



BASIC PRINCIPLES OF MOTORCYCLE SCIENCE:

Motorcycle systems may appear complex, but the actual principals are quite simple. The attached drawings are over-simplifications of the processes which occur in within an operating motorcycle.

To demonstrate, let's go for a ride and see what's happening within the roaring machine beneath our seat:

It's a fine sunny day in June, a perfect day for a ride. In fact, you got up early this morning to ensure that you were on the road before anyone else. For the next couple hours it's just you, the open road, and your bike. You gear up, roll the machine out of your garage, take a seat, and put up the kickstand.

STARTING CIRCUIT:

When you turn on the ignition switch, electricity is allowed to flow from the battery to all of the electrical systems on your bike. Your headlight is on, your radio is playing, and your speedometer is lit up and energized. Now you flip your kill switch to "run". This energizes your fuel injection system and puts power to your start button. Once your fuel system is fully pressurized, the indicator light goes out and you hit the start button. This energizes your starter relay, a magnetic switch which energizes the starter solenoid. The starter solenoid serves two purposes, it energizes the starter motor and it actuates the starter gear which meshes with the mating gear on the clutch which turns the engine over.

IGNITION SYSTEM:

At this point the ignition system takes over. When you turned on your ignition switch you powered up the ECM which is the computer that controls the ignition system. The ECM takes input information from all over the motorcycle including the crank position sensor which tells it what position the crankshaft is in. This tells the ECM what position the pistons are in allowing the ECM to accurately set the timing. The coil is essentially a transformer which takes low voltage input from the ECM and converts it to very high voltage which is then sent to the spark plug. The ECM energizes the Coil at the right instant to initiate a spark at the spark plug. The ECM also tells the fuel injectors when to inject fuel into the cylinders.

4-STROKE MOTORCYCLE MOTOR:

When the starter turns over the engine and the ECM initiates spark and fuel injection, combustion occurs. The name "4-stroke" refers to the 4 strokes the piston makes within the cylinder during the engine cycle. In a 4-stroke engine, the four "strokes" are: 1. Intake 2. Compression 3. Power 4.



Exhaust (See 4-Stroke Motorcycle Motor Drawing). During the intake stroke, the piston moves down and the intake valve opens, this allows a fresh charge of air to enter the cylinder. Fuel is injected into the cylinder during the intake stroke to take advantage of air turbulence and maximize mixing of air and fuel. During the compression stroke, both valves close and the piston moves upward compressing the air/fuel mixture into a much smaller volume. During the power stroke a spark is introduced into the cylinder which initiates combustion of the air/fuel mixture. This causes rapid expansion of gases, pushing the piston down. This is where the power of the engine comes from. The force is transferred from piston to wrist pin to connecting rod to crank shaft where the linear motion of the piston is converted to useful rotary motion. Finally, during the exhaust stroke, the exhaust valve opens and the piston travels upward expelling exhaust gases to atmosphere through the muffler and preparing the cylinder for the next intake stroke.

CAM DRIVE:

If you look at the “4-Stroke Motorcycle Motor” drawing you will notice that we have only included one cylinder. A V-Twin consists of two cylinders on a single crankshaft, operating 45 degrees from one another. The 45-degree design makes for an “uneven” or “odd” firing pattern which gives the V-Twin its unique sound (pop..pop.....pop..pop.....pop..pop.....pop..pop). The valves of the V-Twin are operated by the camshaft. The Twin Cam™ Engine actually has two camshafts, one for each cylinder. This is where the Twin Cam™ name comes from. As you can see in the “Cam Drive” drawing the Rear camshaft is connected to the crankshaft by a chain. The front and rear camshafts are connected by another chain. Pushrods are actuated by the cam lobes via hydraulic lifters with roller cam followers, as can be seen in the drawing. The camshaft turns at one half the speed of the crankshaft in a 4-stroke engine.

CHARGING CIRCUIT:

Whenever the engine is turning it is also turning an alternator. The alternator consists of a Stator(stationary part) which is a tubular housing with wires coiled around it. Around the stator spins a Rotor (Armature) which has electromagnets fixed to its inside surface. The wires of the stator have the rotating magnetic field passing through them. This induces current to flow in the stator and out to the electrical system. The alternator puts out three phase alternating current. Alternating current moves back and forth (Think of a pipe with water flowing forward and then backward). The A/C current coming out of the Alternator is rectified into Direct Current (D/C) in the voltage regulator. The voltage regulator contains diodes which only allow current to flow in one direction. A diode acts like a check valve. Because the net potential of 3-phase power is constant (if you add the total current moving at any moment across the phases you will get a constant value) you get a constant output (See graph on “Charging Circuit” drawing). The current coming off the voltage regulator charges the battery; it also



supplies power to all engine loads and accessories. This explains why too many accessories will eventually cause a dead battery as insufficient current is flowing to the battery for proper charging.

DRIVETRAIN:

Now your motorcycle is running, you are ready to go for a ride. While your engine is running, your rear wheel is not turning. If you look at the "Drivetrain" drawing you will notice the compensating sprocket. This sprocket is connected to the crankshaft and it turns when the engine runs. The compensating sprocket also turns the primary chain which turns your clutch hub. The clutch disengages the engine from the transmission. When you have your clutch lever pulled in, the clutch is separating the rotating primary chain from the transmission. When you are in neutral, the transmission gears are separated so that power cannot be transferred to the rear wheel. If you pull in your clutch and shift into first gear, the transmission gears are meshed together. As you release your clutch, a disk turns the transmission. There is some slip in this disk to allow for smooth transition from a stopped condition to a turning condition. When the transmission is engaged, power is being transmitted from the primary drive to the transmission sprocket which turns the secondary drive belt. The drive belt turns your rear sprocket, which is bolted to your rear wheel. Now, the motorcycle is moving!

BRAKING SYSTEM:

But of course, you need to control this moving mass of exploding gasses, spinning gears, reciprocating pistons, and flowing electricity. To facilitate this, motorcycles have a braking system. Both the front and the rear brake operate on the same principle. There is a master cylinder, which has a chamber full of brake fluid. All fluids are mostly incompressible and when pressure is introduced in one area of a sealed fluid system, pressure rises in the entire system. When the brake is operated, a plunger pushes against the brake fluid in the master cylinder, and fluid pressure is transmitted throughout the braking system. The only other moveable components in the brake fluid system are the brake pistons in the brake caliper. The pistons move to make up for the volume lost in the master cylinder and press against a Brake Disk which is attached to a wheel. This creates friction and heat which take energy away from the wheel, thus slowing the motorcycle down.

Perhaps the most amazing part of the process is that you are a part of it. Steering, throttle, gear ratio selection, braking, and balance are all the responsibility of the operator. Motorcycles truly make a rider feel like they are part of the machine. As you grip the throttle and finger the clutch the violence of internal combustion yields to beauty of interaction. As you lean into the curves motorcycle science



yields to meditation. You smile in the warm summer air as you feel the harmonic vibration of your machine and hear mellifluous symphony of various systems operating in harmony. At this moment the fun system engages the smile actuator..... you may get a few bugs in your teeth.