1965 Tiger Cub

Top End

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Location and Function

- Power source of the motorcycle
- Mounted to the center of the bike frame at three points
- Along with the crankcase, clutch, and transmission, the top end comprises the engine
- Through the ignition of fuel within the top end the piston drives the flywheel, which eventually rotates the wheel





Connected Systems

Carburetor: Connected to the top end at the intake manifold. Carburetor brings in the air-fuel mixture during the intake stroke **Oil System**: Oil is delivered to the top end of the engine near the rocker assembly



Electrical System: Spark Plug is connected to the top end, and timed to correspond with the power stroke



Bottom End: Piston is connected to the flywheel through the connecting rod, driving the crankshaft and eventually the bike itself



Engine Head

- Primary part of the top end
- Houses the valve assembly, spark plug, rocker arms, etc.
- Connected to oil system, cylinder, pushrods, and carburetor
- Exterior is covered in cooling fins in order to prevent the engine from overheating
- Sealed together with the cylinder to form the top end (copper gasket separates the two entities)



Piston and Cylinder

- Piston is connected to the flywheel via the connecting rod
- Piston rings keep the cylinder pressurized (gaps are oriented in a staggered way)
- Cooling fins are on the exterior of the cylinder to keep the engine from overheating
- Piston is oriented specific way due to different sized divots made for the intake made for the intake and exhaust and valves







Valve Assembly

- Consists of two valves: intake and exhaust
- Intake valve is bigger than the exhaust in order to ensure a sufficient amount of fuel and air are taken into the cylinder
- Each valve is connected to a rocker arm; when pressed pushes the respective valve downward, opening the exhaust or intake
- The valve spring then returns the valve to its initial closed position
- Both valves are connected via the pushrods, cam, and rocker assembly













Pushrods and Camshaft

- Rocker arm Rocker shaft Valve clearance. Valve clearance adiuster Valve spring Exhaust valve Intake valve Pushrod Camshaft. Tappet sprocket Camshaft Timing chain Crankshaft sprocket
- Camshaft is attached to the crankshaft through the timing chain
- Responsible for coordinating the movement of the valves with the cycle of the engine
- Cam has lobes that pushes a push rod into the rocker arm, which opens the respective valve
- The larger the cam lobes the more air-fuel is brought into engine
- Pushrods are oriented in crossed configuration and alternate to match the intake, compression, power, exhaust sequence

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The Engine:

- The top end is comprised of head (which contains the combustion chamber, the connecting rod, the piston, and rings), the pushrods, the exhaust and intake ports, the valves, valve springs, rockers, tappets, and spark plug
- A Tiger Cub has a 200 CC (cubic centimeters of displacement) singlecylinder engine capable of producing a claimed 14 HP (horsepower) at around 6,000 RPM (revolutions per minute)
- The engine is a four-stroke, meaning the crank turns two times per cycle



Engine Mechanics: Overview of connected systems, cont.

- Piston are connected to the crankshaft via the connecting rod, mounted on a pivoting pin
- The valves are actuated by the rockers (and rebound because of valve springs), which are in turn connected to the pushrods
- The pushrods rest on the tappets, which ride on top of the cam lobes
- The cam itself is driven by a gear that corresponds to the rotation of the crankshaft
- The teeth of the cam must be aligned so that the piston position and valve movement align during the engine's rotation
- The intake valves depress to allow air-fuel mixture to enter the combustion chamber and the exhaust valves allow ignited gases to exit, depending on engine stroke





Intake and exhaust valves (interior)





Engine Mechanics:

The Four-Stroke Cycle

- Intake (1): the air-fuel mixture enters the combustion chamber via the open intake valve on the piston's downstroke
- Compression (2): the upward stroke of the piston compresses the air-fuel mixture
- Power (3): the spark plug ignites the air-fuel mixture, forcing the piston downwards
- Exhaust (4): the exhaust gases from the explosion are forced out the open exhaust port as the piston moves upwards







power Explosion forces piston down.

exhaust Piston pushes out burned gases.

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Engine Mechanics: Intake Stroke

- The air and fuel are mixed in the carburetor (fuel particles are atomized, join the airstream from intake)
- The burst of air and fuel is pulled into the combustion chamber on the intake stroke by a vacuum created in the cylinder by the downward stroke of the piston
- The air-fuel mixture has an ideal stoichiometric ratio of 14.7:1
- Mixtures with a higher ratio are called *lean* (more air per unit fuel), and mixtures with a lower ratio are called *rich* (less air per unit fuel)



Engine Mechanics: Compression Stroke

- The intake valve closes, and the piston starts to move upwards, compressing the air-fuel mixture at a ratio of 7:1
- The compression ratio of an engine indicates that if the initial volume of the mixture at the bottom of the stroke was 7 units, it's volume at TDC (top dead center) is 1 unit
- A higher compression ratio means more power can be generated by an engine, since more fuel (which provides the energy for the explosion) can be forced into the same space at TDC inside the cylinder



Engine Mechanics: Compression Stroke, cont.

- However, a higher compression ratio can affect efficiency and the engine's tendency to knock (or ignite the air-fuel mixture prematurely, before the piston reaches the downstroke)
- In an Otto cycle engine (as opposed to a diesel), the compressed air-fuel mixture is stable and should require a spark to ignite
- Octane rating refers to the "anti-knock" properties of the fuel, or the ability to resist spontaneous combustion because of the superheating that occurs during rapid compression on the piston's upstroke



Engine Mechanics: Power Stroke

- With both the intake and exhaust valves closed, the spark from the plug ignites the air-fuel mixture
- The explosion generates heat and the ignited gases expand, forcing the piston back down, generating power for the motorcycle through the rotation of the crankshaft
- This spark should occur somewhere just before TDC, allowing for the flame front to spread throughout the cylinder and cause the air-fuel mixture to reach maximum pressure at 8-12 degrees past TDC, where the most force can be generated on the top of the piston and transmitted to the crankshaft to drive the motorcycle
- See Combustion Chemistry for more on the power stroke



Engine Mechanics: Exhaust Stroke

- The exhaust gases from the explosion are now forced out the open exhaust valve into the pipe as the piston rises
- At the very end of the exhaust stroke, the intake valve opens again, allowing a new burst of air-fuel mixture into the combustion chamber, restarting the cycle
- In a four-stroke engine, only one in every four strokes is powered, or driven by an explosion (as opposed to a two-stroke, where one in every two strokes is powered)
- In order to smooth out the engine's movement, a flywheel is connected to the crankshaft - a heavy mass that stores the kinetic energy of the explosion in rotational inertia during the remaining three strokes of the engine



The hot gases in the cylinder escape through the open exhaust valve as the piston rises again for the exhaust stroke.

The Chemistry of Combustion

Calculating engine efficiency (adapted from *Triumph Tiger Cub Calculations*):

The combustion of gasoline and air is an exothermic process that produces carbon dioxide and water vapor. For every gram of octane (C8H18) burned, 44,400 joules of energy is released. Since air is 21% oxygen and 79% nitrogen, there are around four nitrogen molecules for every oxygen molecule in air. Using molecular weights and molarity, we can calculate that the air-to-fuel ratio is approximately 15:1. The Triumph Tiger Cub has a displacement of 200cc, which weighs 0.26 grams, meaning 0.017 grams of fuel must react during each combustion. Since octane has an energy density of 44,400 joules per gram, each explosion releases 760 joules. With a top speed of 6000 RPM, the Triumph Cub engine can operate at a maximum of 50 explosions per second. This means the most possible power that the engine can put out is 38,000 watts (joules/second). Since one horsepower is 746 watts, at 100% efficiency the engine can put out 51 Hp. Triumph quotes the engine at 14 horsepower, which gives the engine an efficiency of around 27%.

1965 Triumph Tiger Cub: Facts and Figures

The Triumph's engine is 200cc, meaning the cylinder (combustion chamber) is 200 cubic centimeters of displacement. This can be calculated by multiplying the piston's area by its stroke, or the distance it travels vertically in the cylinder. Cylinder diameter is 6.3 cm, so piston area is approximately 31.2 cm squared. The piston stroke is 6.4 cm, which puts the displacement volume at roughly 200 cubic centimeters. Notice that the cylinder diameter and stroke are nearly identical. This is called a "square" engine.



The Science of Speed

Whether building, designing, and restoring commercial machines or racing machines, motorcycle enthusiasts are constantly occupied by an obsession of going faster.

Here's how you do it:

In order to obtain more power (energy/unit time) from the engine, you can either derive more energy from each explosion, or have more explosions per second.

- More displacement (a larger engine, more cylinders)
- Higher initial cylinder pressure (super- or turbo-charge)
- Pure oxygen (O2) instead of air, which is mostly nitrogen
- Fuel with higher energy density than gasoline, or one that contains oxygen in its molecular structure (nitromethane)



The Isle of Man TT: the world's best race



If you haven't already seen it, *The World's Fastest Indian* is an incredible movie about Burt Monro's (68) pursuit of the land speed record at the Bonneville Salt Flats

Restoration Process

- Disassembled head, scrubbed individual parts in the parts cleaner
- Sandblasted exterior, polished with abrasive grit to seal against oil stains
- Recut valves, ground valve seats to optimize air-fuel flow into chamber
- Measured cylinder to check "squareness"
- Replaced gaskets, retrofitted to correct size to eliminate leakage during operation
- Installed new spark plug, reset spark gap
- Trued pushrods to ensure correct length
- Planed copper gasket with an abrasive on flat surface using machinist's oil



Restoration Process, cont.

Fitting rings onto piston







Setting spark gap



Sand blasting

Citations

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- Kaskus.co (Stroke and bore diagram)



The refurbished exterior