

Otto Cycle model

Dr A. French. September 2017



Nikolaus Otto
(1832-1891)

Input parameters

Temperature T1 of air draw into piston /Celsius	20
Low pressure state p1 /atm	1.00
High pressure state p3 /atm	100
Volume V1 of uncompressed gas /litres	1
Volume V2 of compressed /litres	0.1
Degrees of freedom of molecular motion	3
Molar mass of gas /gmol^-1	28.966

Outputs

Heat input during isochoric heating /kJ	0.814
Heat output during isochoric cooling /kJ	0.175
Total work done by gas on surroundings /kJ	0.639
Efficiency (work done / heat input)	0.785

Theoretical efficiency

0.785

$$\eta = 1 - \frac{1}{r^{\gamma-1}}$$
$$r = \frac{V_1}{V_2} \quad \gamma = \frac{c_p}{c_v}$$

Note all temperatures incorporated into calculations
will be converted to Kelvin first - i.e. add 273 to Celsius number.

Pressure, volume, temperature coordinates of heat cycle

	p1	1.00
	V1	1.000
	T1	293
	p2	46.42
	V2	0.100
	T2	1360
	p3	100.00
	V3	0.100
	T3	2930
	p4	2.15
	V4	1.000
	T4	631

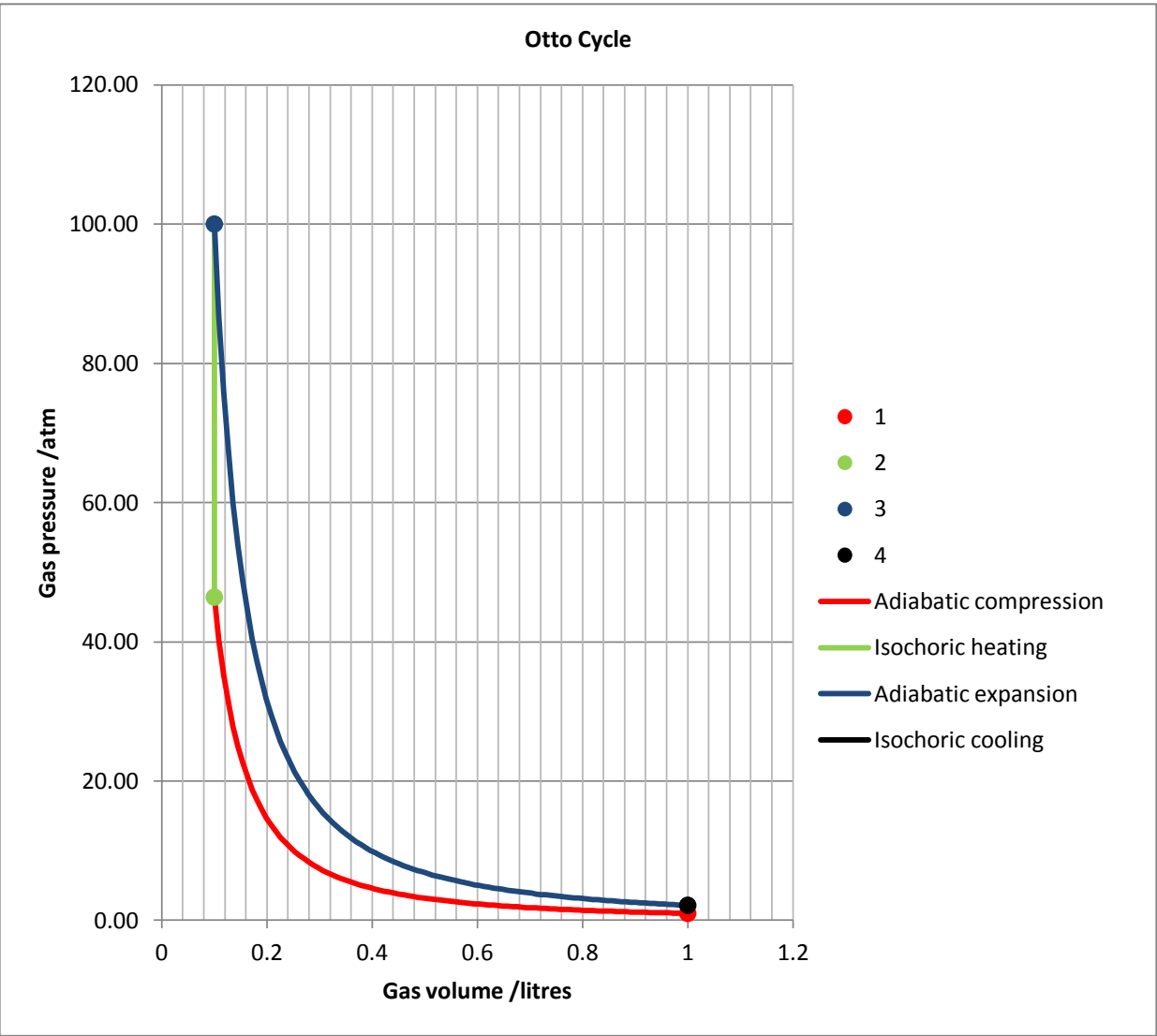
Power per cylinder

Engine RPM	6500
Power output /kW	69.21979

Number of cylinders	1
Total power output /kW	69.22

Note all pressures are quoted in atmospheres. 1atm = 101,325 Pa. Volumes in litres. T in K.

Number of moles of gas in engine	0.042
Ratio of specific heats gamma	1.667
Constant volume specific heat capacity /Jkg^-1K^-1	431
Constant pressure specific heat capacity /Jkg^-1K^-1	718



Note real petrol engines have an efficiency of more like 20%, whereas diesels can be up to 40%. In other words, significant losses!

FORD MOTOR CO.

1.0L ECOBOOST

DOHC DI I-3

Displacement:
999 cc

Block / head material:
cast iron / aluminum

Horsepower (SAE net):
123 @ 6,000 rpm

Torque:
125 lb.-ft. (169 Nm)
@ 2,500 rpm

Specific output:
123 hp/L

Bore x stroke:
71.9 x 82 mm

Compression ratio:
10.0:1

EPA city / highway:
31 / 43 mpg

Assembly site:
Cologne, Germany;
Craiova, Romania

Application tested:
'14 Ford Fiesta SE

Additional applications:
Ford Focus, C-Max,
Mondeo, Transit Courier
(Europe); B-Max (Europe,
Asia/Pacific); EcoSport
(Asia/Pacific)

V or p diff fraction	1 to 2		2 to 3		3 to 4		4 to 1	
	Adiabatic compression		Isochoric heating		Adiabatic expansion		Isochoric cooling	
	p	V	p	V	p	V	p	V
0	1.000	1.000	46.416	0.100	100.000	0.100	2.154	1.000
0.01	1.015	0.991	46.952	0.100	86.621	0.109	2.143	1.000
0.02	1.031	0.982	47.488	0.100	75.892	0.118	2.131	1.000
0.03	1.047	0.973	48.023	0.100	67.142	0.127	2.120	1.000
0.04	1.063	0.964	48.559	0.100	59.901	0.136	2.108	1.000
0.05	1.080	0.955	49.095	0.100	53.834	0.145	2.097	1.000
0.06	1.097	0.946	49.631	0.100	48.693	0.154	2.085	1.000
0.07	1.115	0.937	50.167	0.100	44.295	0.163	2.074	1.000
0.08	1.133	0.928	50.703	0.100	40.500	0.172	2.062	1.000
0.09	1.151	0.919	51.238	0.100	37.199	0.181	2.051	1.000
0.1	1.170	0.910	51.774	0.100	34.309	0.190	2.039	1.000
0.11	1.190	0.901	52.310	0.100	31.762	0.199	2.027	1.000
0.12	1.210	0.892	52.846	0.100	29.505	0.208	2.016	1.000
0.13	1.230	0.883	53.382	0.100	27.494	0.217	2.004	1.000
0.14	1.252	0.874	53.918	0.100	25.693	0.226	1.993	1.000
0.15	1.273	0.865	54.454	0.100	24.074	0.235	1.981	1.000
0.16	1.296	0.856	54.989	0.100	22.613	0.244	1.970	1.000
0.17	1.319	0.847	55.525	0.100	21.288	0.253	1.958	1.000
0.18	1.343	0.838	56.061	0.100	20.083	0.262	1.947	1.000
0.19	1.367	0.829	56.597	0.100	18.984	0.271	1.935	1.000
0.2	1.392	0.820	57.133	0.100	17.978	0.280	1.924	1.000
0.21	1.418	0.811	57.669	0.100	17.054	0.289	1.912	1.000
0.22	1.444	0.802	58.204	0.100	16.205	0.298	1.900	1.000
0.23	1.472	0.793	58.740	0.100	15.421	0.307	1.889	1.000
0.24	1.500	0.784	59.276	0.100	14.696	0.316	1.877	1.000
0.25	1.529	0.775	59.812	0.100	14.024	0.325	1.866	1.000
0.26	1.559	0.766	60.348	0.100	13.400	0.334	1.854	1.000
0.27	1.590	0.757	60.884	0.100	12.819	0.343	1.843	1.000
0.28	1.622	0.748	61.419	0.100	12.277	0.352	1.831	1.000
0.29	1.655	0.739	61.955	0.100	11.772	0.361	1.819	1.000
0.3	1.689	0.730	62.491	0.100	11.302	0.370	1.807	1.000
0.31	1.724	0.721	63.027	0.100	10.866	0.379	1.795	1.000
0.32	1.760	0.712	63.563	0.100	10.463	0.388	1.783	1.000
0.33	1.797	0.703	64.100	0.100	10.092	0.397	1.771	1.000
0.34	1.835	0.694	64.636	0.100	9.752	0.406	1.759	1.000
0.35	1.874	0.685	65.173	0.100	9.442	0.415	1.747	1.000
0.36	1.914	0.676	65.710	0.100	9.161	0.424	1.735	1.000
0.37	1.955	0.667	66.247	0.100	8.908	0.433	1.723	1.000
0.38	1.997	0.658	66.784	0.100	8.682	0.442	1.711	1.000
0.39	2.040	0.649	67.321	0.100	8.482	0.451	1.699	1.000
0.4	2.084	0.640	67.858	0.100	8.307	0.460	1.687	1.000
0.41	2.154	0.631	68.385	0.100	7.610	0.469	1.681	1.000
0.42	2.206	0.622	68.921	0.100	7.373	0.478	1.670	1.000
0.43	2.261	0.613	69.457	0.100	7.147	0.487	1.658	1.000
0.44	2.317	0.604	69.993	0.100	6.932	0.496	1.646	1.000
0.45	2.376	0.595	70.529	0.100	6.727	0.505	1.635	1.000
0.46	2.437	0.586	71.065	0.100	6.532	0.514	1.623	1.000
0.47	2.501	0.577	71.600	0.100	6.346	0.523	1.612	1.000
0.48	2.567	0.568	72.136	0.100	6.168	0.532	1.600	1.000
0.49	2.636	0.559	72.672	0.100	5.998	0.541	1.589	1.000
0.5	2.709	0.550	73.208	0.100	5.835	0.550	1.577	1.000
0.51	2.784	0.541	73.744	0.100	5.680	0.559	1.566	1.000
0.52	2.863	0.532	74.280	0.100	5.530	0.568	1.554	1.000
0.53	2.946	0.523	74.815	0.100	5.387	0.577	1.543	1.000



0.54	3.032	0.514	75.351	0.100	5.250	0.586	1.531	1.000
0.55	3.123	0.505	75.887	0.100	5.118	0.595	1.519	1.000
0.56	3.218	0.496	76.423	0.100	4.992	0.604	1.508	1.000
0.57	3.317	0.487	76.959	0.100	4.870	0.613	1.496	1.000
0.58	3.422	0.478	77.495	0.100	4.754	0.622	1.485	1.000
0.59	3.532	0.469	78.031	0.100	4.641	0.631	1.473	1.000
0.6	3.648	0.460	78.566	0.100	4.533	0.640	1.462	1.000
0.61	3.770	0.451	79.102	0.100	4.429	0.649	1.450	1.000
0.62	3.899	0.442	79.638	0.100	4.328	0.658	1.439	1.000
0.63	4.035	0.433	80.174	0.100	4.231	0.667	1.427	1.000
0.64	4.179	0.424	80.710	0.100	4.138	0.676	1.416	1.000
0.65	4.331	0.415	81.246	0.100	4.047	0.685	1.404	1.000
0.66	4.492	0.406	81.781	0.100	3.960	0.694	1.393	1.000
0.67	4.663	0.397	82.317	0.100	3.876	0.703	1.381	1.000
0.68	4.845	0.388	82.853	0.100	3.795	0.712	1.369	1.000
0.69	5.038	0.379	83.389	0.100	3.716	0.721	1.358	1.000
0.7	5.244	0.370	83.925	0.100	3.640	0.730	1.346	1.000
0.71	5.464	0.361	84.461	0.100	3.567	0.739	1.335	1.000
0.72	5.699	0.352	84.996	0.100	3.495	0.748	1.323	1.000
0.73	5.950	0.343	85.532	0.100	3.426	0.757	1.312	1.000
0.74	6.220	0.334	86.068	0.100	3.360	0.766	1.300	1.000
0.75	6.509	0.325	86.604	0.100	3.295	0.775	1.289	1.000
0.76	6.821	0.316	87.140	0.100	3.232	0.784	1.277	1.000
0.77	7.158	0.307	87.676	0.100	3.171	0.793	1.266	1.000
0.78	7.522	0.298	88.211	0.100	3.112	0.802	1.254	1.000
0.79	7.916	0.289	88.747	0.100	3.055	0.811	1.242	1.000
0.8	8.345	0.280	89.283	0.100	2.999	0.820	1.231	1.000
0.81	8.812	0.271	89.819	0.100	2.945	0.829	1.219	1.000
0.82	9.322	0.262	90.355	0.100	2.892	0.838	1.208	1.000
0.83	9.881	0.253	90.891	0.100	2.841	0.847	1.196	1.000
0.84	10.496	0.244	91.427	0.100	2.792	0.856	1.185	1.000
0.85	11.174	0.235	91.962	0.100	2.744	0.865	1.173	1.000
0.86	11.926	0.226	92.498	0.100	2.697	0.874	1.162	1.000
0.87	12.761	0.217	93.034	0.100	2.651	0.883	1.150	1.000
0.88	13.695	0.208	93.570	0.100	2.607	0.892	1.139	1.000
0.89	14.743	0.199	94.106	0.100	2.563	0.901	1.127	1.000
0.9	15.925	0.190	94.642	0.100	2.521	0.910	1.115	1.000
0.91	17.266	0.181	95.177	0.100	2.480	0.919	1.104	1.000
0.92	18.798	0.172	95.713	0.100	2.440	0.928	1.092	1.000
0.93	20.560	0.163	96.249	0.100	2.401	0.937	1.081	1.000
0.94	22.601	0.154	96.785	0.100	2.363	0.946	1.069	1.000
0.95	24.987	0.145	97.321	0.100	2.326	0.955	1.058	1.000
0.96	27.804	0.136	97.857	0.100	2.290	0.964	1.046	1.000
0.97	31.165	0.127	98.392	0.100	2.255	0.973	1.035	1.000
0.98	35.226	0.118	98.928	0.100	2.221	0.982	1.023	1.000
0.99	40.206	0.109	99.464	0.100	2.187	0.991	1.012	1.000
1	46.416	0.100	#####	0.100	2.154	1.000	1.000	1.000