intelligent Engine Analyzer

Training

Anatomy of the Compression Waveform

by Bernie Thompson - ATS

The compression waveform produced from the internal combustion engine holds the key to determine if the mechanical condition of the cylinder is in good working order or if there is a deficiency within the mechanical condition of the cylinder.

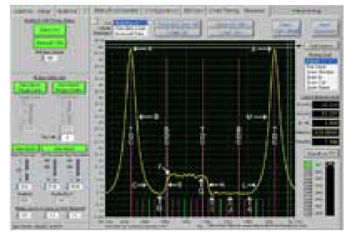


Fig. 1

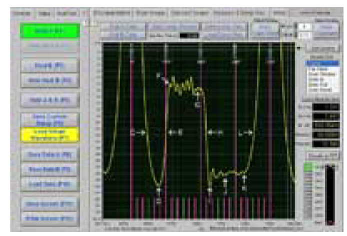
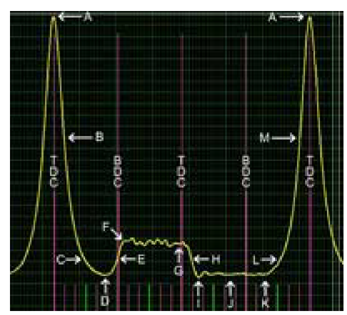


Fig. 2



Letter points

It is necessary to break the waveform down into several divisions in order to make a determination of the cylinder condition. In figure 1 (taken with a 300psi transducer) and in figure 2 (taken with a -30hg transducer to increase the resolution of the exhaust plateau) a compression waveform is shown from a good spark ignition engine at idle and has key points of the waveform marked. Note that the compression waveforms, figure 1 and figure 2, were taken from the same spark ignition engine. At the top of the waveform point A marks the peak pressure that occurred. This point will correspond to the point at which the piston position came within the closest distance to the cylinder head. This pressure is the sum of compression from point K to point A. The amount of pressure built will depend on the volume between the cylinder head and the piston, when the distance from the piston to the head is at its closest point. This peak pressure point will represent the top dead center (TDC 0º) position of the piston's movement. This is the point at which the piston has come to rest and is no longer in movement. This occurs when the crankshaft has reached the end of its stroke. This pressure will change due to the operating condition the engine is running under.

When the engine is in a cranking condition the compression on a spark ignition engine should be about 130lbs/square inch (psi). When this cranking pressure drops below 90psi it is an indication that the pressure within the cylinder is no longer adequate to support combustion of the hydrocarbon chains. When the engine is in a running condition the compression at idle should be about 70psi. When this running pressure drops below 40psi a misfire will occur. This is an indication that the pressure within the cylinder is no longer adequate to support the combustion of the hydrocarbon chains.

During a snap throttle compression test the idle compression pressure should increase by about 3 times. As the crankshaft rotates past the top dead center position the piston starts to move away from the cylinder head. This allows the volume between the cylinder head and the piston to increase. Under this condition the peak pressure that has been produced will start to decrease.

If the compression tower is measured from its lowest point, D, to its highest point, A, and this pressure is divided in half; then this point should occur at 30º after top dead center. This point is indicated by point B, halfway down the compression tower. The piston will then continue to move away from the cylinder head increasing the volume between the head and piston. The piston velocity will continue to increase until the crankshaft has reached the 90º position. The piston was at rest at top dead center and, as the crankshaft rotation continues, the piston speed increased until it obtained its maximum velocity at the 90º point. From this 90º position to the bottom dead center (BDC) point the piston will slow its velocity down until it reaches BDC and stops. The piston movement has now reached its half way position at 90º of crankshaft rotation.

In this first 90º of crankshaft rotation the cylinder has totally decompressed and now enters into a negative pressure or vacuum state. The piston continues its downward travel building more negative pressure within the cylinder. At the point the exhaust valve opens, point D, the piston travel is still moving in a downward direction but, the cylinder pressure starts to rise. This is due to the pressure in the exhaust being higher than the pressure in the cylinder. The cylinder pressure will continue to rise until it is equal with the exhaust pressure, point F. This exhaust pressure change should occur at the point the piston has decelerated to a stop or has obtained BDC 180º. The pressure change from point D to point F is referred to as the exhaust ramp. The target point is for the center of the exhaust ramp to be equal with the BDC 180º point, figure 3. At this point the exhaust camshaft timing is correctly timed to the crankshaft. If this exhaust ramp crosses the BDC 180º position within -10º to +15º of this target the camshaft is in proper time of the piston position.

On some performance based engines it is normal for the exhaust cam timing to be advanced and can still be in proper time with a +20º of this target. The piston being at bottom dead center is not in movement. The crankshaft continues to rotate which in turn moves the piston. The piston now starts to accelerate in an upward direction on the exhaust stroke. This forces the contents of the cylinder out of the cylinder into the exhaust system. The piston crosses the half way point, 90º position, reaching its maximum velocity and then starts to slow down and stop as it reaches the TDC 360º position. Approximately 15º to 30º before TDC 360º the intake valve will open. This pressure change can be seen at point G however, in different engines this pressure change may not be apparent.

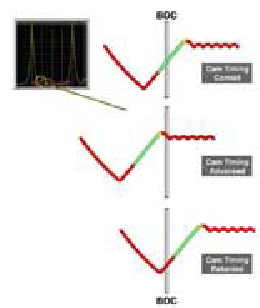


Fig. 3

When the piston is coming to a stop and the intake valve opens the piston has very low velocity. The exhaust valve is still open at this point and will equalize the cylinder pressure to the higher pressure that is within the exhaust system. When the piston reaches TDC 360º and then starts to move away from the TDC 360º position in a downward movement, the negative pressure will overcome the exhaust pressure within the cylinder and the cylinder pressure will decrease. The pressure decreases until it equalizes with the intake manifold pressure. The intake manifold is in a negative state of pressure or a vacuum. This intake pressure change creates the intake ramp, point G to point I. The exhaust valve will now close at approximately point I. This intake ramp should start to drop at the TDC 360º position and equalize with the intake pressure by the 60º mark after TDC 360º, point I. If the pressure from point G to point I is divided in half this target point should occur at 20º after TDC 360º, figure 4. This indicates that the intake camshaft is in time with the crankshaft. If the intake ramp crosses the TDC 360º plus 20º position within -10º to +10º of this target the intake camshaft is in proper time with the piston position.

On variable valve timed (VVT) engines the target for the center of the intake ramp is TDC 360º +30º within +/-10º. The intake pressure at point J should be approximately equal to the exhaust pressure at point D. This is due to the intake manifold pressure, point J, being compressed to the peak pressure and then decompressed to this starting pressure, which should be equal to point D.

The exhaust plateau, point D to point I, is created by the pressure differential within the intake manifold or the vacuum that is contained in the intake manifold. As this intake vacuum changes so will this exhaust plateau. For example, figure 5, when the engine is in a cranking condition the engine can only produce 1 inch hg to 3 inches hg of intake manifold cranking vacuum. With this reduced intake manifold vacuum the exhaust plateau will also be reduced or will decrease in its definition. With this decrease in the exhaust plateau's definition the exhaust plateau will change in the way that it appears and is used. Since the height of the plateau is based on only 1 to 3 inches hg, this plateau will no longer cross the bottom dead center 180º mark or the TDC 360º +20 mark. The intake manifold vacuum will need to be much greater in order for the exhaust plateau to have enough height or pressure change for these exhaust and intake ramps to cross their targets. Since the exhaust and intake ramps cannot be used to check cam timing during a cranking condition, the valve openings must be checked instead. The exhaust valve opening should occur 30º to 50º before BDC 180º. The intake valve opening should occur just after TDC 360º. The intake valve closing should occur 30º to 60º after BDC 540º. If these targets are met the camshafts are timed closely enough for the engine to start however, the camshaft timing could still be up to 1 tooth out of time. In order for the cam timing to be known the engine must be at a steady idle state. The piston then continues to increase its velocity in a downward direction until it reaches the 90º position. At this point the piston has reached its maximum velocity. The piston then continues to move downward, slowing until it reaches the stopping point or BDC 540º. The crankshaft continues to rotate and the piston starts to move in an upward direction but, the piston velocity is low. At this point the intake valve is still open so the pressure is equalized by the pressure within the intake manifold. The intake valve closes at point K and the cylinder pressure begins to rise. This intake valve closing should occur at approximately 50º after BDC 540º. The piston continues to travel in an upward direction, gaining velocity until it reaches its maximum velocity at 90º. The compression ramp at this point is clearly increasing in pressure. The piston continues to travel upward and is now slowing its velocity as it approaches 30º before TDC 720º point. At this point the compression should be halfway between the minimum pressure and the maximum pressure, point M. The compression then continues to build until the piston slows down and reaches a stopping point at TDC 720º. It is important to note that most of the compression pressure is produced in the last 30º of crankshaft rotation.

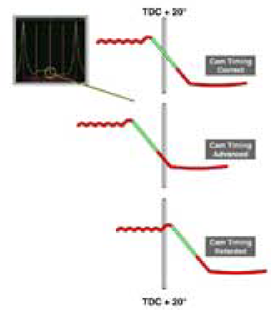


Fig. 4

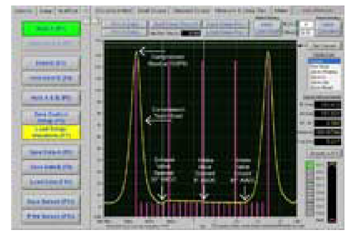
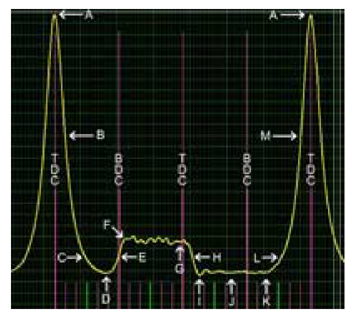


Fig. 5



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