Summary 2 Stroke Oil Testing

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Summary comments oil mixes and carbon formation:

These tests were designed to simulate the effects of long-term high engine temperatures on the formation of carbon from the different two-cycle oils tested. The target temperature was 220 degrees F. However, it was only achieved on a couple of engine runs. A more typical temperature was in the 190-200 degree F range. In order for these tests to be truly scientific, each engine run would have to be replicated on a different engine and the order of the oil mix runs randomly selected. The only thing close to science about these results is that they were run by an individual who makes a living as a scientist. The cost of this trial was estimated to be between $2500-$3000. It was conducted in support of an ongoing research program utilizing large RC aircraft to conduct aerial sampling for various projects. I am happy to share the results with you.

After conducting the tests, the real question in my mind is whether the engine temperature within normal running parameters actually has any influence on the formation of carbon at all. It seems to me that the temperature of combustion of a fuel mix over an extended period would not change very much regardless of the temperature of the engine. Testing this idea would require another series of engine runs which won't happen anytime soon in my shop.

The validity of the idea that engine temperature within normal range has little impact on the formation of carbon in the engine because the heat of combustion is similar regardless of engine temperature (within normal range), impacts the conclusions of this test. If you believe that engine temperature impacts carbon formation then these results only apply to engine runs of extended length with elevated engine temperatures. However, if you believe that the heat of combustion is similar regardless of engine temperature (within normal ranges) then it is the heat of combustion which impacts the formation of carbon and these results apply to the typical flyer who runs an engine at all throttle settings and engine temperatures. It is my belief (without data which is dangerous) that within the normal engine temperature ranges of 100-200 degrees F, the heat of combustion changes little throughout the engine run and carbon formation is consistent regardless of engine temperature. The amount of carbon in an engine seems to be related to the quantity of fuel burned for a specific oil brand.

I think (maybe I am optimistic) that the data from these extended engine runs is an indicator of the carbon formation for each of these oil mixes under normal engine running conditions. A quick check of the validity of this concept would be for several modelers who has used one of these oils and burned at least 3 gal of fuel in an engine to pull the cylinder off the engine, take a picture and post it. We could then compare the picture I will post (with the help of Ken) to the picture of carbon deposit accumulated under normal conditions.

Interpreting the results:

As you look through the pictures, you will notice 4 different patterns of carbon formation on the piston. Amsoilgenerally coated the entire piston, Mobil and a couple of others coated the majority of the piston leaving some portions clean, Pennzoildeposited carbon in a single stripe and Belray deposited carbon in a couple of spots. I don't know the explanation of the deposition patterns or the importance of the patterns.

Bel Ray oilmix:

I believe that I have an explanation about the initial increased temperatures and increased fuel consumption with Bel Ray H1R.

For the test engine to turn the propeller at 6000 rpms, a very similar amount of energy was required from each oil-gas combination. Surprisingly, all of the oil-gas mixes except 2, required only very minor adjustments of the high speed needle to achieve peak rpms. Therefore, the energy per unit volume of all of the oil-gas mixes except two were very close. The two oil-gas mixes which required a major adjustment of the high speed needle were Belray @ 32:1 and Amsoil@ 100:1. Both of these mixes required that the high speed needle be opened between 1/8 and 3/16 of a turn. Therefore, these 2 mixes had less energy per unit volume than the other 8 mixes. Since these two mixes are very different, what is the explanation?

I believe the evidence strongly suggests that on the 8 mixes which only required minor adjustment of the HS needle, combustion of the oilcontributed a significant amount to the energy required to turn the prop. These mixes also had significant carbon accumulation.

In the case of Belray, the oildid not combust and did not provide any energy to the task of moving the propeller. Therefore, the HS needle needed to be opened to allow more gas into the engine to provide the energy to spin the prop at 6000 rpms. The lack of carbon formation with this oilalso supports the suggestion that the oilwas not burning and adding energy to the fuel. The high cylinder temperatures observed early in the run was from a lean run. Opening the needle valve was required to allow enough gas into the engine to readjust the mixture to the proper ratios. Since the oildoes not combust, the fuel requirements of the BelRay oilmix is increased by around 15%. In other words, you need to carry around 15% more fuel on your airplane for the same flight time. This is not much of an issue for the average modeler but it may be a real issue for me. If I burn off a gallon of fuel per flight (typical of some flights), I will have to carry an additional 20 ozs of fuel if I choose to use Belray h1R (an extra 1.5 lbs of fuel load).

In the case of Amsoil100:1 mixed at 100:1, there is so little oilin the mix, the combustion of the oiladded very little to the energy needed to turn the prop. The HS needle had to be opened to allow in the extra required gas to turn the prop at full speed. The presence of carbon with this mix indicates that the oilwas burning but was in insufficient quantities to provide much power.

Finally, please remember that this test looked at carbon formation but did not examine the ability of the oil mixes to lubricate.

Several individuals have ask me to conclude which oil I would use in my "high engine stress" flying in the summer of '05. Remember, this is my biased opinion.

1) I would never use Amsoil100:1 mixed at 100:1. There is no decrease of carbon formation and I noticed an increase of piston scuffing on the test engine. Even though I have over $20,000 of engines in my shop which I did not purchase on my own money, I still think it is "nuts" to shorten the life of an expensive engine from limited lubrication for the benefit of airplane cleanup.

2) If you don't mind scraping a little carbon every couple of years, any of the oils mixed 32:1 to 50:1 are a good choice.

3) For my net-pulling planes which really work hard, I will probably switch to BelRay H1R at 32:1. The 100 cc planes will burn 1 gal+ per flight and the 200 cc planes will burn 2 gal+ per flight.

4) For my fleet of 12-3W-50 powered planes which run full throttle of 35 min but don't pull as draggy of sampling devices as the net planes, I plan to evaluate BelRay MC-1 at 40:1 or 50:1 before making a decision.

Test Parameters

Test engine: 3W-42 (1/2 of an 85) which was well broken in. The cylinder was removed and the piston, ring and inside of the cylinder was cleaned of carbon. The picture of the piston is a typically cleaned piston before the start of each test. The engine was reassembled. This process was repeated before the start of each new oil test.

I think everyone should respect the toughness of the test engine. It is hooked to an immovable object, runs full bore with too large a prop for 6 hrs straight with temperatures near the acceptable maximum. This engine has churned through 30 gallon of gas/oil mix, run for 58 hrs and never missed a beat. It is running just as strong as when I started. I think one could call this test, engine abuse.

Amsoil Dominator 50:1 at 50:1. Gas was 93 octane.

The engine was run for 6 hrs and almost 3 gal of fuel was burned. Engine temperatures fluctuated 210-220 degrees. Outside temperature was 30-32 degrees. Engine rpm with a 24 x 10 prop was 6000.

After 6 hrs of running at full throttle, the piston was covered with brown hard carbon 5-10 thousands thick. A 1/2 inch band running from the intake port to the center of the piston was shiny clean otherwise the entire piston was covered with carbon. No carbon was found on the ring, ring groove or inside the dome of the cylinder. This carbon buildup was very similar to AmsoilSaber 100:1 mixed at 50:1.


Amsoil Dominator 50:1 oil mixed at 20:1. Gas was 93 octane.

The engine was run full throttle for 6.5 hrs. During this time period, 3 gallons of fuel was burned. For the first 2.5 hrs, the engine was propped with a 22 x 10 prop and the head temperatures fluctuated around 180 degrees F. With this prop, the engine turned 6200 rpm. In an effort to raise engine temperatures to the 220 degree F range, the prop size was increased to 24 x 10 for the final 4 hrs of the run. Engine rpm were 6000 and head temperatures fluctuated around 200 degrees F. Outside temperature was 30-32 degrees F.

In 6.5 hrs of running, there was significant carbon formation on the top of the entire piston and in the entire dome of the cylinder. There was no carbon formation on the ring or in the ring groves. The carbon had a brownish cast and was very hard. Carbon layer was in the range of 10-15 thousands thick.

Amsoil Saber 100:1 mixed at 50:1 - gas was 93 octane

The engine was run for 6 hrs and almost 3 gal of fuel was burned. Engine temperatures fluctuated around 220 degrees. Outside temperature was 30-32 degrees. Engine rpm with a 24 x 10 prop was 5900-6000.

After 6 hrs of running, there was a light carbon coating on the entire piston, which scraped very easily. The dome of the cylinder was the same. There was no carbon formation on the ring but the top of the ring has a slight brownish cast. This reduced carbon over oil#1 may be a result of higher engine temperatures (20 degrees F) or the oilitself. It was interesting to note that the initial engine temperature shot up to 235 degrees F after running 15 min and then cooled down to the 220 degree F range.

Amsoil100:1 at 100:1. Gas was 93 octane.

The engine was run for 6 hrs and almost 3 gal of fuel was burned. Engine temperatures ranged between 190-205 degrees F. Outside temperature was 30-32 degrees. Engine rpm with a 24 x 10 prop was 5680-5900. This drop in engine rpm was very obvious. Either the engine is finally showing the wear of the long accumulated runtime or the 100:1 oilmix did not give the ring seal of the higher oilmixes or both.

After 6 hrs of running, there was a carbon coating on the entire piston which was quite hard. The carbon was harder and slightly thicker than the AmsoilSaber 100:1 mixed at 50:1. Hard carbon was also forming on the cylinder head just above the exhaust port. Two spots of carbon were also forming on the ring. Piston scuffing on the skirt started showing up after this 6 hr run on 100:1. Scuffing was on both the intake and exhaust sides of the piston. This may be due to the low oilor just to the 54 hrs of accumulated time and the wearing of the wrist pin and bearings. I will be interested to see if the engine rpm return in test run #10 when we go back to the high oilratio mix.

The photos are representative of 50:1 and 100:1.

Mobil 1 MX2T mixed at 32:1. Gas was 93 octane.

The engine was run for 6 hrs and almost 3 gal of fuel was burned. Engine temperatures fluctuated 210-220 degrees. Outside temperature was 43-45 degrees. Engine rpm with a 24 x 10 prop was 5880-5910 down from 6000 with most other oils.

After 6 hrs of running at full throttle, the piston was covered with hard black carbon 5-10 thousands thick. A 1/2 inch band running from the intake port to the center of the piston was shiny clean. The piston edge close to the intake port had a 1/8" clean area and the piston edge next to the exhaust port also had a clean band 1/8" wide. Otherwise the entire piston was covered with carbon. Carbon buildup also was starting on the upper edge of the ring and in the cylinder dome. This carbon buildup was very similar to AmsoilSaber 100:1 mixed at 50:1 and AmsoilDominator mixed at 50:1. The only difference was the color of the carbon. Mobile carbon was black and Amsoilcarbon had a brownish cast. Both carbons were very hard.


Mobil 1 MX2T + injector cleaner

The final test was to take Mobil 1 MX2T which formed carbon in the previous test and mix 2 oz/gal of injector cleaner into the gas/oilmix to see if the injector cleaner had any effect on carbon formation as suggested by one modeler.

We ran the engine for 3.5 hr at full throttle. Engine rpm returned to the 5900-6000 rpm level indicating a better ring seal that Amsoil 100:1 at 100:1. With the air temperature 24 degrees F, we were only able to achieve cylinder temperatures of 190-195. In spite of the lower temperatures, we still had significant carbon formation very similar to when Mobil was run without the injector cleaner and the cylinder temperature was higher. After 3.5 hrs, we pulled the plug and looked with a flashlight. Since we could see carbon formation on the piston, we stopped the test, pull the cylinder and took pictures.

Remember, this carbon formation is just in 3.5 hrs rather than 6 hrs.


Pennzoilair cooled at 20:1 - gas is 93 octane.

The engine was run for 6 hrs and almost 3 gal of fuel was burned. Engine temperatures fluctuated 215-220 degrees. Outside temperature was 30-32 degrees. Engine rpm with a 24 x 10 prop was 5900.

After 6 hrs of running, the 1/3 of the piston next to the intake port was shiny clean. A band of carbon equal to about 1/2 of the area of the piston ran down the middle of the piston in line with the boost ports in the front and back. The thickness of the carbon band was 5-10 thousands and it was black carbon and soft. The area directly in front of the exhaust port was shiny clean. The dome inside the cylinder was without any carbon buildup. There was no carbon formation on the ring or ring groves in the piston.

PennzoilTWC-3 outboard synthetic mixed 32:1 gas is 93 octane

The engine was run for 6 hrs and nearly 3 gal of fuel was burned. Engine temperatures fluctuated around 200 degrees F. Outside temperature was 24-26 degrees F. Engine rpm with a 24 x 10 prop was initially 6130 rpm for the first hour, 6060 for the second hour then settled to 6000 for the remainder of the run.

After 6 hrs of running, the carbon formation looked a lot like the Pennzoilair-cooled. The 1/3 of the piston next to the intake port was shiny clean, and a band of carbon equal to about 1/2 of the area of the piston ran down the middle of the piston in line with the boost ports in the front and back. The thickness of the carbon band was 5-10 thousands and it was black hard carbon. The area directly in front of the exhaust port was shiny clean. The dome inside the cylinder was without any carbon buildup. There was no carbon formation on the ring or ring groves in the piston.

While the piston and cylinder look great, this oilmix really plugs up exhaust systems with carbon.

Belray H1R mixed at 32:1, gas is 93 octane.

The engine was started and tuned slightly rich as in past tests. The engine temperature soared to 235-240 degrees within 5 min of running. The mixture was richened a bit more and the engine temperatures dropped back into the 220 degree range for the remainder of the run. However, the engine burned the 3 gal of fuel in 5.25 hrs compared to a small amount of fuel remaining after 6 hrs of run time. Outside temperature was 42-48 degreed F. Engine rpm with a 24 x 10 prop was 5900.

After 5.25 hrs of running at full throttle, there was almost no carbon on either the piston or within the dome of the cylinder. The little bit of carbon present on the piston was two small spots in front of the boost ports close to the piston edge. The carbon was black and very soft. Otherwise, the piston was shiny clean. The cylinder dome was also shiny clean. This is the best looking oiltested to this point with lots of oilthroughout the engine and no carbon buildup.

This mix requires about a 15% increase in fuel consumption.