minimum	1	1	0.
	Maximum	1	1	0.
R3 Rotation	Minimum	1	1	0.
	Maximum	1	1	0.

Sort By : 51..Total Constraint Force in Ascending Order

Title : Constraint force

Output Set 1 - MSC/NASTRAN Case 1

FORCES OF SINGLE-POINT CONSTRAINT

POINT ID.		T1	T2	T3	R1	R2	R3
35	G	1.456613E-13	0.	0.	0.	0.	0.
36	G	-2.353673E-13	-3.846923E-14	0.	0.	0.	0.
34	G	3.076601E-13	2.295256E-15	0.	0.	0.	0.
33	G	3.285150E-13	-4.676814E-15	0.	0.	0.	0.
8	G	0.	1.400000E+3	0.	-3.000000E+3	0.	0.
24	G	0.	1.400000E+3	-7.023939E+2	-3.000000E+3	0.	0.
23	G	0.	2.600000E+3	0.	-3.000000E+3	0.	0.
9	G	0.	2.600000E+3	-6.818652E+2	-3.000000E+3	0.	0.
16	G	4.449496E+3	-1.119749E+1	6.921296E+2	0.	0.	0.
1	G	1.955050E+4	1.119749E+1	6.921296E+2	0.	0.	0.

Set	MAX/MIN Summary Table	Set	ID	Value
T1 Constraint Force	Minimum	1	36	-2.35367E-13
	Maximum	1	1	19550.5
T2 Constraint Force	Minimum	1	16	-11.1975
	Maximum	1	23	2600.
T3 Constraint Force	Minimum	1	24	-702.394
	Maximum	1	16	692.13
R1 Constraint Moment	Minimum	1	8	-3000.
	Maximum	1	2	0.
R2 Constraint Moment	Minimum	1	2	0.
	Maximum	1	2	0.
R3 Constraint Moment	Minimum	1	2	0.
	Maximum	1	2	0.

Output Vector 51 - Total Constraint Force (Model Vector 19)

Maximum Node ID = 1 Value = 19562.8

Minimum Node ID = 2 Value = 0.

Type = Force Calc = Y Component Dir = Y Centroid = Y

Component 0 52 - T1 Constraint Force

Component 1 53 - T2 Constraint Force

Component 2 54 - T3 Constraint Force

1	19562.8	24	1566.32
8	1400.	33	3.28548E-13
9	2687.92	34	3.07669E-13
16	4503.02	35	1.45663E-13
23	2600.	36	2.3849E-13

Output Vector 55 - Total Constraint Moment (Model Vector 20)

Maximum Node ID = 8 Value = 3000.

Minimum Node ID = 1 Value = 0.

Type = Force Calc = Y Component Dir = Y Centroid = Y

Component 0 56 - R1 Constraint Moment

Component 1 57 - R2 Constraint Moment

Component 2 58 - R3 Constraint Moment

8	3000.	9	3000.
23	3000.	24	3000.

Output Vector 56 - R1 Constraint Moment (Model Vector 10)

Maximum Node ID = 1 Value = 0.

Minimum Node ID = 8 Value = -3000.

Type = Force Calc = N Component Dir = Y Centroid = Y

Component 0 56 - R1 Constraint Moment

8	-3000.	9	-3000.
23	-3000.	24	-3000.

Output Vector 57 - R2 Constraint Moment (Model Vector 11)

Maximum Node ID = 1 Value = 0.

Minimum Node ID = 1 Value = 0.

Type = Force

Output Vector 58 - R3 Constraint Moment (Model Vector 12)

Maximum Node ID = 1 Value = 0.

Minimum Node ID = 1 Value = 0.

Type = Force

Output Vector 3036 - Rod Axial Force (Model Vector 13)

Maximum Element ID = 81 Value = 801.005

Minimum Element ID = 1 Value = -9174.38

Type = Force Calc = N Component Dir = Y Centroid = Y

Component 0 3036 - Rod Axial Force

Component 1 3036 - Rod Axial Force

1	-9174.38	2	-8981.86	3	-8596.82
4	-8083.44	5	-7505.89	6	-6799.99
7	-6029.93	8	0.	9	-6403.71
10	-7151.27	11	-7774.24	12	-8272.61
13	-8708.69	14	-9082.47	15	-9082.47
16	-765.392	17	765.392	18	-2977.38
19	-3164.27	20	-3538.05	21	-4036.42
22	-4597.1	23	-5282.36	24	-6029.93
25	0.	26	-5644.89	27	-4874.82
28	-4233.1	29	-3719.72	30	-3270.51
31	-2885.47	32	-2885.47	33	788.435
34	-788.435	35	702.394	36	9.31323E-13
37	-0.000064824	38	-681.865	39	-4.65661E-13
40	-0.00020404	41	-8.80391E-13	42	-9.31323E-13

43	0.	44	9.31323E-13	45	0.
46	0.	47	0.00024477	48	0.00005286
49	0.00013262	50	-0.00014611	51	-0.000092857
52	0.00016674	53	-0.00026401	54	0.00036591
55	-0.00019228	56	-0.00036379	57	0.00018816
58	777.594	59	-777.594	60	777.594
61	-749.642	62	749.642	63	-725.972
64	725.971	65	-725.972	66	707.014
67	-707.014	68	707.014	69	0.000084367
70	0.000012073	71	0.000062064	72	-0.000081392
73	-0.00002146	74	0.000066802	75	-0.00014095
76	0.00024576	77	-0.00017724	78	-0.00026414
79	0.00016579	80	-801.005	81	801.005
82	-801.005	83	772.211	84	-772.211
85	747.828	86	-747.828	87	747.828
88	-728.3	89	728.3	90	-728.3

Output Vector 3038 - Rod Torque Force (Model Vector 14)

Maximum Element ID = 1 Value = 0.

Minimum Element ID = 1 Value = 0.

Type = Force

Output Vector 3183 - Rod Axial Stress (Model Vector 15)

Maximum Element ID = 81 Value = 400502.

Minimum Element ID = 24 Value = -3014963.

Type = Stress Calc = N Component Dir = Y Centroid = Y

Component 0 3183 - Rod Axial Stress

Component 1 3183 - Rod Axial Stress

1	-1529063.	2	-1496977.	3	-1432804.
4	-1347241.	5	-1250982.	6	-1133332.
7	-1004988.	8	0.	9	-1067285.

10	-1191878.	11	-1295707.	12	-1378769.
13	-1451449.	14	-1513746.	15	-1513746.
16	-382696.	17	382696.	18	-1488688.
19	-1582134.	20	-1769024.	21	-2018212.
22	-2298548.	23	-2641181.	24	-3014963.
25	0.	26	-2822445.	27	-2437410.
28	-2116548.	29	-1859858.	30	-1635255.
31	-1442737.	32	-1442737.	33	394218.
34	-394218.	35	351197.	36	4.65661E-10
37	-0.032412	38	-340933.	39	-2.32831E-10
40	-0.10202	41	-4.40195E-10	42	-4.65661E-10
43	0.	44	4.65661E-10	45	0.
46	0.	47	0.12239	48	0.02643
49	0.066311	50	-0.073053	51	-0.046428
52	0.083371	53	-0.132	54	0.18296
55	-0.096139	56	-0.1819	57	0.094078
58	388797.	59	-388797.	60	388797.
61	-374821.	62	374821.	63	-362986.
64	362986.	65	-362986.	66	353507.
67	-353507.	68	353507.	69	0.042184
70	0.0060367	71	0.031032	72	-0.040696
73	-0.01073	74	0.033401	75	-0.070475
76	0.12288	77	-0.08862	8	-0.13207
79	0.082894	80	-400502.	81	400502.
82	-400503.	83	386105.	84	-386106.
85	373914.	86	-373914.	87	373914.
88	-364150.	89	364150.	90	-364150.

Output Vector 3186 - Rod Torsional Stress (Model Vector 16)

Maximum Element ID = 1 Value = 0.

Minimum Element ID = 1 Value = 0.

Type = Stress

Displacement Summary

Maximum Value	0.000064219	Output Vector 1 - Total Translation
Minimum Value	-0.000064219	Output Vector 2 - T1 Translation

Force Summary

Maximum Value	19562.8	Output Vector 51 - Total Constraint Force
Minimum Value	-9174.38	Output Vector 3036 - Rod Axial Force

Stress Summary

Maximum Value	400502.	Output Vector 3183 - Rod Axial Stress
Minimum Value	-3014963.	Output Vector 3183 - Rod Axial Stress

Tabel dan Grafik

Table 17/5. Dimensioning of axles and shafts with circular cross-section.
For more exact expression of permissible stress see examples under section 17.3 and also p. 66

Tran

Type	Calculation	Data
Axles under bending: (see example 1)	From $M_b = W_b \cdot \sigma_b \approx 0{,}1\, d^3 \cdot \sigma_b$: $\boxed{d = 2{,}17 \sqrt[3]{\frac{M_b}{\sigma_b}}}$ (cm)	$\sigma_{b_{zul}}$ = 600 to 1000 kgf/cm² for stationary axle St 50.11 = 300 to 600 kgf/cm² for rotating axles, St 50.11
Shafts (approximate calculation): For $\tau_t = 120$ kgf/cm²:	From $M_t = W_t \cdot \tau_t \approx 0{,}2\, d^3 \cdot \tau_t$: $d = 1{,}72 \sqrt[3]{\frac{M_t}{\tau_t}} = 71 \sqrt[3]{\frac{N_{PS}}{n\, \tau_t}}$ $\boxed{d = 0{,}35 \sqrt[3]{M_t} = 14{,}4 \sqrt[3]{\frac{N_{PS}}{n}}}$ (cm)	$\tau_{t_{zul}}$ = 120 kgf/cm² for transmission shafts, St 42.11 = 200 to 400 for lifting machinery shafts, St 50.11 = 50 to 60 for water wheel shafts, oak wood
Shafts under bending and torsion: (see example 2)	From $M_v = \sqrt{M_b^2 + \left(\frac{a}{2} M_t\right)^2}$: $\boxed{d = 2{,}17 \sqrt[3]{b \cdot \frac{M_v}{\sigma_b}}}$ (cm) $b = 1$ for solid shaft $b = \frac{1}{1 - (d_i/d)^4}$ for hollow shaft $b = 1{,}065$ for $d_i/d = 0{,}5$	$\sigma_{b_{zul}}$ = 400 to 600 kgf/cm² for lifting machinery shafts, St 50.11 $\tau_{t_{zul}}$ = 300 to 500 kgf/cm² for lifting machinery shafts, St 50.11 $\sigma_{b_{zul}}$ = 1000 to 1500 kgf/cm² for rack and pinion jack, St 70.11 $\tau_{t_{zul}}$ = 600 to 800 kgf/cm² for rack and pinion jack, St 70.11 $a = \frac{\sigma_{b_{zul}}}{\tau_{t_{zul}}}$ { $a \approx 1$ for τ_t repetitive, σ_b reversing; $a \approx 1{,}7$ for τ_t reversing, σ_b reversing
Shaft with *overhung pinion*: For tan β = 1/1000:	$\operatorname{tg} \beta = \frac{a \cdot P}{E \cdot J}$ $\boxed{d \geq 0{,}314 \sqrt[4]{P \cdot a}}$ (cm) with J = const. and $E = 2.1 \cdot 10^6$ kgf/cm²	$a = \frac{a_1 \cdot a_2}{3} + \frac{a_1^2}{2}$ a_1 = distance of pinion centre to bearing centre a_2 = Distance between bearings, Fig. 17/2
Long shafts: according to permissible torsional angle φ_m For $G = 8.1 \times 10^5$ kgf/cm² and φ_m = 1/4 °/m:	From $\varphi_m = \frac{18\,000\, M_t}{\pi \cdot G \cdot J_t}$; $J_t = \frac{\pi d^4}{32}$ $d = 15{,}5 \sqrt[4]{\frac{M_t}{G \cdot \varphi_m}}$ $\boxed{d = 0{,}73 \sqrt[4]{M_t} = 12 \sqrt[4]{\frac{N_{PS}}{n}}}$ (cm)	*Moreover:* Bearing distance $a \leq 100\sqrt{d}$ (cm) for multiple supported shafts, corresponding to deflection due to own weight $f = 0.16$ mm *bearing distance* $a \leq 50 \sqrt[3]{d^2}$ (cm), corresponding to tan β = 1/1000
Critical speed of rotation n_K (1/min) (see example 3)	*Flexural vibration:* $\boxed{n_K = 300\, K \sqrt{1/f}}$	For several mounted masses 1, 2 ... we have[1] $f \approx f_1 + f_2 + \ldots$ (cm), whereby the deflection f_1, $f_2 \ldots$ are determined individually for each weight the mass as load $K = 1$ for freely supported shaft/axle $K = 1.3$ for shaft/axle built in on both sides $K = 0.9$ for shaft overhung on one side
	Torsional vibration:[2] $\boxed{n_K = \frac{30}{\pi} \sqrt{\frac{c}{J_m}}}$ $\frac{1}{c} = \frac{\varphi}{M_t} = \frac{32}{\pi G} \left(\frac{L_1}{d_1^4} + \frac{L_2}{d_2^4} + \cdots \right)$	For stepped shaft $L = L_1 + L_2 \ldots$ (cm) is the length effective torsional spring, consisting of the length $L_1, L_2, \ldots$ of diameter $d_1, d_2, \ldots$

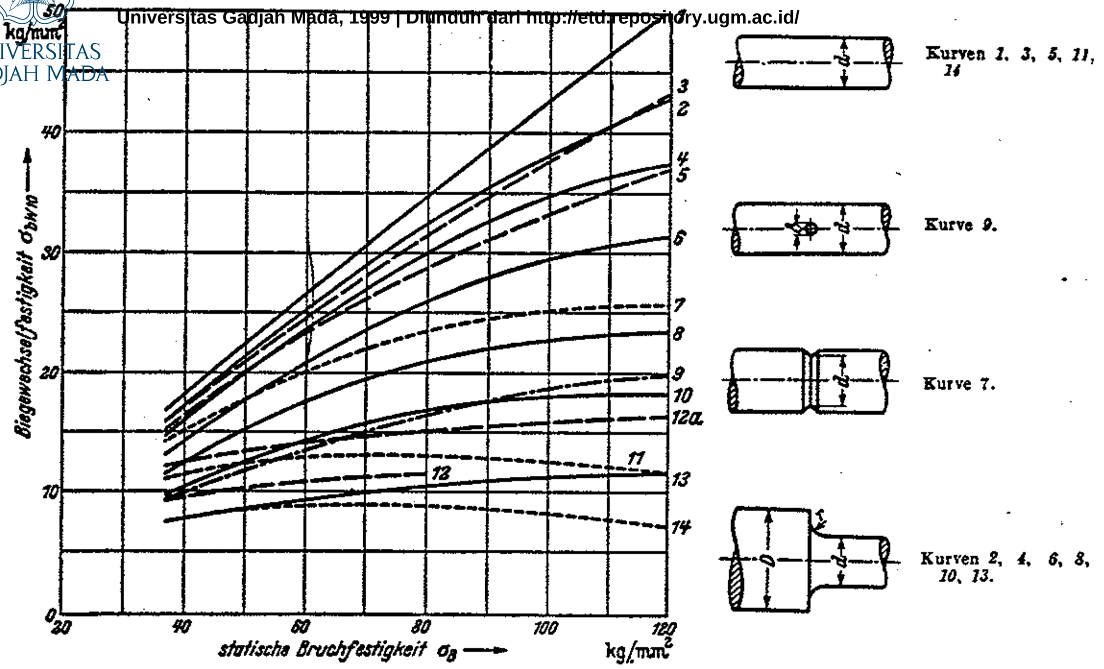


Fig. 3/27.* Relation between endurance strength for reversed bending of 10 mm dia. C-steel test pieces and the static ultimate strength σ_B. (a) Smooth shafts: Polished (curve 1); ground or fine machined (curve 3); rough machined (5), corroded by ordinary water (11); corroded by salt water (14); (b) With transverse hole: $\delta = 0.175\,d$ (curve 9); (c) With sharp notch: 1 mm deep (curve 7); (d) With hub: keyed (curve 12); pressed without key (12a); (e) With step $D/d = 2$: $y = r/d = 0.5$ (curve 2); $= 0.3(4)$; $= 0.2(6)$; $= 0.1(8)$; $= 0.05(10)$; $= 0(13)$; (f) For steps with other D/d ratios: Substitute $y = r/d + q$. (g) For other diameters d:** $\sigma_{bW} \approx \sigma_{bW10} \cdot b_0$ and $\tau_{tW} \approx \tau_{tW10} \cdot b_0$.

statische Bruchfestigkeit = static ultimate stress; Biegewechselfestigkeit = endurance strength for reversed bending; Kurve(n) = curve(s).

* The diagram is based on test data of Thum and Lehr.

**After the initial tests of Lehr and Bautz; see footnote 5 on p. 61 for reason.

Table 3/4. Mean values of endurance strength for iron and steel polished round test piece. For σ_B and σ_F, see materials Tables 5/2 to 5/4 and 5/8. Notch strength, see Fig. 3/27 and Table 4/1 p. 73

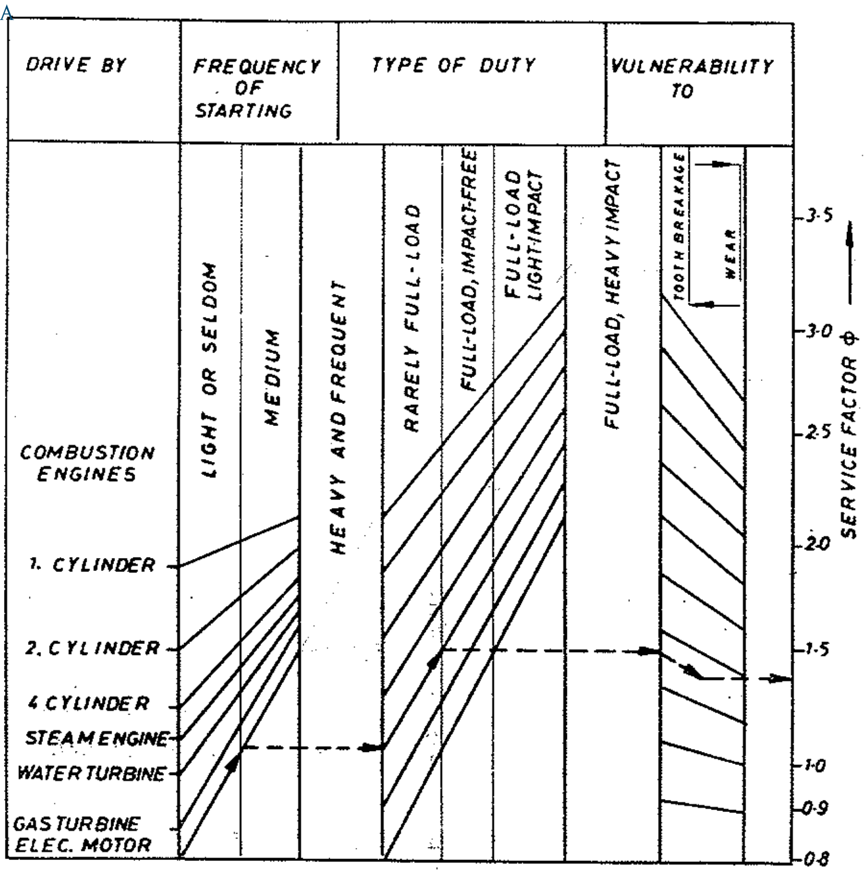
Material	Tension**		Bending***			Torsion		
	σ_W	σ_{Ur}	$\sigma_{bW\,10}$	σ_{bUr}	σ_{bF}	τ_{tW}	τ_{tUr}	τ_{tF}
C steel	$0{,}315\,\sigma_B \approx 0{,}7\,\sigma_{bW\,10}$	$1{,}8\,\sigma_W$	$0{,}45\,\sigma_B$	$1{,}8\,\sigma_{bW}$	$1{,}15\,\sigma_F$	$0{,}58\,\sigma_{bW}$	$1{,}9\,\tau_{tW}$	$0{,}6\,\sigma_F$
Cast steel	$0{,}26\,\sigma_B \approx 0{,}65\,\sigma_{bW\,10}$	$1{,}8\,\sigma_W$	$0{,}4\,\sigma_B$	$1{,}8\,\sigma_{bW}$	$1{,}15\,\sigma_F$	$0{,}58\,\sigma_{bW}$	$1{,}9\,\tau_{tW}$	$0{,}7\,\sigma_F$
Cast iron*	$0{,}25\,\sigma_B \approx 0{,}5\,\sigma_{bW\,10}$	$1{,}6\,\sigma_W$	$0{,}5\,\sigma_B$	$1{,}6\,\sigma_{bW}$	—	$0{,}75\,\sigma_{bW}$	$1{,}4\,\tau_{tW}$	—
Malleable cast iron	$0{,}28\,\sigma_B \approx 0{,}7\,\sigma_{bW\,10}$	$1{,}8\,\sigma_W$	$0{,}4\,\sigma_B$	$1{,}8\,\sigma_{bW}$	$1{,}1\,\sigma_F$	$0{,}64\,\sigma_{bW}$	$1{,}9\,\tau_{tW}$	$0{,}7\,\sigma_F$

*For cast iron $\sigma_{-Ur} \approx 3\,\sigma_{Ur}$, $\sigma_{bB} \approx 9 + 1.4\,\sigma_B$.

**σ_{-Ur} is higher for compression, e.g., 1.3 σ_{Ur} for spring steel.

***$\sigma_{bW} = \sigma_{bW10} \cdot b_0$ for diameters other than 10 mm. See Fig. 3/27 for b_0.

Table 2.16 Service factor for different service conditions



Based on Die Tragfaehigkeit der Zahnraeder, Thomas and Charchut, 7th Edition, 1971, table no. 5, p.129. ırl Hanser Verlag, Munich.

Table 2.14 Factor K_v in relation to factor K_o and velocity v

K_o in N/cm	v in m/s: 1	2	4	6	8	10	12	14	16	18	20
	$K_v \times 10^{-2}$ in s/m										
500	5.7	5.6	5.6	4.6	3.4	2.9	2.6	2.1	1.9	1.9	1.6
1000	5.0	4.9	4.8	4.1	3.4	3.0	2.7	2.4	2.1	1.9	1.8
2000	3.8	3.7	3.2	3.0	2.7	2.5	2.4	2.3	2.2	2.1	2.0
3000	3.3	3.0	2.5	2.4	2.3	2.3	2.3	2.2	2.2	2.1	2.1
4000	3.1	2.9	2.5	2.3	2.3	2.3	2.3	2.2	2.2	2.2	2.2
5000	3.0	2.9	2.5	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
10000	3.0	2.9	2.4	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
12000	2.9	2.8	2.4	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3

Based on Die Tragfachigkeit der Zahnraeder. Thomas and Charchut, 7th Edition, 1971, table no. 6, p. 30. Carl Hanser Verlag, Munich.

Table 2.23 Permissible values of individual and composite errors

(All values of errors in μm)

Gear quality	*Tooth profile error* F_f	*Adjacent pitch error* f_{pt}	*Cumulative pitch error* F_{pk}
3	$3.0 + 0.16\,\phi_f$	$2.0 + 0.16\,\phi_t$	$1.6 + 0.63\sqrt{L}$
4	$4.0 + 0.25\,\phi_f$	$3.2 + 0.25\,\phi_t$	$2.5 + 1.00\sqrt{L}$
5	$5.0 + 0.40\,\phi_f$	$5.0 + 0.40\,\phi_t$	$4.0 + 1.60\sqrt{L}$
6	$6.3 + 0.63\,\phi_f$	$8.0 + 0.63\,\phi_t$	$6.0 + 2.50\sqrt{L}$
7	$8.0 + 1.00\,\phi_f$	$11.0 + 0.90\,\phi_t$	$8.0 + 3.55\sqrt{L}$
8	$10.0 + 1.60\,\phi_f$	$16.0 + 1.25\,\phi_t$	$12.0 + 5.00\sqrt{L}$
9	$16.0 + 2.50\,\phi_f$	$22.0 + 1.80\,\phi_t$	$17.0 + 7.10\sqrt{L}$
10	$25.0 + 4.00\,\phi_f$	$32.0 + 2.50\,\phi_t$	$25.0 + 10.00\sqrt{L}$
11	$40.0 + 6.30\,\phi_f$	$45.0 + 3.55\,\phi_t$	$33.0 + 14.00\sqrt{L}$
12	$63.0 + 10.00\,\phi_f$	$63.0 + 5.00\,\phi_t$	$50.0 + 20.00\sqrt{L}$

Note: $\phi_f = m + 0.10\sqrt{d}$, $\phi_t = m + 0.25\sqrt{d}$, L (mm) = Arc length $k\pi m$ on a sector of k number of pitches, $L_{max} = \pi d/2$, m (module) and d (pcd) are in mm.

Gear quality	*Tooth alignment error* F_β	*Radial run-out* f_r
3	$2.5 + 0.50\sqrt{b}$	$7 + 0.56\,\phi_t$
4	$3.0 + 0.63\sqrt{b}$	$11 + 0.90\,\phi_t$
5	$4.0 + 0.80\sqrt{b}$	$18 + 1.40\,\phi_t$
6	$5.0 + 1.00\sqrt{b}$	$28 + 2.24\,\phi_t$
7	$6.0 + 1.25\sqrt{b}$	$40 + 3.15\,\phi_t$
8	$10.0 + 2.00\sqrt{b}$	$50 + 4.00\,\phi_t$
9	$16.0 + 3.15\sqrt{b}$	$63 + 5.00\,\phi_t$
10	$25.0 + 5.00\sqrt{b}$	$80 + 6.30\,\phi_t$
11	$40.0 + 8.00\sqrt{b}$	$100 + 8.00\,\phi_t$
12	$63.0 + 12.50\sqrt{b}$	$125 + 10.00\,\phi_t$

Note: b (mm) = Tooth width, b_{max} = 150 mm

Gear quality	*Tooth-to-tooth composite error, double flank* f''_i	*Total composite error, double flank* F''_i
3	$4.0 + 0.32\,\phi_t$	$10 + 0.80\,\phi_t$
4	$6.0 + 0.45\,\phi_t$	$16 + 1.25\,\phi_t$
5	$9.0 + 0.56\,\phi_t$	$25 + 2.00\,\phi_t$
6	$12.0 + 0.90\,\phi_t$	$40 + 3.20\,\phi_t$
7	$16.0 + 1.25\,\phi_t$	$56 + 4.50\,\phi_t$
8	$22.0 + 1.80\,\phi_t$	$71 + 5.60\,\phi_t$
9	$28.0 + 2.24\,\phi_t$	$90 + 7.10\,\phi_t$
10	$36.0 + 2.80\,\phi_t$	$112 + 9.00\,\phi_t$
11	$45.0 + 3.55\,\phi_t$	$140 + 11.20\,\phi_t$
12	$56.0 + 4.50\,\phi_t$	[illegible] + $14.00\,\phi_t$

Table 2.15 Allowable circumferential velocity of gears in relation to the manufacturing processes and quality

v m/sec	*Manufacturing process*	*Quality*
0-0.8	Cast, coarse cut, gas cut, flame cut	10-12
0.8-4	Smooth finished	8-10
4-12	Ground	6-8
12-60	Scraped, shaved, fine ground	4-6

Gear Materials

Sl. No.	Material	IS: No.	IS: Symbol (new)	IS: Symbol (old)	Typical uses
1 2	Cast iron	210	FG 200 FG 260	Grade 20 Grade 25	Gears of light duty work, low speed (upto 0.8 m/s), hand-operated winches, etc.
3 4	Cast iron with spheroidal graphite	1865	SG 500/7 SG 600/3		Gears with increased load capacity and resistance to contact stress
5 6	Cast steel	1030	Grade: 26-52 Grade: 30-57	Grade 2 Grade 1	Medium speed gears (upto 8 m/s), crane wheel gears, crane cross travel and long travel gears
7 8 9 10	Standard or structural steels	1570	Fe 410 Fe 490 Fe 620 Fe 690	St 42 St 50 St 63 St 70	For general purpose gears
11 12 13 14 15	Heat treatable steel	1570	45 C 8 60 C 4	C 45 C 60 55 Cr 70 37 Si 2 Mn 90 40 Cr 1 Mo 28	Low speed, light duty gears Medium speed, medium duty gears Gears for gear oil pumps Gears for conventional gear boxes Cross and long travel gears for cranes Medium to high speed gears machine tool gear boxes, etc.

Sl. No.	Material	IS: No.	IS: Symbol (new)	IS: Symbol (old)	Typical uses
16 17 18 19	Case carburising steel	1570	10 C 4 15 C 4	C 10 C 15 17 Mn 1 Cr 95 20 Mn Cr 1	Heavy duty transmission gears General purpose gear boxes where hardened gear surface is imperative Hoisting, crane, timing gears involving medium to heavy duty
20 21 22	Flame or induction hardening steel	1570	45 C 8 40 Cr 4	C 45 40 Cr 1 37 Si 2 Mn 90	For gears of heavy duty For gears with high surface hardness and where the stresses are high and exacting
23 24	Steel hardened in cynide bath	1570	40 Cr 4	40 Cr 1 37 Si 2 Mn 90	Gears for superficially hard tooth surfaces

St. No.	Ult. ten. St. σ_{Ut}	Yield St. σ_Y (0.2)	End limit σ_e	Perm. Ben. St. σ_{bf}	Sur. fat. Str. P_{cr}	Br. Hardness HB	Heat Treatment
	Average values (N/mm²)						
1	200	—	90	35	295	1670	—
2	260	—	115	45	375	2060	
3	500	320	—	120	470	1960	—
4	600	370	—	150	550	2260	
5	520	260	205	90	365	1470	Annealed
6	570	300	235	110	490	1720	
7	410	250	220	110	335	1230	Annealed
8	490	290	255	120	390	1470	
9	620	380	305	125	440	1770	
10	690	410	370	160	510	2040	
11	600	380	320	130	490	1810	Quenched hardened and tempered
12	700	430	370	150	600	2060	
13	900	650	400	170	745	2550	
14			375	190	640	2160	
15	700	500	500	185	745	3340	
16	500	300	260	130	1630	5790.	Hardened
17	500	300	270	155	1730	6250	
18	800	590		250	1790	6380	
19	980	685		260	1790	6380	

Table 5/8. Machine construction steels to DIN 1611 (Dec. 1935) (Unalloyed C-Steel)

Symbol	Mean C-Content %	Tensile strength σ_B kgf/mm²	Min. yield str. σ_F %	Min. ultimate str. δ_5 %	Brinell hardness[1] H_B kgf/mm²	Application
St 00.11	0,1	<50	—	—	—	low stressed components.
St 34.11	0,12	34···42	19	30	95···120	Forged steel; easy machining, carburising and forge welding, highly ductile.
St 34.13[2]	0,12	34···42	19	30	95···120	Rivets.
St 37.11	0,16	37···45	(21)	25	105···125	Common forged steel.
St 42.11	0,25	42···50	23	25	120···140	Medium stressed shafts and gears, small connecting rod, pressed and die forged components.
St 50.11	0,35	50···60	27	22	140···170	Higher stressed shafts and gears; connecting rods, pistons; easy machining, less hardenable; suitable for sliding loads.
St 60.11	0,45	60···70	30	17	170···106	Stronger parts; components subject to sliding like dowels, taper lays, gears, warms, spindles and plungers; hardenable.
St 70.11	0,6	70···85	35	12	195···240	Tool steel for highly loaded, naturally hard components like cans, rollers, rolls, dies, also hardened components like leaf and coiled springs, punches, cutting edges and rolls; highly hardenable; can be machined.

[1] Values added by Prof. Niemann.

[2] According to DIN 1613 (Sept. 1943).

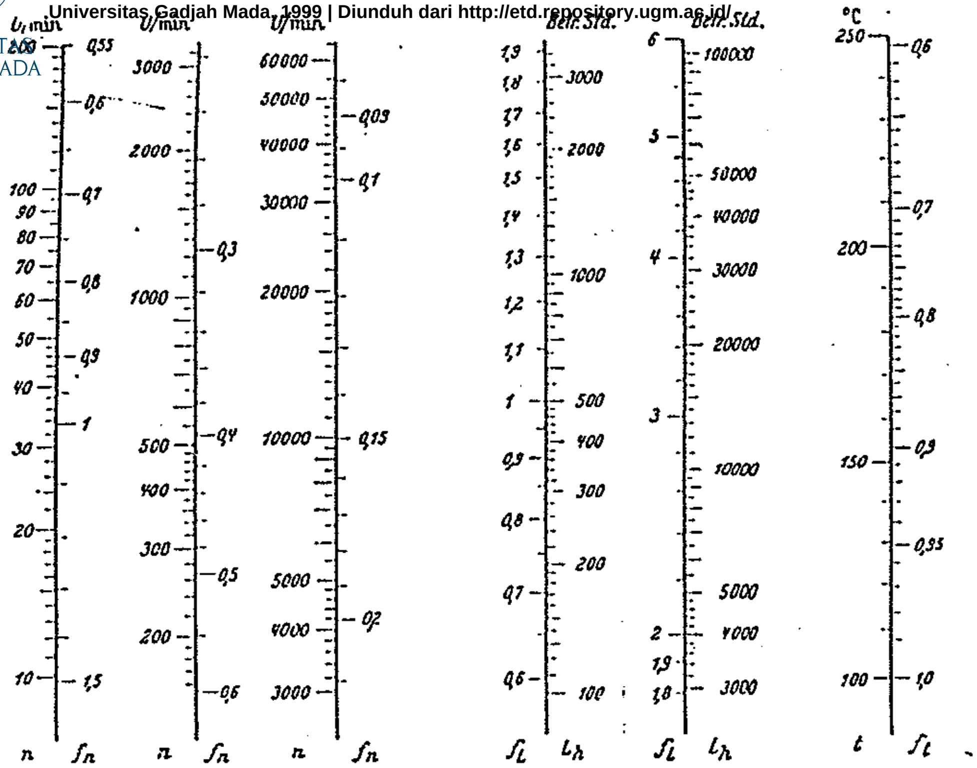


Fig. 14/7. Nomograms for coefficients for f_n, f_L, f_t as a function of speed of rotation n (rpm), of life L_h in service hours and of bearing temperature t (°C). For $t \leq 100$ °C, $f_t = 1$.
U/min = rpm; Betr. Std. = operational hours.

Table 29/4. Characteristics of friction clutches and brakes

Type	Figure reference	b/d	$K_U = \frac{U}{b\,d\,j}$ kgf/cm²	$K_G = \frac{G_w}{b\,d\,j}$ kgf/cm²	$K_T = \frac{N_R\, 10^3}{b\,d\,j\,v^{3/2}}$ $\frac{\text{HP } 10^3}{\text{cm}^2 (\text{m/s})^{3/2}}$	Other remarks
Clutches:						
Shoe, band, cone	Table 29/1	0,15···0,3	2 ···8		1,0 ···1,6	$j = 1$
disc, j = 1 to 2		0,15···0,3	2 ···5			
Plate, j = 4 to 20		0,1 ···0,25	0,8···3,5		0,45···0,65	dry running
		0,1 ···0,25	0,8···3,5		0,45···1,0	wet (oil)
		0,1 ···0,25	0,8···3,5		2,0 ···4,5	oil flow
Automobile wheel brakes	29/17	0,1 ···0,15	3 ···5,5			$b_v = 3{,}2 \cdots 4{,}6$ m/s²
Passenger car		0,1 ···0,15	3 ···5,5	4,8···8		G_w = weight of the vehicle per brake
Truck		0,1 ···0,15	3 ···5,5	4 ···6		
Crane brakes	29/32	0,3 ···0,4	0,2···0,8		0,8···1,4	for:
Holding brakes	to	0,3 ···0,4	0,75			Load $b_v < 1{,}4$ m/s²
Stopping brakes	29/34	0,3 ···0,4	0,2···0,4			$t_B = 0{,}5 \cdots 5$ sec.
Lowering brakes . . .		0,3 ···0,4	0,25			z and L_h (Table 29/5)
Dynamometer brakes . .	29/18	0,2 ···0,5				for $\vartheta_{ba} = 60°$ C
					1,1···1,8	Dry running and air cooling
					6,5···11	Dry running and water cooling
					22···28	Water lubrication and water cooling

Table 2.1 Terrain Values

Terrain	Moisture Content (%)	n	k_c		k_ϕ		c		ϕ
			lb/in.$^{n+1}$	kN/m^{n+1}	lb/in.$^{n+2}$	kN/m^{n+2}	lb/in.^{2}	kPa	
Dry Sand (Land Locomotion Lab., LLL)	0	1.1	0.1	0.95	3.9	1528.43	0.15	1.04	28°
Sandy Loam (LLL)	15	0.7	2.3	5.27	16.8	1515.04	0.25	1.72	29°
	22	0.2	7	2.56	3	43.12	0.2	1.38	38°
Sandy Loam Michigan (Strong, Buchele)	11	0.9	11	52.53	6	1127.97	0.7	4.83	20°
	23	0.4	15	11.42	27	808.96	1.4	9.65	35°
Sandy Loam (Hanamoto)	26	0.3	5.3	2.79	6.8	141.11	2.0	13.79	22°
	32	0.5	0.7	0.77	1.2	51.91	0.75	5.17	11°
Clayey soil (Thailand)	38	0.5	12	13.19	16	692.15	0.6	4.14	13°
	55	0.7	7	16.03	14	1262.53	0.3	2.07	10°
Heavy Clay (Waterways Experiment Stn., WES)	25	0.13	45	12.70	140	1555.95	10	68.95	34°
	40	0.11	7	1.84	10	103.27	3	20.69	6°
Lean Clay (WES)	22	0.2	45	16.43	120	1724.69	10	68.95	20°
	32	0.15	5	1.52	10	119.61	2	13.79	11°
Snow (Harrison)		1.6	0.07	4.37	0.08	196.72	0.15	1.03	19.7°
		1.6	0.04	2.49	0.10	245.90	0.09	0.62	23.2°

Source. References 2.3 and 2.16.

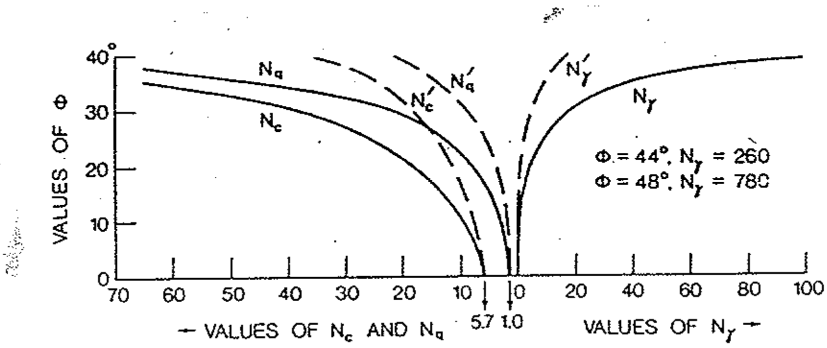


Fig. 2.19 Variation of the Terzaghi bearing capacity factors with the angle of internal shearing resistance. (From *Theoretical Soil Mechanics*, by K. Terzaghi, 1966, reproduced by permission of John Wiley and Sons, Inc.)

Simbol Komponen-komponen Hidrolik

THE SYMBOLS SHOWN CONFORM TO THE AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI) SPECIFICATIONS. BASIC SYMBOLS CAN BE COMBINED IN ANY COMBINATION. NO ATTEMPT IS MADE TO SHOW ALL COMBINATIONS.

LINES AND LINE FUNCTIONS	
LINE, WORKING	
LINE, PILOT (L>20W)	
LINE, DRAIN (L<5W)	
CONNECTOR	
LINE, FLEXIBLE	
LINE, JOINING	
LINE, PASSING	

LINES AND LINE FUNCTIONS (CONT.)	
DIRECTION OF FLOW, HYDRAULIC PNEUMATIC	
LINE TO RESERVOIR ABOVE FLUID LEVEL BELOW FLUID LEVEL	
LINE TO VENTED MANIFOLD	
PLUG OR PLUGGED CONNECTION	
RESTRICTION, FIXED	

VALVE EXAMPLES	
UNLOADING VALVE, INTERNAL DRAIN, REMOTELY OPERATED	
DECELERATION VALVE, NORMALLY OPEN	
SEQUENCE VALVE, DIRECTLY OPERATED, EXTERNALLY DRAINED	
PRESSURE REDUCING VALVE	
COUNTER BALANCE VALVE WITH INTEGRAL CHECK	
TEMPERATURE AND PRESSURE COMPENSATED FLOW CONTROL WITH INTEGRAL CHECK	
DIRECTIONAL VALVE, TWO POSITION, THREE CONNECTION	
DIRECTIONAL VALVE, THREE POSITION, FOUR CONNECTION	
VALVE, INFINITE POSITIONING (INDICATED BY HORIZONTAL BARS)	

METHODS OF OPERATION	
PRESSURE COMPENSATOR	
DETENT	
MANUAL	
MECHANICAL	
PEDAL OR TREADLE	
PUSH BUTTON	
LEVER	
PILOT PRESSURE	
SOLENOID	
SOLENOID CONTROLLED, PILOT PRESSURE OPERATED	
SPRING	
SERVO	

PUMPS	
PUMP, SINGLE FIXED DISPLACEMENT	
PUMP, SINGLE VARIABLE DISPLACEMENT	
MOTOR AND CYLINDERS	
MOTOR, ROTARY FIXED DISPLACEMENT	
MOTOR, ROTARY VARIABLE DISPLACEMENT	
MOTOR, OSCILLATING	
CYLINDER, SINGLE ACTING	
CYLINDER, DOUBLE ACTING	
CYLINDER, DIFFERENTIAL ROD	
CYLINDER, DOUBLE END ROD	
CYLINDER, CUSHIONS BOTH ENDS	
MISCELLANEOUS UNITS	
DIRECTION OF ROTATION (ARROW IN FRONT OF SHAFT)	
COMPONENT ENCLOSURE	
RESERVOIR, VENTED	
RESERVOIR, PRESSURIZED	
PRESSURE GAGE	

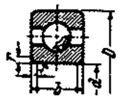
MISCELLANEOUS UNITS (CONT.)	
TEMPERATURE GAGE	
FLOW METER (FLOW RATE)	
ELECTRIC MOTOR	M
ACCUMULATOR, SPRING LOADED	
ACCUMULATOR, GAS CHARGED	
FILTER OR STRAINER	
HEATER	
COOLER	
TEMPERATURE CONTROLLER	
INTENSIFIER	
PRESSURE SWITCH	
BASIC VALVE SYMBOLS	
CHECK VALVE	
MANUAL SHUT OFF VALVE	
BASIC VALVE ENVELOPE	
VALVE, SINGLE FLOW PATH, NORMALLY CLOSED	
BASIC VALVE SYMBOLS (CONT.)	
VALVE, SINGLE FLOW PATH, NORMALLY OPEN	
VALVE, MAXIMUM PRESSURE (RELIEF)	
BASIC VALVE SYMBOL, MULTIPLE FLOW PATHS	
FLOW PATHS BLOCKED IN CENTER POSITION	
MULTIPLE FLOW PATHS (ARROW SHOWS FLOW DIRECTION)	

Table 14/5. Radial bearings. Dimension group 0 (very light series)

All dimensions are in mm

C = basic load rating

Deep-groove ball bearing, DIN 625 (Aug. 1942)

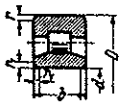


$P = x \cdot P_r + y \cdot P_a$

$x = 1$ $x = 1{,}4$[1]

$C : P_a$	5	10	20	40
y	1,4	1,6	1,8	2,0

Cylindrical roller bearing, DIN 5412 (Aug. 1942)



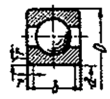
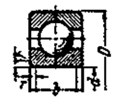
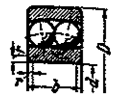
$P = x \cdot P_r$

$x = 1$[1]
$x = 1{,}4$
$y = 0$

d	D	r	Symbol	b	C kgf	Symbol	b	r_1	C kgf
3	10	0,5	EL 3 [2]	4	40	—	—	—	—
4	13		4 [2]	5	80	—	—	—	—
5	16		5 [2]	5	140	—	—	—	—
6	19		6 [2]	6	216	—	—	—	—
7	19		7	6	156	—	—	—	—
8	22		8	7	240	—	—	—	—
9	24		9	7	260	—	—	—	—
10	26		6000x	8	340	—	—	—	—
12	28		01x	8	375	—	—	—	—
15	32		02x	9	405	—	—	—	—
17	35		03x	10	430	—	—	—	—
20	42	1	04x	12	695	—	—	—	—
25	47		05x	12	750	NUE 25	12	0,5	830
30	55	1,5	06x	13	1 000	30	13	0,8	1 100
35	62		07x	14	1 200	35	14		1 340
40	68		08x	15	1 270	40	15	1	1 560
45	75		09x	16	1 630	45	16		1 860
50	80		10x	16	1 700	50	16		2 000
55	90	2	11x	18	2 200	55	18	1,5	2 280
60	95		12x	18	2 280	60	18		2 360
65	100	2	13x	18	2 400	65	18	1,5	2 450
70	110		14x	20	3 000	70	20		3 550
75	115		15x	20	3 150	75	20		3 650
80	125		16x	22	3 750	80	22		4 500
85	130		17x	22	3 900	85	22		4 900
90	140	2,5	18x	24	4 550	90	24	2	5 500
95	145		19x	24	4 800	95	24		5 600
100	150		20x	24	4 800	100	24		5 850
105	160	3	21x	26	5 700	105	26		6 800
110	170		22x	28	6 400	110	28		8 500
120	180		24x	28	6 700	120	28		9 150
130	200		26x	33	8 300	130	33		11 200
140	210		28x	33	8 650	140	33		12 000
150	225	3,5	30x	35	9 800	150	35	2,5	13 400
160	240		32x	38	11 000	160	38		16 300
170	260		34x	42	12 900	170	42	3,5	19 600
180	280		36x	46	14 600	180	46		24 500
190	290		38x	46	15 600	190	46		25 500
200	310		40x	51	17 600	200	51		28 000
220	340	4	44x	56	20 000	220	56	4	36 500
240	360		48x	56	21 200	240	56		39 000
260	400	5	52x	65	24 500	260	65	5	48 000
280	420		56x	65	25 500	280	65		51 000
300	460		60x	74	30 500	300	74		67 000
320	480		64x	74	32 000	320	74		68 000
340	520	6	68x	82	38 000	340	82	6	83 000
360	540		72x	82	40 000	360	82		86 500
380	560		76x	82	40 000	380	82		88 000
400	600		80x	90	45 000	400	90		110 000

[1]The small values of x are applicable for peripheral load, the large ones for point load for the inner r
[2]Belongs to dimension group 2 (light series)

Table 14/6. Radial bearings. Dimension group 2

All dimensions are in mm; C = basic load rating	Deep groove ball bearing	Angular-contact ball bearing	Self-aligning ball bearing
	DIN 625 (Aug. 1942)	DIN 628 (Aug. 1942)	DIN 630 (Aug. 1942)
			
	$P = x \cdot P_r + y \cdot P_a$	$P = x \cdot P_r + y \cdot P_a$	$P = P_r + y \cdot P_a$
	$x = 1$ $x = 1{,}4$ [1]	$x = 0{,}5$ [1] $x = 0{,}7$ $y = 0{,}7$	

Deep groove ball bearing, values of y:

$C : P_a$	5	10	20	40
y	1,4	1,6	1,8	2,0

Self-aligning ball bearing, values of y:

Bearing no.	y	Bearing no.	y
13300/04	2,25	1206/07	3,25
1200/03	2,5	1208/09	3,5
1204/05	2,75	1210/12	4,0
		1213/22	4,5

d	D	r	Symbol	b	C kgf	Symbol	b	C kgf	Symbol	b	C kgf
4	16	0,5	R 4 [2]	5	140	—	—	—	—	—	—
5	19		R 5 [2]	6	216	—	—	—	133 00	6	166
7	22		R 7	7	240	—	—	—	02	7	193
9	26	1	R 9	8	340	—	—	—	04	8	275
10	30		6200	9	340	QA 10	9	430	1200	9	390
12	32		01	10	530	12	10	465	01	10	415
15	35		02	11	585	15	11	540	02	11	570
17	40	1,5	03	12	720	17	12	735	03	12	640
20	47		04	14	980	20	14	1 120	04 (1 b)	14	830
25	52		05	15	1 040	25	15	1 270	05 (1 b)	15	1020
30	62		06	16	1 460	30	16	1 560	06 (1 b)	16	1400
35	72	2	07	17	1 960	35	17	1 900	07 (1 b)	17	1530
40	80		08	18	2 240	40	18	2 280	08 (1 b)	18	1930
45	85		09	19	2 500	45	19	2 360	09 (1 b)	19	2160
50	90		6210	20	2 700	50	20	2 450	1210 (1 b)	20	2320
55	100	2,5	11	21	3 250	55	21	3 150	11 (1 b)	21	2800
60	110		12	22	4 000	60	22	4 000	12 (1 b)	22	3200
65	120		13	23	4 400	65	23	4 550	13 (1 b)	23	3450
70	125		14	24	4 650	70	24	4 750	14 (1 b)	24	3800
75	130		15	25	5 000	75	25	5 000	15 (1 b)	25	4250
80	140	3	6216	26	5 500	QA 80	26	5 850	1216 (1 c)	26	4500
85	150		17	28	6 300	85	28	6 550	17 (1 c)	28	5400
90	160		18	30	7 100	90	30	7 350	18 (1 c)	30	6000
95	170	3,5	19	32	8 000	95	32	8 500	19 (1 c)	32	6800
100	180		20	34	9 000	100	34	9 500	20 (1 c)	34	7350
105	190		21	36	9 800	105	36	10 600	21 (1 c)	36	8000
110	200		22	38	10 800	110	38	11 800	22 (1 c)	38	9300
120	215		24	40	11 000	120	40	12 500	—	—	—
130	230	4	26	40	12 000	130	40	12 900	—	—	—
140	250		28	42	12 900	140	42	14 000	—	—	—
150	270		30	45	13 700	150	45	16 600	—	—	—
160	290		32	48	14 600	160	48	18 600	—	—	—
170	310	5	34	52	17 000	170	52	21 200	—	—	—
180	320		36	52	18 300	180	52	22 000	—	—	—
190	340		38	55	20 800	190	55	23 600	—	—	—
200	360		40	58	22 000	200	58	26 500	—	—	—
220	400		44	65	24 500	—	—	—	—	—	—
240	440		48	72	30 000	—	—	—	—	—	—
260	480	6	52	80	34 000	—	—	—	—	—	—
280	500		56	80	36 000	—	—	—	—	—	—

[1]The small values of x are applicable for peripheral load, the large ones for point load for the inner race.
[2]Belongs to dimension group 2 (light series).