

1. Properties of Steam

1.1. Enthalpy of Dry Saturated Steam (kJ/kg)

$$h_g = h_f + h_{fg}$$

h_g = Enthalpy of dry steam in kJ/kg

h_f = Sensible heat in kJ/kg

h_{fg} = Enthalpy of evaporation or latent heat in kJ/kg

1.2. Enthalpy of Wet Steam (kJ/kg)

$$h = h_f + xh_{fg}$$

x = Dryness fraction of the steam $0 < x < 1$

1.3. Enthalpy of Superheated Steam (kJ/kg)

$$h_{sup} = h_g + C_{sup}(T_{sup} - T_{sat})$$

h_{sup} = Enthalpy of superheated steam in kJ/kg

C_{sup} = Specific heat of superheated steam = 2.25 kJ/kg K

T_{sup} = Superheated temperature in °C

T_{sat} = Saturation temperature in °C

1.4. Degree of Superheat (DOS) (°C)

$$DOS = (T_{sup} - T_{sat})$$

1.5. Amount of Superheat (AOS) (kJ/kg)

$$AOS = C_{sup}(T_{sup} - T_{sat})$$

1.6. Enthalpy of Feed Water (kJ)

$$h_w = mC_p(T - 0)$$

m = Mass of water in kg

C_p = Specific heat of water = 4.187 kJ/kg K

T = Temperature of feed water in °C

1.7. Dryness Fraction

$$x = \frac{m_g}{m_f + m_g}$$

m_g = Mass of dry steam present in the sample quantity of wet steam

m_f = Mass of suspended water molecules in the sample quantity of wet steam

1.8. Boiler Efficiency

$$\eta = \frac{Q(h_s - h_w)}{m_{fu} \times GCV} \times 100$$

Q = Quantity of steam generated per unit time in kg/hr

h_s = Enthalpy of steam generated in kJ/kg

h_w = Enthalpy of feed water in kJ/kg

m_{fu} = Quantity of fuel consumed per unit time in kg/hr

GCV = Gross calorific value of the fuel in kJ/kg

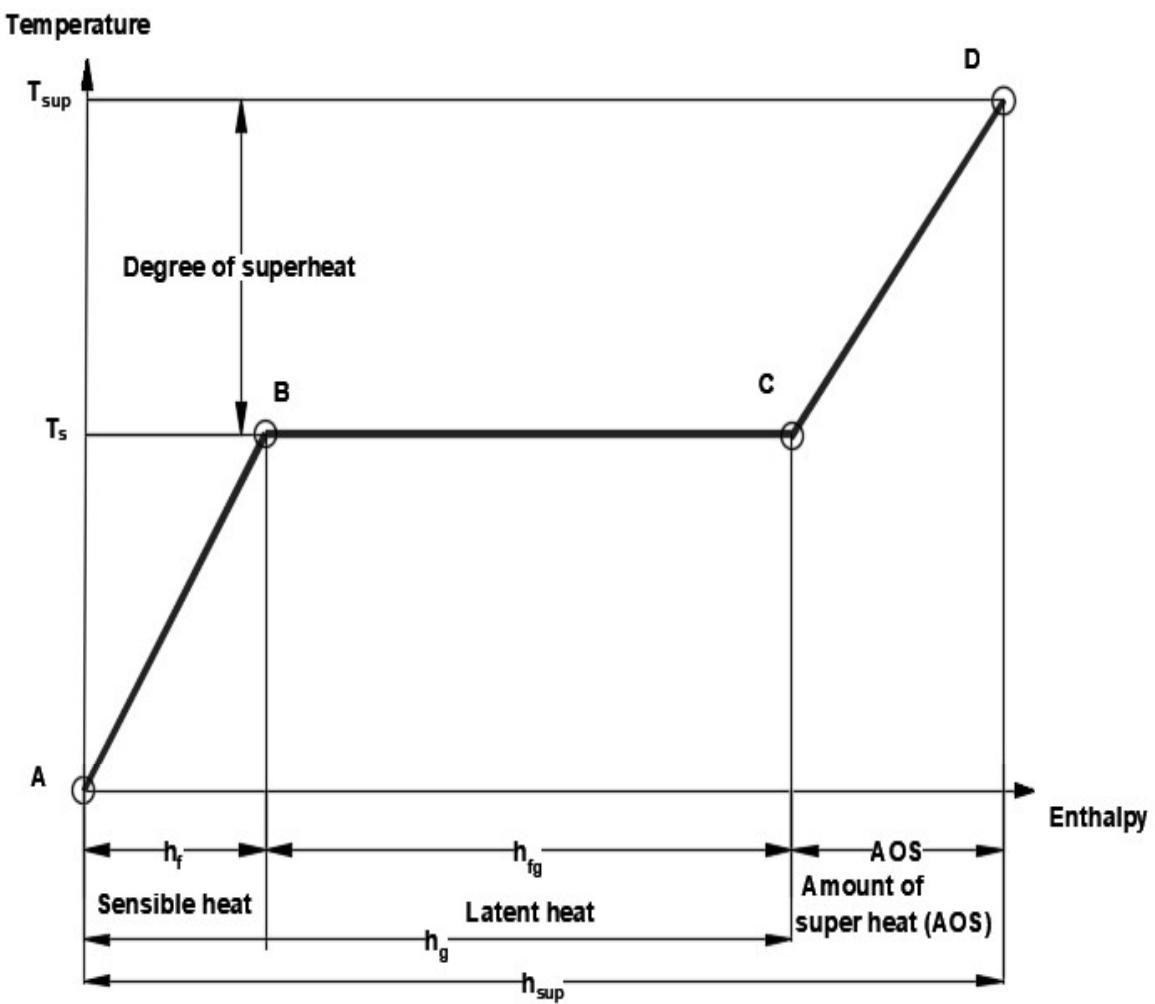


Figure 1.1 Temperature – Enthalpy diagram

Saturated Water and Steam (Pressure) Tables

Absolute pressure in bar (p)	Temperature in °C (t)	Specific volume in m³/kg		Specific enthalpy in kJ/kg			Specific entropy in kJ/kg K		Absolute pressure in bar (p)
		water (v _f)	Steam (v _g)	Water (h _f)	Evaporation (h _{fg})	Steam (h _g)	Water (s _f)	Evaporation (s _{fg})	
0.0061	0.000	0.001 000	206.31	0.0	2 501.6	2 501.6	0.000	9.158	0.0061
0.010	6.983	0.001 000	129.21	29.3	2 485.1	2 514.4	0.106	8.871	0.010
0.015	13.04	0.001 001	87.982	54.7	2 470.8	2 525.5	0.196	8.634	0.015
0.020	17.51	0.001 001	67.006	73.5	2 460.1	2 533.6	0.261	8.464	0.020
0.025	21.10	0.001 002	54.256	88.4	2 451.8	2 540.2	0.312	8.333	0.025
0.030	24.10	0.001 003	45.667	101.0	2 444.6	2 545.6	0.354	8.224	0.030
0.035	26.69	0.001 003	39.479	111.8	2 438.6	2 550.4	0.391	8.132	0.035
0.040	28.98	0.001 004	34.802	121.4	2 433.1	2 554.5	0.423	8.053	0.040
0.045	31.03	0.001 005	31.141	130.0	2 428.2	2 558.2	0.451	7.983	0.045
0.050	32.90	0.001 005	28.194	137.8	2 423.8	2 561.6	0.476	7.920	0.050
0.060	36.18	0.001 006	23.741	151.5	2 416.0	2 567.5	0.521	7.810	0.06
0.070	39.03	0.001 007	20.531	163.4	2 409.2	2 572.6	0.559	7.718	0.07
0.080	41.53	0.001 008	18.105	173.9	2 403.2	2 577.1	0.593	7.637	0.08
0.090	43.79	0.001 009	16.204	183.3	2 397.8	2 581.1	0.622	7.566	0.09
0.100	45.83	0.001 010	14.675	191.8	2 392.9	2 584.7	0.649	7.502	0.10
0.11	47.71	0.001 011	13.416	199.7	2 388.4	2 588.1	0.674	7.444	0.11
0.12	49.45	0.001 012	12.362	206.9	2 384.3	2 591.2	0.696	7.391	0.12
0.13	51.06	0.001 013	11.466	213.7	2 380.3	2 594.0	0.717	7.342	0.13
0.14	52.57	0.001 013	10.694	220.0	2 376.7	2 596.7	0.737	7.296	0.14
0.15	54.00	0.001 014	10.023	226.0	2 373.2	2 599.2	0.755	7.254	0.15

Saturated Water and Steam (Pressure) Tables

(p)	(t)	(v _f)	(v _g)	(h _f)	(h _{fg})	(h _g)	(s _f)	(s _{fg})	(s _g)	(p)
0.16	55.34	0.001 015	9.433 1	231.6	2 370.0	2 601.6	0.772	7.215	7.987	0.16
0.17	56.62	0.001 015	8.911 1	236.9	2 366.9	2 603.8	0.788	7.178	7.966	0.17
0.18	57.83	0.001 016	8.445 2	242.0	2 363.9	2 605.9	0.804	7.142	7.946	0.18
0.19	58.98	0.001 017	8.027 2	246.8	2 361.1	2 607.9	0.818	7.109	7.927	0.19
0.20	60.09	0.001 017	7.649 8	251.5	2 358.4	2 609.9	0.832	7.077	7.909	0.20
0.21	61.15	0.001 018	7.307 3	255.9	2 355.8	2 611.7	0.845	7.047	7.892	0.21
0.22	62.16	0.001 018	6.995 1	260.1	2 353.4	2 613.5	0.858	7.018	7.876	0.22
0.23	63.14	0.001 019	6.709 3	264.2	2 351.0	2 615.2	0.870	6.991	7.861	0.23
0.24	64.08	0.001 019	6.446 7	268.2	2 348.6	2 616.8	0.882	6.964	7.846	0.24
0.25	64.99	0.001 020	6.204 5	272.0	2 346.3	2 618.3	0.893	6.939	7.832	0.25
0.26	65.87	0.001 020	5.980 3	275.7	2 344.2	2 619.9	0.904	6.915	7.819	0.26
0.27	66.72	0.001 021	5.772 4	279.2	2 342.1	2 621.3	0.915	6.891	7.806	0.27
0.28	67.55	0.001 021	5.577 8	282.7	2 340.0	2 622.7	0.925	6.868	7.793	0.28
0.29	68.35	0.001 022	5.398 2	286.0	2 338.1	2 624.1	0.935	6.847	7.781	0.29
0.30	69.12	0.001 022	5.229 3	289.3	2 336.1	2 625.4	0.944	6.825	7.769	0.30
0.32	70.62	0.001 023	4.922 0	295.6	2 332.4	2 628.0	0.962	6.785	7.747	0.32
0.34	72.03	0.001 024	4.650 4	301.5	2 328.9	2 630.4	0.980	6.747	7.727	0.34
0.36	73.37	0.001 025	4.407 6	307.1	2 325.5	2 632.6	0.996	6.711	7.707	0.36
0.38	74.66	0.001 026	4.190 0	312.5	2 322.3	2 634.8	1.011	6.677	7.688	0.38
0.40	75.89	0.001 027	3.993 4	317.7	2 319.2	2 636.9	1.026	6.645	7.671	0.40
0.42	77.06	0.001 027	3.814 8	322.6	2 316.3	2 638.9	1.040	6.614	7.654	0.42
0.44	78.19	0.001 028	3.652 2	327.3	2 313.4	2 640.7	1.054	6.584	7.638	0.44
0.46	79.28	0.001 029	3.503 2	331.9	2 310.7	2 642.6	1.067	6.556	7.623	0.46
0.48	80.33	0.001 029	3.366 3	336.3	2 308.0	2 644.3	1.079	6.530	7.609	0.48
0.50	81.35	0.001 030	3.240 1	340.6	2 305.4	2 646.0	1.091	6.504	7.595	0.50
0.52	82.33	0.001 031	3.123 3	344.7	2 302.9	2 647.6	1.103	6.478	7.581	0.52
0.54	83.28	0.001 031	3.014 8	348.7	2 300.5	2 649.2	1.114	6.455	7.569	0.54
0.56	84.19	0.001 032	2.913 9	352.5	2 298.2	2 650.7	1.125	6.431	7.556	0.56
0.58	85.09	0.001 033	2.819 7	356.3	2 295.8	2 652.1	1.135	6.409	7.544	0.58
0.60	85.95	0.001 033	2.731 7	359.9	2 293.7	2 653.6	1.145	6.388	7.533	0.60

Saturated Water and Steam (Pressure) Tables

(p)	(t)	(v _f)	(v _g)	(h _f)	(h _{fg})	(h _g)	(s _f)	(s _{fg})	(s _g)	(P)
0.62	86.80	0.001 034	2.649 1	363.5	2 291.4	2 654.9	1.155	6.367	7.522	0.62
0.64	87.62	0.001 034	2.571 5	366.9	2 289.4	2 656.3	1.165	6.346	7.511	0.64
0.66	88.42	0.001 035	2.498 5	370.3	2 287.3	2 657.6	1.174	6.326	7.500	0.66
0.68	89.20	0.001 036	2.429 7	373.6	2 285.2	2 658.8	1.183	6.307	7.490	0.68
0.70	89.96	0.001 036	2.364 7	376.8	2 283.3	2 660.1	1.192	6.288	7.480	0.70
0.72	90.70	0.001 037	2.303 1	379.9	2 281.4	2 661.3	1.201	6.270	7.471	0.72
0.74	91.43	0.001 037	2.244 8	382.9	2 279.5	2 662.4	1.209	6.253	7.462	0.74
0.76	92.14	0.001 038	2.189 5	385.9	2 277.7	2 663.6	1.217	6.235	7.452	0.76
0.78	92.83	0.001 038	2.136 9	388.9	2 275.8	2 664.7	1.225	6.219	7.444	0.78
0.80	93.51	0.001 039	2.086 9	391.7	2 274.1	2 665.8	1.233	6.202	7.435	0.80
0.85	95.15	0.001 040	1.972 1	398.6	2 269.8	2 668.4	1.252	6.163	7.415	0.85
0.90	96.71	0.001 041	1.869 1	405.2	2 265.7	2 670.9	1.270	6.125	7.395	0.90
0.95	98.20	0.001 042	1.777 1	411.5	2 261.7	2 673.2	1.287	6.091	7.378	0.95
1.00	99.63	0.001 043	1.693 8	417.5	2 257.9	2 675.4	1.303	6.057	7.360	1.00
1.013 25	100.00	0.001 044	1.673 0	419.1	2 256.9	2 676.0	1.307	6.048	7.355	1.013 25
1.05	101.0	0.001 045	1.618 1	423.3	2 254.3	2 677.6	1.318	6.025	7.343	1.05
1.10	102.3	0.001 046	1.549 2	428.8	2 250.8	2 679.6	1.333	5.995	7.328	1.10
1.15	103.6	0.001 047	1.486 1	434.2	2 247.4	2 681.6	1.347	5.966	7.313	1.15
1.20	104.8	0.001 048	1.428 1	439.3	2 244.1	2 683.4	1.361	5.937	7.298	1.20
1.25	106.0	0.001 049	1.374 6	444.4	2 240.8	2 685.2	1.374	5.911	7.285	1.25
1.30	107.1	0.001 050	1.325 0	449.2	2 237.8	2 687.0	1.387	5.885	7.272	1.30
1.35	108.2	0.001 050	1.279 1	453.4	2 234.8	2 688.7	1.399	5.860	7.259	1.35
1.40	109.3	0.001 051	1.236 3	458.4	2 231.9	2 690.3	1.411	5.836	7.247	1.40
1.45	110.4	0.001 052	1.196 3	462.8	2 229.0	2 691.8	1.423	5.812	7.235	1.45
1.50	111.4	0.001 053	1.159 0	467.1	2 226.3	2 693.4	1.433	5.790	7.223	1.50
1.60	113.3	0.001 055	1.091 1	475.4	2 220.8	2 696.2	1.455	5.747	7.202	1.60
1.70	115.2	0.001 056	1.030 9	483.2	2 215.8	2 699.0	1.475	5.706	7.181	1.70
1.80	116.9	0.001 058	0.977 18	490.7	2 210.8	2 701.5	1.494	5.668	7.162	1.80
1.90	118.6	0.001 059	0.928 95	497.9	2 206.1	2 704.0	1.513	5.631	7.144	1.90
2.00	120.2	0.001 061	0.885 40	504.7	2 201.6	2 706.3	1.530	5.597	7.127	2.00

Saturated Water and Steam (Pressure) Tables

(p)	(t)	(v _p)	(v _g)	(h _p)	(h _{fg})	(h _g)	(s _p)	(s _{fg})	(s _g)	(t)
2.1	121.8	0.001 062	0.845 86	511.3	2 197.2	2 708.5	1.547	5.564	7.111	2.1
2.2	123.3	0.001 064	0.809 80	517.6	2 193.0	2 710.6	1.563	5.532	7.095	2.2
2.3	124.7	0.001 065	0.776 77	523.7	2 188.9	2 712.6	1.578	5.502	7.080	2.3
2.4	126.1	0.001 066	0.746 41	529.6	2 184.9	2 714.5	1.593	5.473	7.066	2.4
2.5	127.4	0.001 068	0.718 40	535.3	2 181.1	2 716.4	1.607	5.445	7.052	2.5
2.6	128.7	0.001 069	0.692 47	540.9	2 177.3	2 718.2	1.621	5.418	7.039	2.6
2.7	130.0	0.001 070	0.668 40	546.2	2 173.7	2 719.9	1.634	5.392	7.026	2.7
2.8	131.2	0.001 071	0.646 00	551.4	2 170.1	2 721.5	1.647	5.367	7.014	2.8
2.9	132.4	0.001 072	0.625 09	556.5	2 166.6	2 723.1	1.660	5.342	7.002	2.9
3.0	133.5	0.001 074	0.605 53	561.5	2 163.2	2 724.7	1.672	5.319	6.991	3.0
3.1	134.7	0.001 075	0.587 18	566.2	2 159.9	2 726.1	1.683	5.297	6.980	3.1
3.2	135.8	0.001 076	0.569 95	570.9	2 156.7	2 727.6	1.695	5.274	6.969	3.2
3.3	136.8	0.001 077	0.553 73	575.5	2 153.5	2 729.0	1.706	5.253	6.959	3.3
3.4	137.9	0.001 078	0.538 43	579.9	2 150.4	2 730.3	1.717	5.232	6.949	3.4
3.5	138.9	0.001 079	0.523 97	584.3	2 147.3	2 731.6	1.727	5.212	6.939	3.5
3.6	139.9	0.001 080	0.510 29	588.5	2 144.4	2 732.9	1.738	5.192	6.930	3.6
3.7	140.8	0.001 081	0.497 33	592.7	2 141.4	2 734.1	1.748	5.173	6.921	3.7
3.8	141.8	0.001 082	0.485 02	596.7	2 138.6	2 735.3	1.758	5.154	6.912	3.8
3.9	142.7	0.001 083	0.473 33	600.8	2 135.7	2 736.5	1.767	5.136	6.903	3.9
4.0	143.6	0.001 084	0.462 20	604.7	2 132.9	2 737.6	1.776	5.118	6.894	4.0
4.1	144.5	0.001 085	0.451 59	608.5	2 130.2	2 738.7	1.786	5.100	6.886	4.1
4.2	145.4	0.001 086	0.441 47	612.3	2 127.5	2 739.8	1.795	5.083	6.878	4.2
4.3	146.3	0.001 087	0.431 81	616.0	2 124.9	2 740.9	1.803	5.067	6.870	4.3
4.4	147.1	0.001 088	0.422 57	619.6	2 122.3	2 741.9	1.812	5.050	6.862	4.4
4.5	147.9	0.001 089	0.413 73	623.2	2 119.7	2 742.9	1.820	5.035	6.855	4.5
4.6	148.7	0.001 090	0.405 26	626.7	2 117.2	2 743.9	1.829	5.018	6.847	4.6
4.7	149.5	0.001 090	0.397 14	630.1	2 114.7	2 744.8	1.837	5.003	6.840	4.7
4.8	150.3	0.001 091	0.389 34	633.5	2 112.2	2 745.7	1.845	4.988	6.833	4.8
4.9	151.1	0.001 092	0.381 86	636.8	2 109.8	2 746.6	1.853	4.973	6.826	4.9
5.0	151.8	0.001 093	0.374 66	640.1	2 107.4	2 747.5	1.860	4.959	6.819	5.0

Saturated Water and Steam (Pressure) Tables

(p)	(t)	(v_f)	(v_g)	(h_f)	(h_{fg})	(h_g)	(s_f)	(s_{fg})	(s_g)	(p)
5.2	153.3	0.001 095	0.361 06	646.5	2 102.7	2 749.2	1.875	4.931	6.806	5.2
5.4	154.8	0.001 096	0.348 44	652.8	2 098.1	2 750.9	1.890	4.903	6.793	5.4
5.6	156.2	0.001 098	0.336 69	658.8	2 093.7	2 752.5	1.904	4.877	6.781	5.6
5.8	157.5	0.001 099	0.325 72	664.7	2 089.3	2 754.0	1.918	4.851	6.769	5.8
6.0	158.8	0.001 101	0.315 46	670.4	2 085.1	2 755.5	1.931	4.827	6.758	6.0
6.2	160.1	0.001 102	0.305 84	676.1	2 080.8	2 756.9	1.944	4.803	6.747	6.2
6.4	161.4	0.001 104	0.296 80	681.5	2 076.7	2 758.2	1.956	4.780	6.736	6.4
6.6	162.6	0.001 105	0.288 29	686.8	2 072.7	2 759.5	1.968	4.757	6.725	6.6
6.8	163.8	0.001 107	0.280 26	692.0	2 068.8	2 760.8	1.980	4.735	6.715	6.8
7.0	165.0	0.001 108	0.272 68	697.1	2 064.9	2 762.0	1.992	4.713	6.705	7.0
7.2	166.1	0.001 110	0.265 50	702.0	2 061.2	2 763.2	2 003	4.693	6.696	7.2
7.4	167.2	0.001 111	0.258 70	706.9	2 057.4	2 764.3	2 014	4.672	6.686	7.4
7.6	168.3	0.001 112	0.252 24	711.7	2 053.7	2 765.4	2 025	4.652	6.677	7.6
7.8	169.4	0.001 114	0.246 10	716.3	2 050.1	2 766.4	2 035	4.633	6.668	7.8
8.0	170.4	0.001 115	0.240 26	720.9	2 046.5	2 767.4	2 046	4.614	6.660	8.0
8.2	171.4	0.001 116	0.234 69	725.4	2 043.0	2 768.4	2 056	4.595	6.651	8.2
8.4	172.4	0.001 118	0.229 38	729.9	2 039.6	2 769.4	2 066	4.577	6.643	8.4
8.6	173.4	0.001 119	0.224 31	734.2	2 036.2	2 770.4	2 075	4.560	6.635	8.6
8.8	174.4	0.001 120	0.219 46	738.5	2 032.8	2 771.3	2 085	4.542	6.627	8.8
9.0	175.4	0.001 121	0.214 82	742.6	2 029.5	2 772.1	2 094	4.525	6.619	9.0
9.2	176.3	0.001 123	0.210 37	746.8	2 026.2	2 773.0	2 103	4.509	6.612	9.2
9.4	177.2	0.001 124	0.206 10	750.8	2 023.0	2 773.8	2 112	4.492	6.604	9.4
9.6	178.1	0.001 125	0.202 01	754.8	2 019.8	2 774.6	2 121	4.476	6.597	9.6
9.8	179.0	0.001 126	0.198 08	758.7	2 016.7	2 775.4	2 130	4.460	6.590	9.8
10.0	179.9	0.001 127	0.194 30	762.6	2 013.6	2 776.2	2 138	4.445	6.583	10.0
10.5	182.0	0.001 130	0.185 48	772.0	2 006.0	2 778.0	2 159	4.407	6.566	10.5
11.0	184.1	0.001 133	0.177 39	781.1	1 998.6	2 779.7	2 179	4.371	6.550	11.0
11.5	186.0	0.001 136	0.170 02	789.9	1 991.4	2 781.3	2 198	4.336	6.534	11.5
12.0	188.0	0.001 139	0.163 21	798.4	1 984.3	2 782.7	2 216	4.303	6.519	12.0
12.5	189.8	0.001 141	0.156 96	806.7	1 977.5	2 784.2	2 234	4.271	6.505	12.5

Saturated Water and Steam (Pressure) Tables

(P)	(t)	(v _f)	(v _g)	(h _f)	(h _{fg})	(h _g)	(s _f)	(s _{fg})	(s _g)	(P)
13.0	191.6	0.001 144	0.151 14	814.7	1 970.7	2 785.4	2.251	4.240	6.491	13.0
13.5	193.3	0.001 146	0.145 76	822.5	1 964.2	2 786.7	2.267	4.211	6.478	13.5
14.0	195.0	0.001 149	0.140 73	830.1	1 957.7	2 787.8	2.284	4.181	6.465	14.0
14.5	196.7	0.001 151	0.136 06	837.5	1 951.4	2 788.9	2.299	4.154	6.453	14.5
15.0	198.3	0.001 154	0.131 67	844.6	1 945.3	2 789.9	2.314	4.127	6.441	15.0
15.5	199.8	0.001 156	0.127 56	851.6	1 939.2	2 790.8	2.329	4.100	6.429	15.5
16.0	201.4	0.001 159	0.123 70	858.5	1 933.2	2 791.7	2.344	4.074	6.418	16.0
16.5	202.9	0.001 161	0.120 06	865.3	1 927.3	2 792.6	2.358	4.049	6.407	16.5
17.0	204.3	0.001 163	0.116 64	871.8	1 921.6	2 793.4	2.371	4.025	6.396	17.0
17.5	205.7	0.001 166	0.113 40	878.2	1 915.9	2 794.1	2.384	4.001	6.385	17.5
18.0	207.1	0.001 168	0.110 33	884.5	1 910.3	2 794.8	2.398	3.977	6.375	18.0
18.5	208.5	0.001 170	0.107 42	890.7	1 904.8	2 795.5	2.410	3.955	6.365	18.5
19.0	209.8	0.001 172	0.104 67	896.8	1 899.3	2 796.1	2.423	3.933	6.356	19.0
19.5	211.1	0.001 174	0.102 04	902.7	1 894.0	2 796.7	2.435	3.911	6.346	19.5
20.0	212.4	0.001 177	0.099 55	908.5	1 888.7	2 797.2	2.447	3.890	6.337	20.0
21.0	214.8	0.001 181	0.094 902	919.9	1 878.3	2 798.2	2.470	3.849	6.319	21.0
22.0	217.2	0.001 185	0.090 663	930.9	1 868.1	2 799.1	2.492	3.809	6.301	22.0
23.0	219.6	0.001 189	0.086 780	941.6	1 858.2	2 799.8	2.514	3.771	6.285	23.0
24.0	221.8	0.001 193	0.083 209	951.9	1 848.5	2 800.4	2.534	3.735	6.269	24.0
25.0	223.9	0.001 197	0.079 915	961.9	1 839.1	2 801.0	2.554	3.699	6.253	25.0
26.0	226.0	0.001 201	0.076 865	971.7	1 829.7	2 801.4	2.574	3.665	6.239	26.0
27.0	228.1	0.001 205	0.074 033	981.2	1 820.5	2 801.7	2.592	3.632	6.224	27.0
28.0	230.0	0.001 209	0.071 396	990.5	1 811.5	2 802.0	2.611	3.600	6.211	28.0
29.0	232.0	0.001 213	0.068 935	999.5	1 802.7	2 802.2	2.628	3.569	6.197	29.0
30.0	233.8	0.001 216	0.066 632	1 008.3	1 794.0	2 802.3	2.646	3.538	6.184	30.0
31.0	235.7	0.001 220	0.064 473	1 017.1	1 785.4	2 802.3	2.662	3.509	6.171	31.0
32.0	237.4	0.001 224	0.062 443	1 025.4	1 776.9	2 802.3	2.679	3.480	6.159	32.0
33.0	239.2	0.001 227	0.060 533	1 033.7	1 768.6	2 802.3	2.694	3.452	6.146	33.0
34.0	240.9	0.001 231	0.058 731	1 041.8	1 760.3	2 802.1	2.710	3.424	6.134	34.0
35.0	242.5	0.001 235	0.057 028	1 049.7	1 752.3	2 802.0	2.725	3.398	6.123	35.0

Saturated Water and Steam (Pressure) Tables

(p)	(t)	(v _p)	(v _f)	(h _f)	(h _{fg})	(h _g)	(s _f)	(s _{fg})	(s _g)	(p)
36.0	244.2	0.001 238	0.055 417	1 057.5	1 744.2	2 801.7	2.740	3.371	6.111	36.0
37.0	245.8	0.001 242	0.053 889	1 065.2	1 736.2	2 801.4	2.755	3.345	6.100	37.0
38.0	247.3	0.001 245	0.052 439	1 072.7	1 728.4	2 801.1	2.769	3.321	6.090	38.0
39.0	248.8	0.001 249	0.051 061	1 080.1	1 720.7	2 800.8	2.783	3.296	6.079	39.0
40.0	250.3	0.001 252	0.049 749	1 087.4	1 712.9	2 800.3	2.797	3.272	6.069	40.0
42.0	253.2	0.001 259	0.047 306	1 101.6	1 697.8	2 799.4	2.823	3.225	6.048	42.0
44.0	256.1	0.001 266	0.045 078	1 115.4	1 682.9	2 798.3	2.849	3.180	6.029	44.0
46.0	258.8	0.001 273	0.043 036	1 128.8	1 668.2	2 797.0	2.874	3.136	6.010	46.0
48.0	261.4	0.001 279	0.041 158	1 141.8	1 653.9	2 795.7	2.897	3.094	5.991	48.0
50.0	263.9	0.001 286	0.039 425	1 154.5	1 639.7	2 794.2	2.921	3.053	5.974	50.0
52.0	266.4	0.001 293	0.037 820	1 166.9	1 625.7	2 792.6	2.943	3.013	5.956	52.0
54.0	268.8	0.001 299	0.036 330	1 179.0	1 611.8	2 790.8	2.965	2.974	5.939	54.0
56.0	271.1	0.001 306	0.034 942	1 190.8	1 598.2	2 789.0	2.986	2.937	5.923	56.0
58.0	273.4	0.001 312	0.033 646	1 202.4	1 584.6	2 787.0	3.007	2.899	5.906	58.0
60.0	275.6	0.001 319	0.032 433	1 213.7	1 571.3	2 785.0	3.027	2.863	5.890	60.0
62.0	277.7	0.001 325	0.031 295	1 224.9	1 558.0	2 782.9	3.047	2.828	5.875	62.0
64.0	279.8	0.001 332	0.030 225	1 235.8	1 544.8	2 780.6	3.066	2.794	5.860	64.0
66.0	281.9	0.001 338	0.029 218	1 246.5	1 531.8	2 778.3	3.085	2.760	5.845	66.0
68.0	283.9	0.001 345	0.028 267	1 257.1	1 518.8	2 775.9	3.104	2.727	5.831	68.0
70.0	285.8	0.001 351	0.027 368	1 267.4	1 506.0	2 773.4	3.122	2.694	5.816	70.0
72.0	287.7	0.001 358	0.026 517	1 277.7	1 493.2	2 770.9	3.140	2.662	5.802	72.0
74.0	289.6	0.001 365	0.025 711	1 287.8	1 480.4	2 768.2	3.157	2.631	5.788	74.0
76.0	291.4	0.001 371	0.024 944	1 297.7	1 467.8	2 765.5	3.174	2.600	5.774	76.0
78.0	293.2	0.001 378	0.024 215	1 307.5	1 455.4	2 762.7	3.191	2.569	5.760	78.0
80.0	295.0	0.001 384	0.023 521	1 317.2	1 442.7	2 759.9	3.208	2.539	5.747	80.0
82.0	296.7	0.001 391	0.022 860	1 326.7	1 430.3	2 757.0	3.224	2.510	5.734	82.0
84.0	298.4	0.001 398	0.022 228	1 336.2	1 417.8	2 754.0	3.240	2.481	5.721	84.0
86.0	300.1	0.001 404	0.021 624	1 345.4	1 405.5	2 750.9	3.256	2.452	5.708	86.0
88.0	301.7	0.001 411	0.021 046	1 354.7	1 393.1	2 747.8	3.271	2.424	5.695	88.0
90.0	303.3	0.001 418	0.020 493	1 363.8	1 380.8	2 744.6	3.287	2.395	5.682	90.0

Saturated Water and Steam (Pressure) Tables

(P)	(t)	(v _f)	(v _f)	(v _g)	(h _f)	(h _{fg})	(h _g)	(s _f)	(s _{fg})	(s _g)	(P)
92	304.9	0.001 425	0.019 962	1 372.8	1 368.5	2 741.3	3.302	2.367	5.669	92	
94	306.5	0.001 432	0.019 453	1 381.7	1 356.3	2 738.0	3.317	2.340	5.657	94	
96	308.0	0.001 439	0.018 964	1 390.6	1 344.1	2 734.7	3.322	2.313	5.644	96	
98	309.5	0.001 446	0.018 493	1 399.4	1 331.9	2 731.2	3.346	2.286	5.632	98	
100	311.0	0.001 453	0.018 041	1 408.0	1 319.7	2 727.7	3.361	2.259	5.620	100	
105	314.6	0.001 470	0.016 981	1 429.5	1 289.2	2 718.7	3.396	2.194	5.590	105	
110	318.0	0.001 489	0.016 007	1 450.5	1 258.8	2 709.3	3.430	2.129	5.560	110	
115	321.4	0.001 508	0.015 114	1 471.3	1 228.2	2 699.5	3.464	2.066	5.530	115	
120	324.6	0.001 527	0.014 285	1 491.7	1 197.5	2 698.2	3.497	2.003	5.500	120	
125	327.8	0.001 547	0.013 518	1 511.9	1 166.5	2 678.4	3.530	1.941	5.471	125	
130	330.8	0.001 567	0.012 800	1 531.9	1 135.1	2 667.0	3.561	1.880	5.441	130	
135	333.8	0.001 588	0.012 130	1 551.8	1 103.3	2 655.1	3.593	1.818	5.411	135	
140	336.6	0.001 611	0.011 498	1 571.5	1 070.9	2 642.4	3.624	1.756	5.380	140	
145	339.4	0.001 634	0.010 905	1 591.3	1 037.9	2 629.2	3.655	1.694	5.349	145	
150	342.1	0.001 658	0.010 343	1 610.9	1 004.2	2 615.1	3.686	1.632	5.318	150	
155	344.8	0.001 683	0.009 813	1 630.7	969.7	2 600.4	3.716	1.570	5.286	155	
160	347.3	0.001 710	0.009 310	1 650.4	934.5	2 584.9	3.747	1.506	5.253	160	
165	349.7	0.001 739	0.008 833	1 670.4	898.5	2 568.9	3.778	1.442	5.220	165	
170	352.3	0.001 770	0.008 372	1 691.6	860.0	2 551.6	3.811	1.375	5.186	170	
175	354.6	0.001 803	0.007 927	1 713.3	820.0	2 533.3	3.844	1.306	5.150	175	
180	357.0	0.001 840	0.007 497	1 734.8	779.1	2 513.9	3.877	1.236	5.113	180	
185	359.2	0.001 881	0.007 082	1 756.5	736.5	2 493.0	3.910	1.164	5.074	185	
190	361.4	0.001 926	0.006 676	1 778.7	691.8	2 470.5	3.943	1.090	5.033	190	
195	363.6	0.001 978	0.006 276	1 801.9	643.9	2 445.8	3.978	1.011	4.989	195	
200	365.7	0.002 037	0.005 875	1 826.6	591.6	2 418.2	4.015	0.926	4.941	200	
205	367.8	0.002 110	0.005 462	1 854.2	532.0	2 386.2	4.056	0.830	4.886	205	
210	369.8	0.002 202	0.005 023	1 886.3	461.2	2 347.5	4.105	0.717	4.822	210	
215	371.8	0.002 342	0.004 509	1 929.4	365.2	2 294.6	4.170	0.566	4.736	215	
220	373.7	0.002 668	0.003 735	2 010.3	186.3	2 196.6	4.293	0.288	4.581	220	
221.2	374.15	0.003 170	0.003 170	2 107.4	000.0	2 107.4	4.443	0.000	4.443	221.2	

2. Power Transmission

2.1. Belt Drive

2.1.1. Velocity Ratio

$$\frac{N_2}{N_1} = \frac{d_1}{d_2}$$

N_1 = Speed of the driving pulley in rpm
 N_2 = Speed of the driven pulley in rpm
 d_1 = Diameter of the driving pulley in mm
 d_2 = Diameter of the driven pulley in mm

2.1.2. Velocity Ratio (Considering slip)

$$\frac{N_2}{N_1} = \frac{d_1}{d_2} \left[\frac{100 - S}{100} \right]$$

S = percentage slip

2.1.3. Initial Tension in the Belt

$$T_0 = \frac{T_1 + T_2}{2}$$

T_0 = Initial tension in the belt in N
 T_1 = Tension on the tight side of belt in N
 T_2 = Tension on the slack side of belt in N

2.1.4. Length and Angle of Lap of a Belt Drive

2.1.4.1. Open Belt Drive

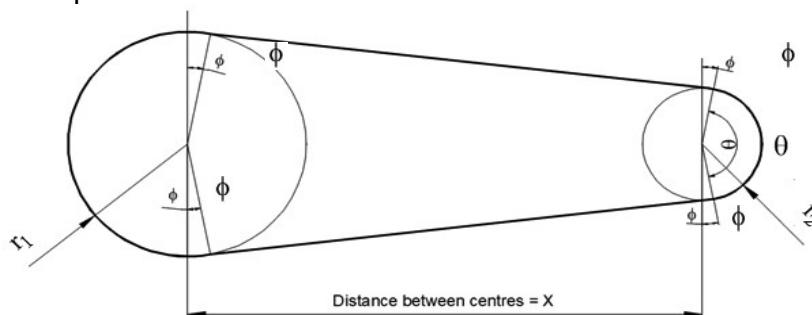


Figure 2.1 Schematic of an open belt drive

Length

$$L = \pi(r_1 + r_2) + \frac{(r_1 - r_2)^2}{X} + 2X$$

L = Total length of the belt in mm

r_1 = Radius of driving pulley in mm

r_2 = Radius of driven pulley in mm

X = Centre distance between

pulleys in mm

θ = Angle of lap in radians

ϕ is measured in radians

Angle of Lap

$$\theta = \pi - 2\phi$$

$$\phi = \sin^{-1} \left[\frac{r_1 - r_2}{X} \right]$$

2.1.4.2. Crossed Belt Drive

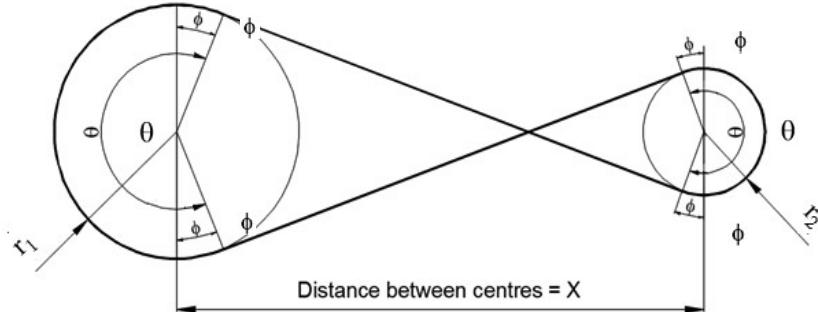


Figure 2.2 Schematic of a crossed belt drive

Length

$$L = \pi(r_1 + r_2) + \frac{(r_1 + r_2)^2}{X} + 2X$$

L = Total length of the belt in mm

r₁ = Radius of driving pulley in mm

r₂ = Radius of driven pulley in mm

X = Centre distance between

pulleys in mm

θ = Angle of lap in radians

φ is measured in radians

Angle of Lap

$$\theta = \pi + 2\phi$$

$$\phi = \sin^{-1} \left[\frac{r_1 + r_2}{X} \right]$$

2.1.5. Ratio of Tensions in a Belt Drive

$$\frac{T_1}{T_2} = e^{\mu\theta} \quad \mu \text{ is coefficient of friction}$$

2.1.6. Linear Velocity of the Belt (m/min)

$$v = \frac{\pi d_1 N_1}{1000} = \frac{\pi d_2 N_2}{1000}$$

2.1.7. Power Transmitted by a Belt Drive (kW)

$$P = \frac{(T_1 - T_2) v}{60000} \quad \begin{aligned} T_1 &= \text{Tension on the tight side of belt in N} \\ T_2 &= \text{Tension on the slack side of belt in N} \\ v &= \text{Linear velocity of the belt in m/min} \end{aligned}$$

2.1.8. Belt width, when permissible tension is known

$$\text{Belt Width} = \frac{\text{Maximum tension in the belt}}{\text{Permissible belt tension per unit length of belt width}}$$

2.2. Gear Drive

$$2.2.1 \text{ Circular Pitch} \quad P_c = \frac{\pi D}{T}$$

D = Pitch circle diameter in mm
T = Number of teeth

$$2.2.2 \text{ Diametral Pitch} \quad P_d = \frac{T}{D}$$

$$2.2.3 \text{ Module} \quad m = \frac{D}{T} \quad \text{or} \quad m = \frac{1}{P_d}$$

2.2.4 Simple Gear Train

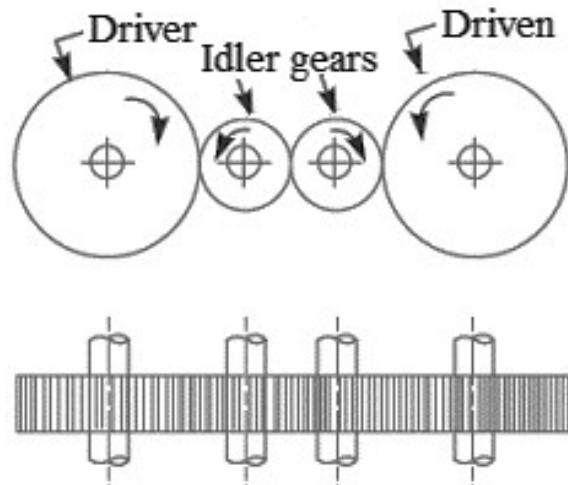


Figure 2.3 Schematic of a simple gear train

2.2.4.1 Velocity Ratio

$$VR = \frac{\text{Speed of the driven gear}}{\text{Speed of the driver gear}} = \frac{\text{Number of teeth on the driver gear}}{\text{Number of teeth on the driven gear}}$$

2.2.5 Compound Gear Train

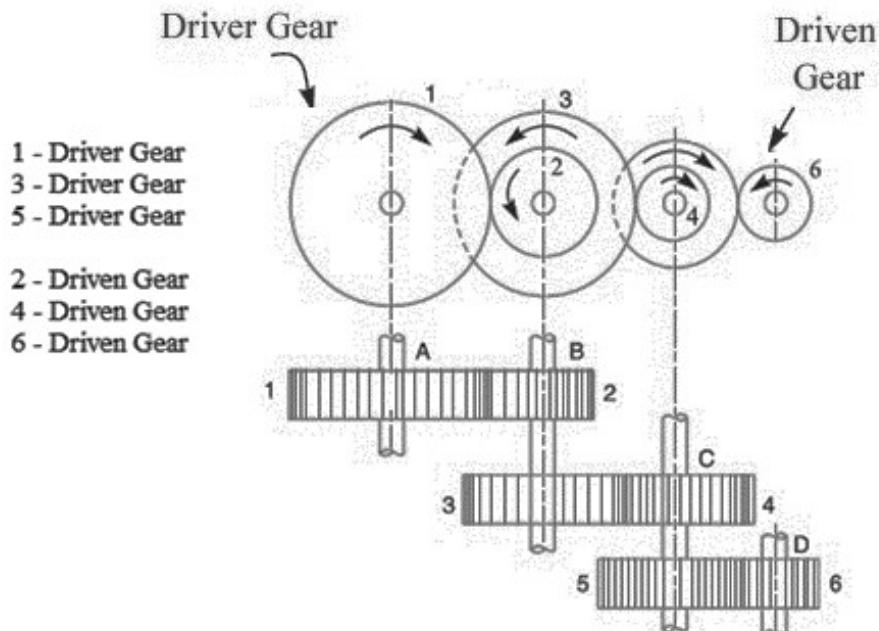


Figure 2.4 Schematic of a compound gear drive

2.2.5.1 Velocity Ratio

$$VR = \frac{\text{Speed of the driven gear}}{\text{Speed of the driver gear}} = \frac{\text{Product of number of teeth on the driver gears}}{\text{Product of number of teeth on the driven gears}}$$

3. Internal Combustion Engine

3.1. Swept Volume (m³)

$$V_s = \frac{\pi d^2 L}{4}$$

d = Bore diameter in m
L = Stroke length in m

3.2. Compression Ratio

$$CR = \frac{(V_s + V_c)}{V_c}$$

V_c = Clearance volume in m³

3.3. Piston Speed (S) (m/min)

$$S = 2LN$$

L = Stroke length in m
N = Rotational speed of crankshaft in rpm

3.4. Indicated Power (IP) (kW)

$$IP = \frac{i P_m L A n}{60000}$$

i = Number of cylinders
P_m = Mean effective pressure in N/m²
L = Length of stroke in m
A = Area of cross section of cylinder in m²
N = Rotational speed of the crank shaft in rpm
n = Number of cycles per minute

n = N for 2 stroke I.C. Engines and n = N / 2 for 4 stroke I.C.Engines

3.5. Brake Power (BP) (kW)

$$BP = \frac{2\pi N T}{60000}$$

N = Rotational speed of the crank shaft in rpm
T = Torque applied due to net load on the brake drum in Nm

3.6. Torque on the Brake Drum (T) (Nm)

$$T = W_{net} \times R$$

W_{net} = Net load acting on the brake drum in N
R = Effective radius in m

W_{net} = Load acting on the brake drum – Spring balance reading

$$R = \frac{(Brake\ drum\ diameter + Rope\ diameter)}{2}$$

3.7. Frictional Power (FP) (kW)

$$FP = Indicated\ Power\ (IP) - Brake\ Power\ (BP)$$

3.8. Mechanical Efficiency (η_{mech})

$$\eta_{mech} = \frac{Brake\ Power\ (BP)}{Indicated\ Power\ (IP)} \times 100$$

3.9. Brake Thermal Efficiency (η_{bth})

$$\eta_{bth} = \frac{BP \times 3600}{CV \times m_{fu}}$$

3.10. Indicated Thermal Efficiency (η_{ith})

$$\eta_{ith} = \frac{IP \times 3600}{CV \times m_{fu}}$$

m_{fu} = Mass of fuel consumed in kg / hr
CV = Calorific value of the fuel in kJ / kg
BP = Brake power in kW
IP = Indicated power in kW

3.11. Brake Specific Fuel Consumption (SFC) (kg/kWh)

$$SFC = \frac{m_{fu}}{BP}$$

4. Machine Tools

4.1. Taper Turning by Swivelling the Compound Rest

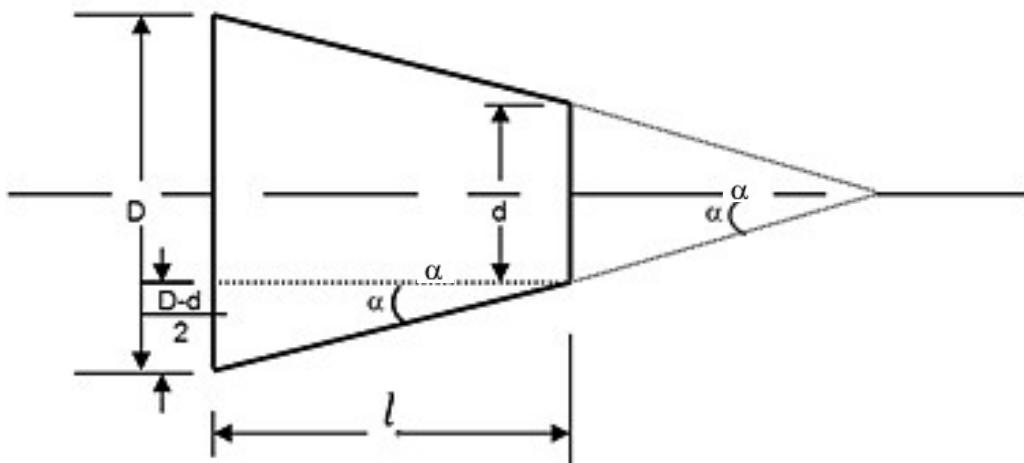


Figure 4.1 Schematic of calculating the swivel angle for taper turning

$$\tan \alpha = \frac{(D - d)}{2l}$$

α = Half taper angle or (simply taper angle) in degrees

D = Larger diameter of taper in mm

d = Smaller diameter of taper in mm

l = Length of the taper in mm

4.2. Taper Turning by Tailstock Set-Over Method

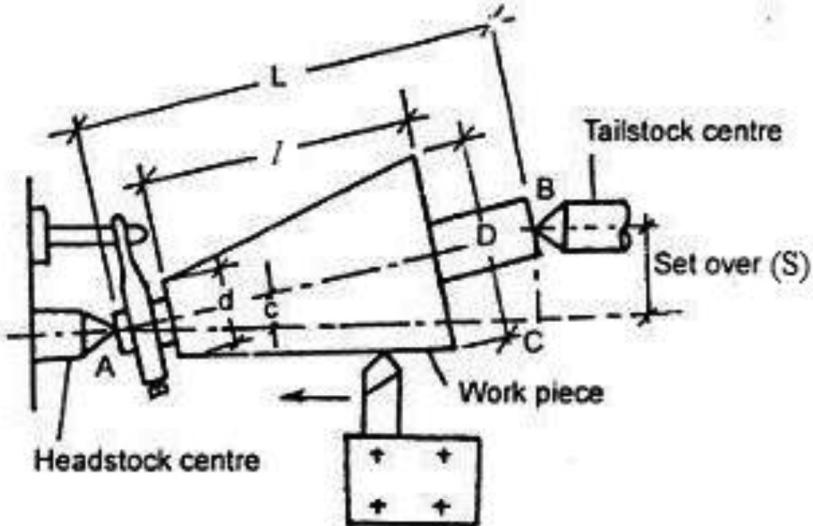


Figure 4.2 Schematic of taper turning by tailstock set-over method

$$S = \frac{L(D - d)}{2l}$$

S = Set-over distance in mm

D = Larger diameter of taper in mm

d = Smaller diameter of taper in mm

L = Length of the job in mm

l = Length of the taper in mm

4.3. Machining Time Calculation

4.3.1. Cutting Speed

$$V = \frac{\pi DN}{1000}$$

V = Cutting speed (surface) in m/min
D = Diameter of the workpiece in mm
N = Rotational speed of the workpiece in rpm

4.3.2. Time for a single pass

$$t = \frac{L + L_o}{fN}$$

t = Time required for single pass in min
L = Length of the job in mm
L_o = Over travel of the tool beyond the length of the job in mm
f = Feed rate in mm/rev

4.3.3. Number of roughing passes

$$P_r = \frac{A - A_f}{d_r}$$

P_r = Number of passes for roughing operation
A = Total machining allowance in mm
A_f = Finish machining allowance in mm
d_r = Depth of cut for roughing in mm

4.3.4. Number of finishing passes

$$P_f = \frac{A_f}{d_f}$$

P_f = Number of passes for finishing operation
A_f = Finish machining allowance in mm
d_f = Depth of cut for finishing in mm