

Honda CRF-150R

<u>Displacement:</u>	149.7 cc	<u>Rod Ratio:</u>	1.73:1
<u>Bore:</u>	66.0 mm	<u>Compression Ratio:</u>	11.7:1
<u>Stroke:</u>	43.7mm	<u>Combustion Chamber Volume:</u>	14.0 cc
<u>BSR:</u>	1.51:1		

Overview

The Honda CRF-150R is a racing dirt bike designed to operate at maximum power for the duration of a race. This engine uses a Unicam, Honda's design for a single overhead cam operating two intake and two exhaust valves. This engine is known for making good top end power, but lauded for valve wear and valve stem failure. It utilizes a short rod ratio with a slipper-type piston, one compression ring and one oil ring. According to sources, this design leads to faster than normal piston wear, with some racers remarking that the piston needs replacement after only a few races. Others remark that this engine has decent durability, but most note that a valve train overhaul is necessary before any serious race use is considered.

Vehicle Design Objectives

As per FHSAE rule A1.3

“For the purpose of this competition, the students are to assume that a manufacturing firm has engaged them to design, fabricate and demonstrate a **prototype hybrid-electric** competition vehicle for evaluation as a **production item**. The intended market is the **nonprofessional weekend autocross competitor**. Therefore, the car must **balance exceptional performance with fuel efficiency**. Performance will be evaluated in terms of its acceleration, braking, and handling qualities. Fuel efficiency will be evaluated during the 44 km endurance event. The car must be **low in cost, easy to maintain, and reliable**. It should accommodate drivers whose stature varies from a 5th percentile female to a 95th percentile male. In addition, the car's marketability is enhanced by other factors such as aesthetics, comfort and use of common parts. The manufacturing firm is planning to **produce four (4) cars per day** for a limited production run. The challenge to the design team is to develop a prototype car that best meets these goals and intents. Each design will be compared and judged with other competing designs to determine the best overall car.”

This rule stipulates that the vehicle must be designed as a production item, where as to minimize repair and have high reliability. To the engine development, this means that our design must have reliability in mind when making our decisions. However, as a track day vehicle, speed and performance is highly favorable to become a marketable item. Therefore, a careful balance must be maintained.

Valve Train

The single overhead cam engine uses two intake and two exhaust valves to allow substantial flow for engine speeds up to 14,000 RPM. This higher engine speed is used to get better performance from this small engine. From research conducted on forums, many claim that this engine will experience sealing issues in both the valve lands and the valve stem seals. These issues appear to only affect those who use this engine for race purposes, where such problems might become more readily apparent. The cam is a 243°/255° - 40° with an LSA of 104.5° at 1mm of lift. Maximum valve lift is 34.2 mm for intake and 44.8 mm for exhaust.

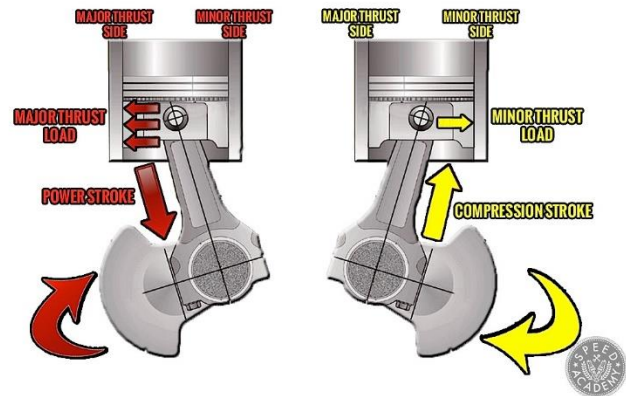
Head Design

The cylinder head on this engine is aluminum, having a dome shape and four valves. The ports are single into twin valve, with angles of XX degrees.

The ports on this engine have capacities of XXX cc on the intake side and XXX cc on the exhaust side. Performance of this head will be measured with a flow bench, a device used to measure the amount of flow and flow efficiency of the cylinder head.

Piston and Cylinder

The Honda engine is designed to have a high RPM limit, necessitating a small rotating and reciprocating mass. The piston is of a slipper design, minimizing weight and skirt area to reduce piston mass and friction. Piston design has a tradeoff between mass/friction and durability. The smaller the skirt on a piston, the lower the friction and mass, but it decreases the durability due to the crankshaft-connecting rod motion introducing force orthogonal to the desired piston motion.



To determine maximum piston speed, the position of the piston is calculated. This is based on crankshaft angle, stroke length, and connecting rod length:

$$x = r * \cos \theta + \sqrt{l^2 - r^2 \sin^2 \theta}$$

Where l is the connecting rod length, r is half the stroke length, and θ is the crankshaft angle from TDC in radians. The first derivative of this equation with respect to angle gives us piston velocity, in units of meters per radian:

$$x' = -r \sin \theta - \frac{r^2 \sin \theta \cos \theta}{\sqrt{l^2 - r^2 \sin^2 \theta}}$$

To determine the maximum velocity, the angle where acceleration is zero needs to be found. The equation for the piston acceleration is the second derivative of position with respect to angle:

$$x'' = -r \cos \theta - \frac{r^2(\cos^2 \theta - \sin^2 \theta)}{\sqrt{l^2 - r^2 \sin^2 \theta}} - \frac{r^4 \sin^2 \theta \cos^2 \theta}{(\sqrt{l^2 - r^2 \sin^2 \theta})^3}$$

When acceleration is solved for zero, we get an angle of 1.308 rad (74.96 deg). Plugging this into the equation for velocity, we get 0.02275 m/rad. At maximum horsepower, the engine is rotating at 12,500 rpm, or 1309 rad/s. Using a time based derivative of piston velocity, we find:

$$V = x' * \omega = 0.02275 \left[\frac{m}{rad} \right] * 1309 \left[\frac{rad}{s} \right] = 29.79 \left[\frac{m}{s} \right]$$

In order to prevent piston rotation, the fully enclosed depth is 61 mm, with additional supports extending an additional 14mm beyond that. Wall thickness is 3.75mm throughout, with a 33.4 mm deep water jacket extending from the top mating surface. Dry liner design.

Crankshaft

The crankshaft and connecting rod are packaged and sold as one piece, with the crankshaft being manufactured in three pieces: the left and right rod ends and balancing weights, and the connecting rod pin.

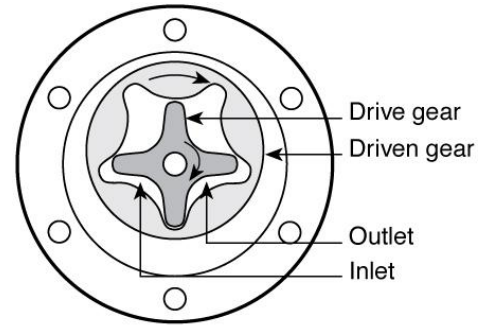
Cooling

Cooling is accomplished via water passages in the cylinder head, cylinder and crank case housing. It is operated by an impeller type water pump.

Lubrication

Lubrication is accomplished through a gerotor type oil pump, with oil passages through the cylinder head studs and the camshaft carrier.

The name gerotor is derived from generated rotor. The gerotor is a positive displacement pump comprised of an inner and outer rotor. The external-tooth drive gear meshes with an internal-tooth gear that has one more tooth than the external-tooth drive gear. As the gears rotate, the close tolerance teeth create two cavities, one that intakes fluid and one that expels fluid. The motion of the gerotor causes the intake cavity to expand drawing in fluid, and as the passage way closes, the cavity becomes the discharge cavity, forcing the fluid out of the pump as the space between the teeth becomes smaller.



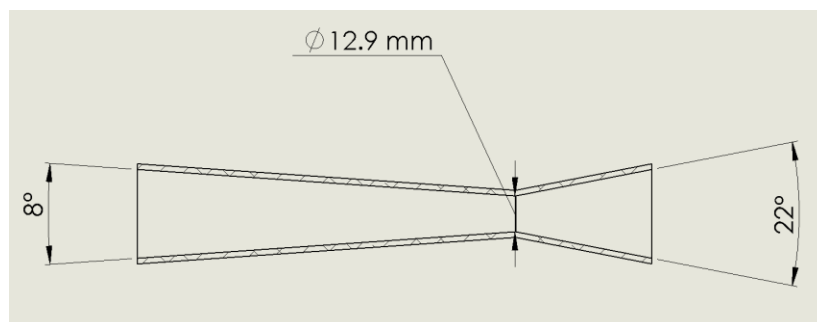
gerotor pump

Intake Restrictor

In order to ensure student safety during the event, the Formula Hybrid committee has enforced a restrictor plate on all modified engines of diameter 12.9 mm. The equation for maximum air flow through such an orifice is calculated at the choke point, where air speed is Mach 1.

$$\dot{m} = \left(D^2 * \frac{\pi}{4} \right) * P_0 * \sqrt{\frac{\gamma}{R * T_0}} * \left(\frac{2}{\gamma + 1} \right)^{\frac{\gamma + 1}{2 * (\gamma - 1)}}$$

Based on these incompressible flow calculations at standard temperature and pressure, this limits maximum air flow to 0.03122 kg/s. Research on how to minimize pressure loss around this restrictor has shown that pressure loss can be minimized to 11% across the restrictor based on a venturi design.



References

FHSAE Rules: Formula Hybrid <http://www.formula-hybrid.org/wp-content/uploads/2016-Formula-Hybrid-Rules-Rev-0.pdf>

Piston Thrust: BBA Media <http://speed.academy/pri-spotlight-je-pistons-asymmetrical-piston-design/>

Piston Motion: EPI Inc. http://www.epi-eng.com/piston_engine_technology/piston_motion_basics.htm

Gerotor Pump: Aviation Supplies & Academics <http://www.datwiki.net/images2/Gerotor-pump.jpg>