The BMC Companion

Revisions

Last update 5/4/2023

Page 53-54. Calculation of compression ratios in this figure are based on measurements shown in service literature and drawings. Other factors also affect the compression ratio such as cylinder head gasket thickness.
Page 98. Revised discussion on inductance.
Pages 84 – 87 data were inadvertently calculated using gross engine torque rather than net engine torque and so data computed is in error by about 10%. Revised calculations show even better agreement with road test figures.

$$C.R. = \frac{SV + CV}{CV}$$

CV is the compressed volume. The swept volume *SV* is:

$$SV = \pi \left(\frac{1}{2}b\right)^2 s$$

For a BMC A series 1098cc engine with bore *b* = 64.58 mm and stroke *s* = 83.72 mm, the total swept volume is 1097.2 cc. The compression ratio is specified 8.3:1, and so the compressed volume is thus:

$$\begin{aligned} CV &= \frac{SV}{CR}\left(\frac{1}{1-\frac{1}{CR}}\right) \\ &= \frac{1097.2}{8.3}\left(\frac{1}{1-\frac{1}{8.3}}\right)\frac{1}{4} = 36.6cc \end{aligned}$$

For an Austin 1800 B series engine, the bore *b* is 80.264mm) and *s* = 88.9mm. The compression ratio is 8.2:1 giving a compressed volume of 61.2cc. For engines of interest, calculations and specifications show:

	850	**998**	**998cc Matic**	**1098**	**1275**	**1798**	Unit	**Notes**
Bore	62.94	64.59	64.59	64.59	70.60	80.26	mm	Specified Eng Data
Stroke	68.26	76.2	76.2	83.72	81.33	88.9	mm	Specified Eng Data
Swept Volume (SV)	212.4	249.7	249.7	274.3	318.4	449.8	cc	Calculated per Cyl
Piston Volume (PV)	0.87	5.69	5.69	6.5	6.692	11	cc	Specified on Drawings
Combustion Chamber Face Volume (CCFV)	23.9	23.9	23.9	24.6	31.8	37.9	sq cm	Specified SLS 94 1966
Combustion Chamber Volume (CCV)	24.5	**24.5**	**22.4**	26.1	21.4	38	cc	Specified SLS81 C54/67
Compression Ratio (CR)	8.3	8.3	9	8.5	9.75	8.2		Specified CR
Compressed Volume (CV)	29.09	34.20	31.21	36.57	36.39	62.47		Calculated from CV and SV

Table 2.3.1 *Compression ratio and combustion chamber volumes*.

An interesting question arises. How much can one take off the head to raise the compression ratio.? Removing a thickness from the bottom surface of the head affects the value of compressed volume CV in the formula above by virtue of a change to the combustion chamber volume CCV.

Fig. 2.3.1 shows an estimated relationship based upon the data in Table 2.3.1 with a reduction in the CV for a range of thickness removed from the head. Interestingly, service literature[5] quotes a removal of 0.020” from the standard 998cc cylinder head raises the compression ratio to 9:1 (Mini-Matic), but the calculations show a new compression ratio of 8.57 so evidently the newly introduced Cylbestos cylinder head gasket is thinner than that previously fitted to manual transmission vehicles.

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[5] C54/67

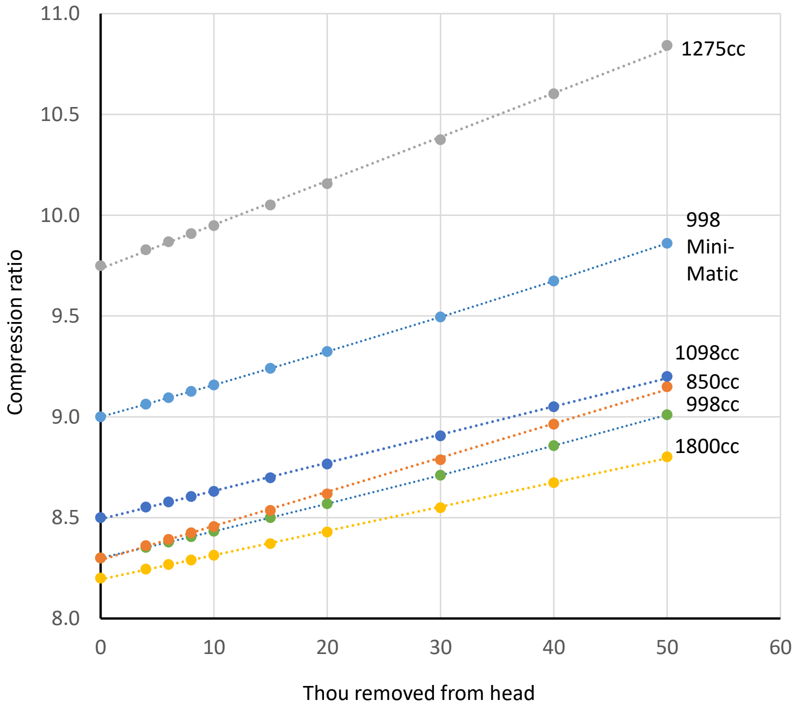

Fig. 2.3.1 *Estimated variation of compression ratio with thickness removed from face of head.*

Given the interplay between the requirements of high thermal efficiency, high volumetric efficiency, and freedom from detonation, the design of a cylinder head is a complicated and specialised affair.

The shape of the combustion chamber is absolutely crucial, and it is no accident that BMC vehicles are adorned with a list of applicable patents on the rocker cover. For BMC engines take advantage of combustion chamber design of Harry Weslake, whose heat-shaped combustion chamber with flat squish area is a familiar sight.

For high thermal efficiency, a combustion chamber and low incidence of detonation, a combustion chamber must have a low surface to volume ratio, result in a short flame travel, and provide turbulence. For a high volumetric efficiency, a high lift camshaft, valve overlap, and large inlet valve diameter is required.

2.4 Engine Vibrations

2.4.1 Turning Moment

Most of the engines fitted to BMC cars are four cylinders. By standards of the day, engine vibration could be expected to be much more pronounced compared to six and eight cylinder cars. Refinements in balancing and engine mounting makes modern four cylinder cars very much smoother and comparable to sixes of yesteryear. So, what exactly makes a four cylinder engine so rough and what is done by the manufacturer to bring vibrations under control for the comfort of the occupants and reliability of the mechanicals?

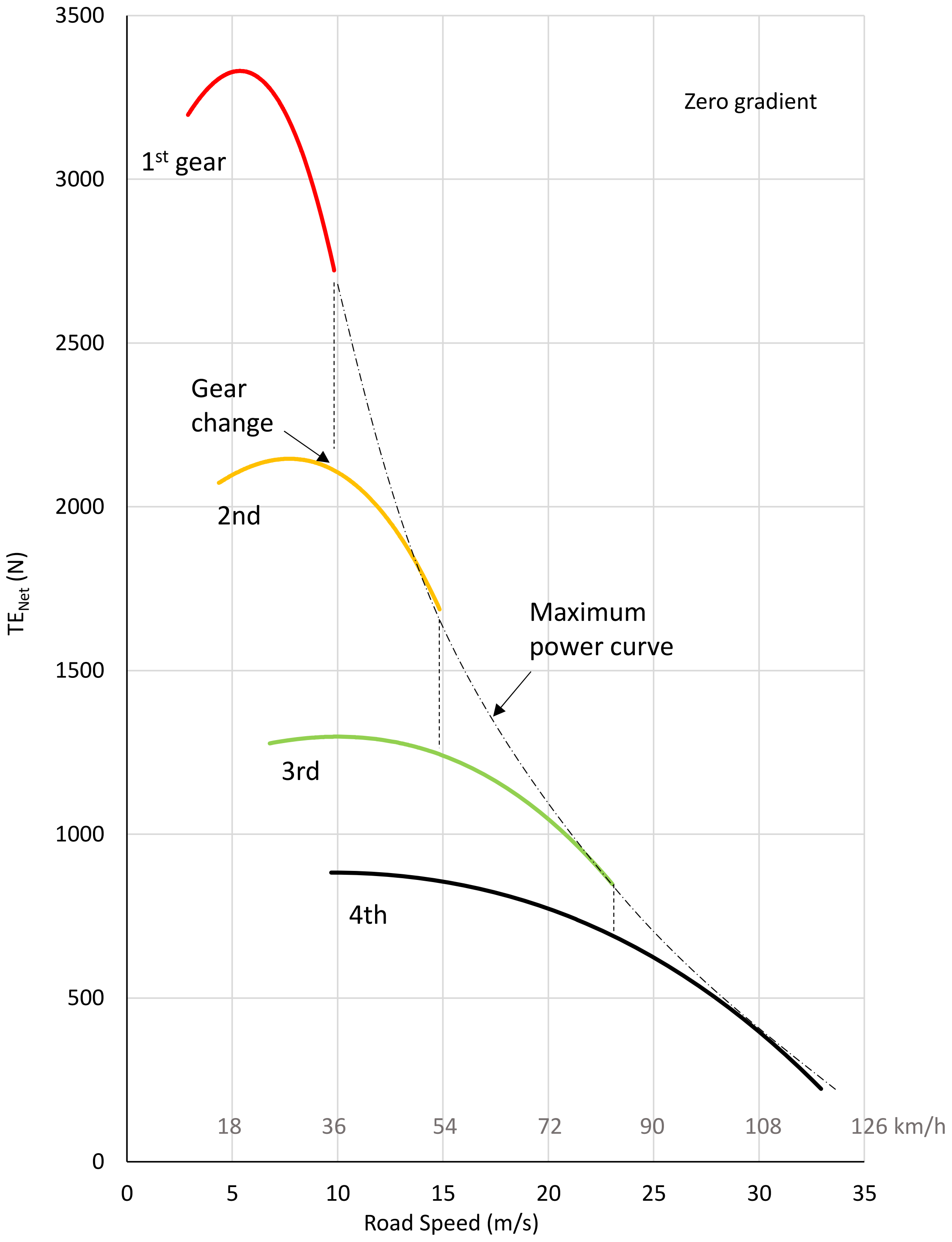

Fig. 2.8.5 *Excess tractive effort for data plotted in Fig. 2.8.3 for zero gradient*.

So, for a particular speed range in a particular gear, we can calculate the acceleration from the effective value of TE_{eff} as applied to the effective mass m_{eff}, and from there, by ordinary kinematical equations, calculate desired quantities of interest.

For example, the acceleration during a period in each gear is found from:

$$a = \frac{TE_{eff}}{m_{eff}}$$

The time taken is:

$$t = \frac{v_2 - v_1}{a}$$

And the distance travelled:

$$d = v_1 t + 0.5at^2$$

Knowing the accumulated time to reach, say, 118.6 km/h, then the kinetic energy expended over that time indicates the power available used in accelerating the vehicle.[9]

As can be seen in Table 2.8.10, we expect the vehicle to take 3.2 seconds to reach 35.4km/h in 1st gear, followed by another 2.2 seconds in 2nd gear to reach 53.4km/h, followed by 5.8 seconds to reach 82.9km/h and 6.3 seconds to reach 118.6km/hr. When added cumulatively, the travel times for 35.4km/h, 53.4km/h, 82.9km/h and 118.6km/h through the gears can be readily predicted. An allowance of 0.75 seconds for each gear change has been made for the accumulated travel times shown in Table 2.8.10.

Comparison with Wheels Magazine test data for the Morris Mini 1100 2/YDO5 is shown in Table 2.8.11.

Speed Range mph (km/h)	**Wheels Magazine (3.77 FDR)**	**Calculated (3.647 FDR)**	**Unit**
0 – 30 (48)	4.8	5.4	sec
0 – 40 (64)	7.8	8.7	sec
0 – 50 (80)	12.0	12.0	sec
0 – 60 (96)	17.6	17.73	sec
0 – 70 (112)	25	24.72	sec
Standing Quarter Mile	20.9	22.7 @108 km/h	sec
20 – 40 (32 – 64)	5.6	5.93	sec
30 – 50 (48 – 80)	7.0	6.80	sec
40 – 60 (64 – 96)	10.3	9.79	sec

Table 2.8.11 *Through-the-gears acceleration, Morris Mini 1100, YDO5.*

Also shown in Table 2.8.11 is a comparison with the computed standing quarter mile with that shown under test and also acceleration times through various speed ranges.

The correspondence between calculated and test data is reasonably good, especially when one considers that the gear change points under test are not known, the effect of any wheel spin upon take-off not accounted for, tail or head wind and gradient effects on test, reaction time when

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[9] The figures indicated in Table 2.8.10 for power have been calculated without the gear change time included. This is the "excess" power required to accelerate the vehicle mass calculated from the kinetic energy of the vehicle over the accumulated time.

However, there are some details about this process that are worth knowing in case of problems and modifications.

4.2.1 Faraday's Law

Fig. 4.2.1 shows the general arrangement. The operation depends upon Faraday's law of induction. This law states that the induced voltage in a coil depends upon the rate of change of current through the coil and the inductance of the coil. When the points are closed, current flows from the battery into the primary side of the ignition coil. The rate of change of current during this process depends upon the resistance of the coil, the inductance of the coil, and the voltage applied to the coil.

There is an equation that describes how the current changes in the coil when the points close:

$$i = \frac{V}{R}\left(1 - e^{\frac{-Rt}{L}}\right)$$

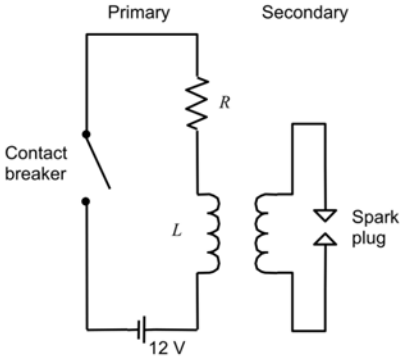

Fig. 4.2.1 *Schematic of ignition system*

In this equation, *i* is the primary current at some time *t*, *V* is the 12 V applied to the coil, *R* is the resistance of the primary, *L* is the inductance of the primary side of the coil.

What this equation tells us is that the current increases over time as shown in Fig. 4.2.2. *I* is the final current reached after a relatively long time.

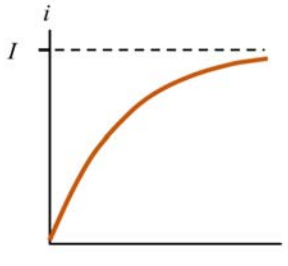

Fig. 4.2.2 *Current vs time in the primary side of the ignition coil.*

The time for the initial rate of increase in current is called the "time constant". It is desirable that the time constant be fairly short because the points are only closed for a brief time, and if the rate of current increase is too slow, then there will be insufficient build-up of current flowing in the primary during the time available that the points are closed. As the rpm of our engine increases, the rate of current rise in the primary has to be even shorter to take into account the even less time that the points remain closed.

Consider a 4 cylinder engine which has a specified dwell angle of say 60°. That is, this is the angle of rotation of the distributor shaft over which the points are closed. At a speed of 850 rpm, the engine requires about 28 sparks per second to operate. Calculations show that the points are closed for 25 msec for each spark. Using the equation above, this corresponds to a current through the points of 8A, or, in this case, about the DC value. This is called the "break current". At 4200 rpm, the spark rate is 140 per second, the points are closed for 5 msec, and the "break current" is 5.6A. In practice, a minimum of about 2 msec dwell time is required, corresponding to an engine speed of 8500 rpm and a break current of 3.6A.

These calculations assume that the heel of the contact breaker remains in contact with the distributor cam. It is desirable therefore that the cam has a somewhat gentle slope, but if this is done, then there is an undesirable variation in ignition timing with only a small change in points gap which occurs naturally as a result of wear during service.

A typical Lucas coil has a DC resistance of about 2 – 3Ω and an inductance of about 5mH.

Interestingly, the time constant τ for an *RL* circuit (the time at the initial rate of increase in primary current) is given by:

$$\tau = \frac{L}{R}$$

This gives a measure of the response time of an RL circuit. Here, *R* is the resistance of the primary circuit (including that of the coil winding itself) and L is the inductance of the primary coil.

When the points close, as would be expected, the greater the inductance, the longer the response time since the back emf is higher, and so requires a longer time to dissipate. What might not seem so obvious is the effect of the resistance.

If the resistance is larger, then the time constant is reduced. What this means is that (if we imagine the resistive part of the circuit separately to the inductive part, the voltage across the resistance rises more quickly for a lower resistance, the back emf across the inductor falls more quickly as a result, but the current tops out at a lower value of *I*. If, in a particular vehicle, the primary resistance is thus too high (such as might occur at the points), then there might not be sufficient energy stored in the coil to induce a spark at the spark plug and a misfire may result.

4.2.2 Generating a High Voltage

When the ignition points close, current flows into the primary side of the coil. The primary, being an inductor, opposes this current via the formation of a "back emf" according to Lenz's law. The magnitude of the back emf depends upon the inductance and the dc resistance of the coil, both of which determine the rate of change of current. The result is that the current flow through the primary starts off at a low value (since the rate of change of current is a maximum as the beginning of the process) and rises to a steady state value which ultimately depends upon the dc resistance of the primary coil. The energy of the primary current becomes stored in the magnetic field of the primary within which the secondary coil is also located as it is wrapped around the primary. A high voltage is generated in the secondary coil at this point, but not sufficient to cross the spark plug gap. The ratio of turns of primary to secondary is of the order of 100, and so for a 12 volt system, the induced secondary voltage at the time the points close is only about 100V.

When the coil is fully "charged", the rate of change of current is zero and there is a dc current of several amps flowing through the primary. When the engine is running, this condition is momentary due to the dwell angle of the points but may be continuous if the ignition is turned on, the points closed, and the engine stalled. At this point the current is flowing from the SW terminal into the coil and to the CB terminal to earth (assuming "conventional current flow" and a negative earth system).

When the points open, the current is abruptly interrupted. The magnetic field thus changes (collapses), and since a changing magnetic field induces a current in the coil the induced emf tends to want to keep the primary current flowing (Lenz's law again). The rate of change of current is very high (because the points open suddenly, and there is no "resistor" in the circuit as there was when the points closed). This rate of change of current is opposite in sign compared to the rate of change of current when the coil was being charged. That is to say, a falling current rather than a rising current.

When the points close, the back emf opposes the 12 V at the SW terminal in a gradually decreasing manner. When the points open, the rate of change of current in the primary coil is very high. The "forward" emf is of the order of 200 to 300V and appears at the CB terminal of the coil – which is now no longer connected to earth. The forward emf, sometimes called the "kick" voltage, or the "primary kick", is responsible for a far higher voltage generated in the secondary compared to the case when the points were closing.

We would expect such a large kick voltage to result in arcing of the points. This arcing would act as a kind of resistor (current flows through the arc) and would thus decrease the rate of change of current and limit the magnitude of the secondary voltage. The capacitor is charged by the kick voltage, and this takes time. Time enough for the points to separate so that arcing across the points is much reduced. Because of the capacitor stores the energy which would otherwise be wasted at an arc at the points, the primary current is more abruptly terminated resulting in a larger kick and higher secondary voltage.

Initially, the capacitor is charged with the kick voltage, but when the voltage at the CB terminal reduces (as the magnetic field in the primary becomes weaker as it discharged), the capacitor then discharges current back into the primary (reverse direction to that which occurs when the coil is being "charged" by the voltage at the SW terminal), and as a result, there is a back emf opposing this current and the voltage at the CB terminal rises. This back emf dissipates as the capacitor is discharged, and then the coil now with a new magnetic field (of reduced intensity) discharges again. The result is a series of oscillations at the CB terminal of a diminishing nature and the spark (now established) continues until the oscillations are reduced along the "spark line", or "burn line".

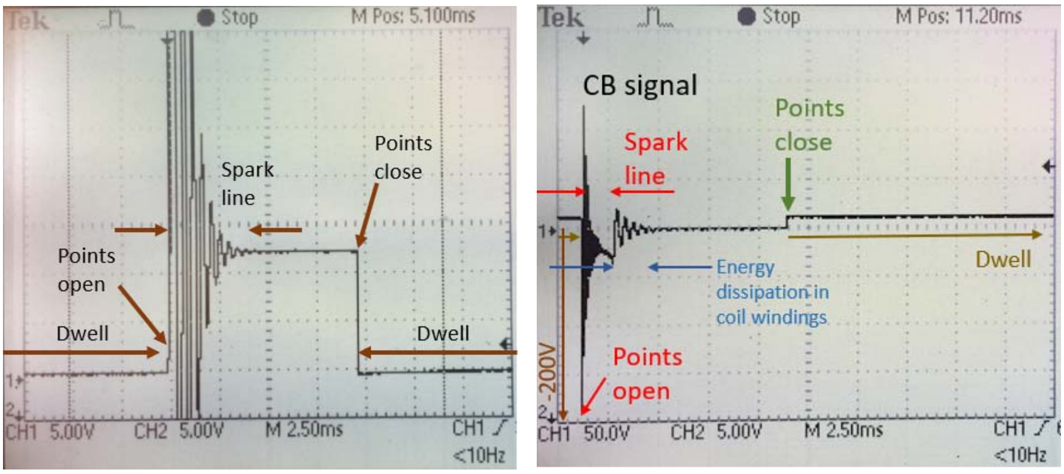

Fig. 4.2.3 Voltage waveform at the CB terminal while engine is running. (a) Negative earth configuration (b) Positive earth.