May 2, 2011

Harley engine balancing…. Reverse engineering and the balancing process…. How I do it.

Hi Everyone,

I was looking for a while for a Harley engine to balance to show my students and the members here how to balance a bottom end. I was also looking for an engine that was vibrating badly.

Since we took care of the Sidewinder project a few months ago, my students seem to like it a lot when we're touching the mechanical stuff like that… and, they are also happy when there are different things to learn on the way. (For those who did not follow the thread, we are talking about the machining process of a S&S sidewinder 93 shovelhead engine.)

I also think that it was my turn to show you how I balance a Harley engine. But, before starting this story, I had to talk with the owner of the bike.

….He told me that he had the bike for a short period now and certainly had the time to ride it but trying to keep up with his friends with newer bikes with EVO and Twinkie motors was not an easy task.

He said that he was riding a lot of the time on the highway at a speed of around 70-75 miles per hour, trying to keep the pace with his friends. He mentioned to me that never mind the speed he goes, they were always in front of him and he simply could not run with them. They were riding too fast and his Shovelhead was vibrating like hell and breaks loose at that speed. So, he told them all that from now on he would still ride with them but will probably arrive well after them. "No big deal," they say, "As long as you still ride with us"……"or," I would say, "behind them."

The main reason for this, he was really feeling uncomfortable with his ride. His bike, a 76 Shovelhead, assembled from a mismatch of parts from an FX model with a bore of 3-5/8" with a stroke of 4-1/2". A '93' engine with S&S flywheels in an STD case.

He told me that his arm was becoming very numb after a short ride. He meant almost paralyzed up to his shoulder. From what he was showing me, it seemed real bad. His ride was really showing signs of problems too. Like the two tank mounting tabs were broken and the carburetor mounting was also found broken. Not to mention, the many parts that became loose on his bike. So, to me it seemed that I found the perfect engine I was looking for. He had a real problem. Now, to show my students how to balance a Harley V-twin engine, why not take an engine that has a real problem. I offered to take care of his engine for him. At first he was not willing due to money. But, I asked again just for the purpose to educate my students around the Harley vibrating myth…. I think it might have helped change his mind when I told him I would work for free.

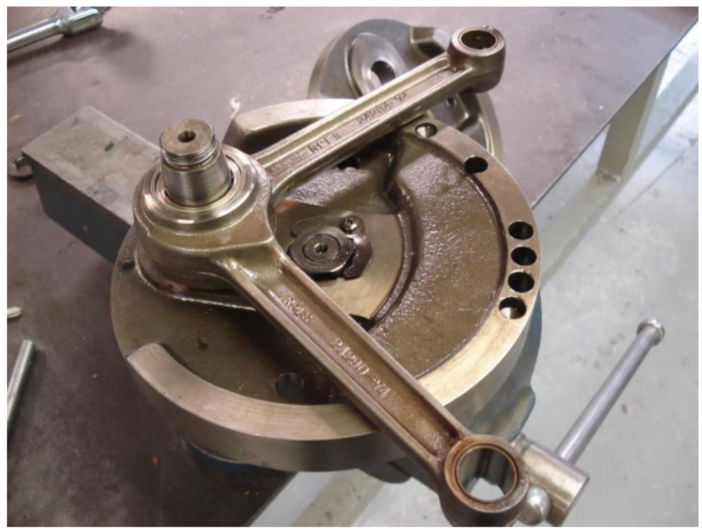
So let the story begin, hope you will enjoy this as my students did…. :)

First thing to do…. start disassembling those flywheels. By the connecting rods side play, I suspect some wear on the crankpin. Here in the picture shown, the two 1/2" rods serve to lock the flywheels against the jaws of the vise to help in taking off the nuts.

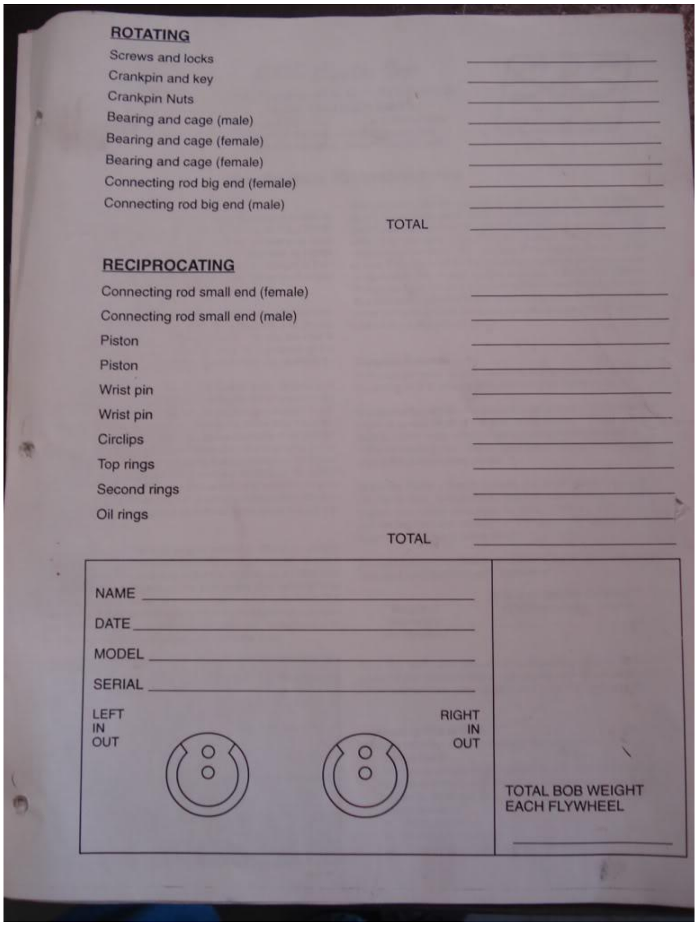
I had checked the assembly on the lathe between centers and put a dial indicator on the pinion shaft where the rollers run and near the remaining Timken bearing before disassembly. Runout was less than 0.001" so that was not the problem.

This engine was run with a set of S&S stroker wheels and a stock set of connecting rods. I could tell it was static balanced at some time in the past by the series of holes located inside the face of both wheels.



When both flywheels were completely disassembled, cleaned and ready to be checked, I noted and wrote down all information. A standard process for me when rebuilding an engine.



ROTATING

Screws and locks ______
Crankpin and key ______
Crankpin Nuts ______
Bearing and cage (male) ______
Bearing and cage (female) ______
Bearing and cage (female) ______
Connecting rod big end (female) ______
Connecting rod big end (male) ______
TOTAL ______

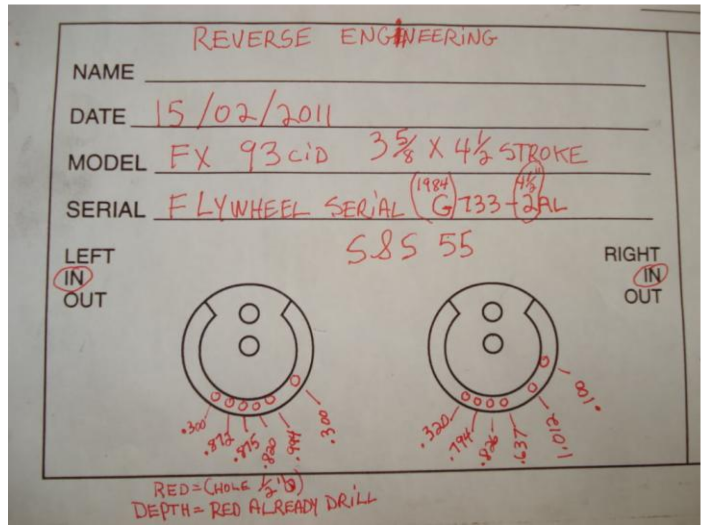
RECIPROCATING

Connecting rod small end (female) ______
Connecting rod small end (male) ______
Piston ______
Piston ______
Wrist pin ______
Wrist pin ______
Circlips ______
Top rings ______
Second rings ______
Oil rings ______
TOTAL ______

NAME ______
DATE ______
MODEL ______
SERIAL ______
LEFT IN OUT
RIGHT IN OUT
TOTAL BOB WEIGHT EACH FLYWHEEL ______

Pictured is the balancing sheet I use for this.

You can see what I usually do. I note the model number, flywheel and/or case serial numbers, whether the holes are made inside or outside of the flywheels, where holes are located on each flywheel and the depth of the holes. All that for future reference.



REVERSE ENGINEERING
NAME ______
DATE 15/02/2011
MODEL FX 93 CID 3 5/8 X 4 1/2 STROKE
SERIAL FLYWHEEL SERIAL (1984) G 733-2AL (4 1/2")
585 55
LEFT IN OUT
RIGHT IN OUT
.300 .300 .320 .794 .637
RED=(HOLE 1/2")
DEPTH= RED ALREADY DRILL

What I do is called a “reverse engineering” to see why this engine was vibrating in the first place. I weigh the rotating and reciprocating parts that were installed in that engine. My final calculations end up with a bob weight amount “X”. (Bob weight is a counter weight that equals the total weigh of the rotating mass plus a percentage of the reciprocating mass. Divide by 2 if you are using the static method)

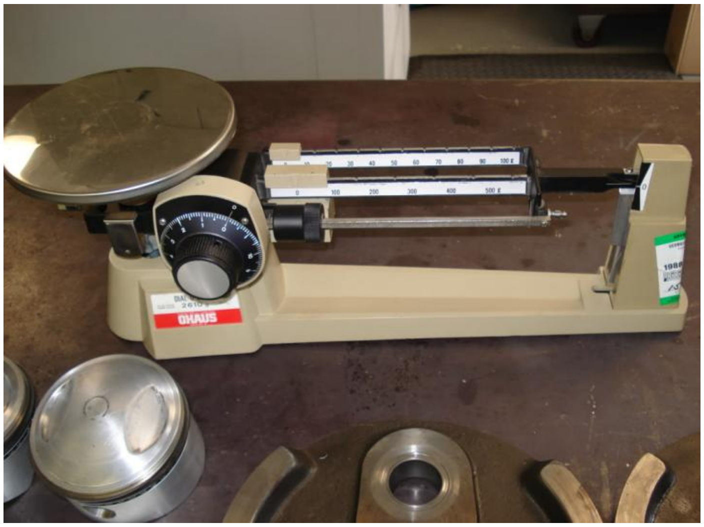
What you see in this picture are the rotating and reciprocating parts involved.

In this picture, parts that are classified as rotating mass are the crankpin nuts, the locks with screws for the nuts, crankpin with small keys, the roller bearings with cages, and the lower part of the connecting rods (also referred to as the "big end"). Those rotating parts count 100% in the calculation divided by 2 for each flywheel at the end.

Weighing the reciprocating mass in the engine shown in this picture. Those included are the upper parts of both connecting rods (also referred to as the "small end"), the two pistons, wrist pins, piston rings, four Teflon buttons in this case (if using cir-clips, those also need to be included). All these parts are going to be included in the formula, as a percentage of the total weight called the "balance factor". We will discuss this later.

What I use to balance the rotating and reciprocating parts is my old Ohaus "Dial-o-gram" precision scale. The degree of precision is within 0.1 grams and I am always working within 0.1 grams.

I had an electronic scale before but that one is long gone. The electronic scale was faster to use but not bullet proof. A mechanical type like this one is more rugged…and last a lot longer.



First thing to do when doing a reverse engineering is weighing all the parts. Write down everything. First, start with the rotating portion. Crankpin with nuts, the small woodruff keys in the shaft and the 2 locks with screws that serve to secure the 2 crankpin nuts.

Weight the two female rollers with cages and the male rollers with cages. These are weighed individually and I note the total amount on my balancing sheet.

Then weigh both connecting rod big ends. Here is the special rod support I made for this purpose. Both aluminum bushings were machined for the “small end” or “big end” and are installed on really smooth turning C3 bearings for less friction. All I have to do is take off the total weight of the platform. (What you see in the picture supporting the big end of the connecting rod on the scale is what I am referring to as the platform). Subtracting the weight of the platform is something that was done faster with the “tare” option on my late electronic scale.

To make this easier, I stamped the weights I need to subtract in the platform itself.

You need to take care to have perfectly level rods when weighing them. Remember, when you are weighing connecting rods, the total of both the big end and small end should equal the total weight of the connecting rod itself to within 6 grams. If it is not within 6 grams, you have to start all over again. Weighing the connecting rods is what normally takes the longest.

In this particular case, I end up within (0.6 grams)… If you have less than 6 grams at the end of the weighing session, you are good to go.

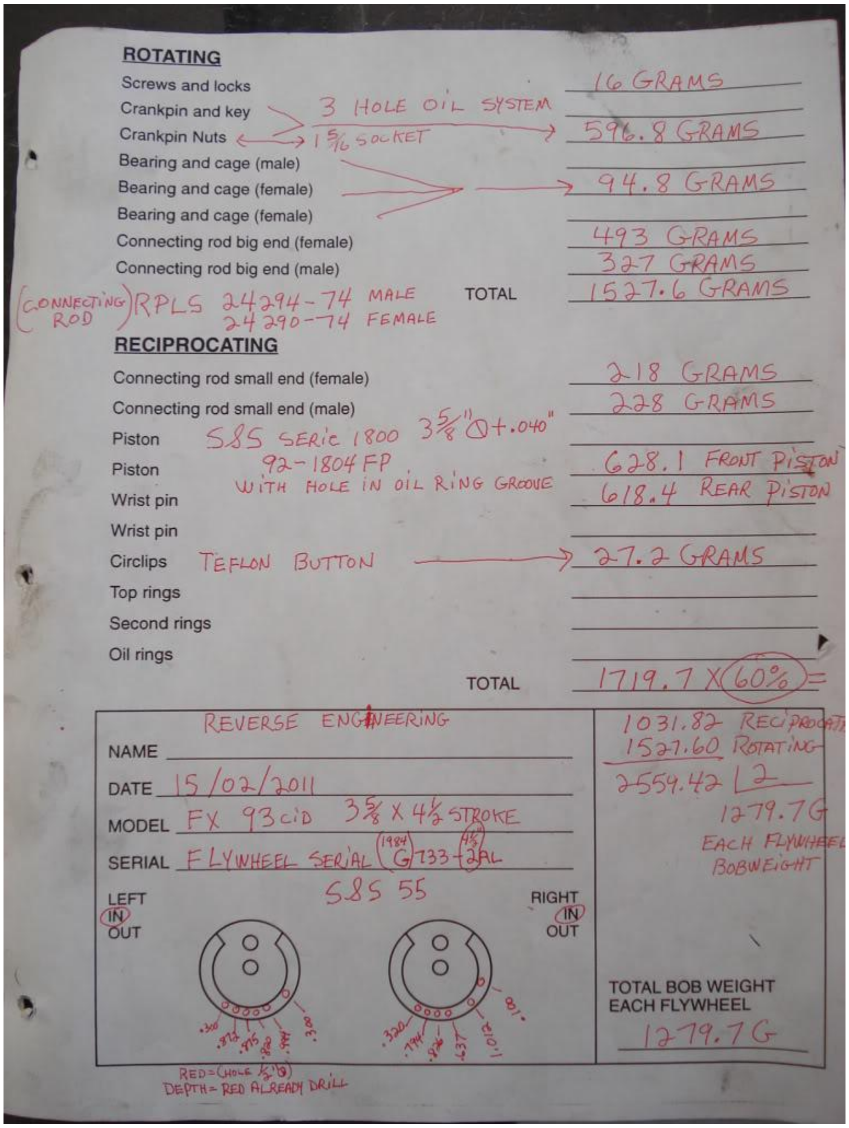
All you need to do now is add or subtract 2/3rds of the remaining weight to the rotating mass and add or subtract 1/3rd of the remaining weight on the reciprocating mass. In my case 0.4 grams was added on the rotating mass and 0.2 grams was added on the reciprocating mass for a total of 0.6 grams.

Supporting the big end for weighing the small end making sure both centers are at the same height.

Part of the reciprocating (small) end of a connecting rod.

Both pistons with rings and wrist pins need to be included in the formula for the weighing session. I did not take off the rings and wrist pin for this. The owner still wants to run the same set of rings since the top end was just done last year with barely noticeable wear. So, why take chances taking off those rings. I am NOT a big fan of using the same rings but in this case the customer wants to save some money.

Finally, to finish weighing the reciprocating mass, the small Teflon buttons that serve to secure the wrist pin instead of cir-clips are weighed.


ROTATING

Screws and locks		16 GRAMS
Crankpin and key	3 HOLE OIL SYSTEM	
Crankpin Nuts	1 5/16 SOCKET	596.8 GRAMS
Bearing and cage (male)		
Bearing and cage (female)		94.8 GRAMS
Bearing and cage (female)		
Connecting rod big end (female)		493 GRAMS
Connecting rod big end (male)		327 GRAMS
(CONNECTING ROD) RPLS 24294-74 MALE, 24290-74 FEMALE	TOTAL	1527.6 GRAMS

RECIPROCATING

Connecting rod small end (female)		218 GRAMS
Connecting rod small end (male)		228 GRAMS
Piston	S&S SERIE 1800 3 5/8" ⌀ +.040"	
Piston	92-1804 FP	628.1 FRONT PISTON
Wrist pin	WITH HOLE IN OIL RING GROOVE	618.4 REAR PISTON
Wrist pin		
Circlips	TEFLON BUTTON	27.2 GRAMS
Top rings		
Second rings		
Oil rings		
	TOTAL	1719.7 X 60% =

REVERSE ENGINEERING

NAME

DATE 15/02/2011

MODEL FX 93 CID 3 5/8 X 4 1/2 STROKE

SERIAL FLYWHEEL SERIAL (1984) G 733-(45) 2AL

S&S 55

LEFT IN OUT

RIGHT IN OUT

1031.82 RECIPROCATING
1527.60 ROTATING
2554.42 / 2
1279.7G
EACH FLYWHEEL BOBWEIGHT

TOTAL BOB WEIGHT EACH FLYWHEEL 1279.7G

RED = (HOLE 1/2") DEPTH = RED ALREADY DRILL

Here are my final calculations. I will figure out at what percentage of "balance factor" this engine was done at first. This is what I call the "reverse engineering." It will show us why this engine was vibrating like hell.

I end up with 1279.7 grams on each flywheel and at a 60% balance factor (balance factor is a percentage of the total reciprocating weight in the calculation). The rotating weight is included as 100% in the calculation.

In this case, I use 60% balance factor as all of my balancing jobs. Some prefer 50% (like pre-73 Harley engines) as all were balanced that way from the motor company. Some use 55% for heavy flywheels. Some prefer 58% and some 59%. But a good rule of thumb is 60% balance factor. I balanced my own 67 Generator Shovel with a 60% balance factor and I am feeling really... and I mean really comfortable with it. And those are among the heaviest wheels you can find on a Harley…

There is a lot of arguing about the "balance factor." Normally, all Harley engines need to be balanced at a certain balance factor located between 50% to almost 70%. Always depending on the set up you have. Early engines were balance at 50% with a average bob weight for all of them. Some were worse bone shakers than others. But remember, if you use the same bob weight for all engines you might end up with at least some slight variation ending up with some that will show more vibration than other… needless to say.

Those pre-73 engines were also ridden at a slower speed than what we ride nowadays. The motor company was using a lower balance factor to make a more equal balancing from the vertical and horizontal plane. Then they decided to change that balance factor in 1973 to a higher percentage at 60%.

The higher you go on your balance factor percentage, the more you move the unbalanced plane to a horizontal one. Horizontal plane make it more comfortable as your bike runs in a horizontal motion. You cannot go higher than 60% on big twins or the vibration will simply get worse on the horizontal plane. So it is safe to say, nothing under 50% and nothing over 60% for big twin engines.

You can go higher with your balance factor, like for example, on newer EVO Sportster engines. Those can be as high as 69%. Again, a different engine set up. And, if you look at the rubber mount engines, they seem to perform a lot better at around 54%…. Remember that whatever the factor you are using, you will only move the annoying unbalance feeling of your own motorcycle to another RPM or speed…it is only a compromise when talking about balancing a Harley engine. You will never achieve a perfectly balance engine with a 45 degree set up…. Again, it is only a compromise to a certain speed or RPM range that you normally ride at most of the time and that speed is normally located between 55 and 75 miles per hour. Below or higher than that speed you will encounter some slight vibrations. Probably the reason why Harley came up with some rubber mounted handlebars and floorboards to try get rid of the numb feeling rider's were complaining about. Also, probably to compete with the import motorcycles from Japan and Europe. Other parts that might be taken in consideration when talking about vibration on a Harley is the motor support, clutch hub, tires and wheels to name a few. Those parts could lead to the same result as unbalanced flywheels. Maybe not as bad but, still quite annoying.

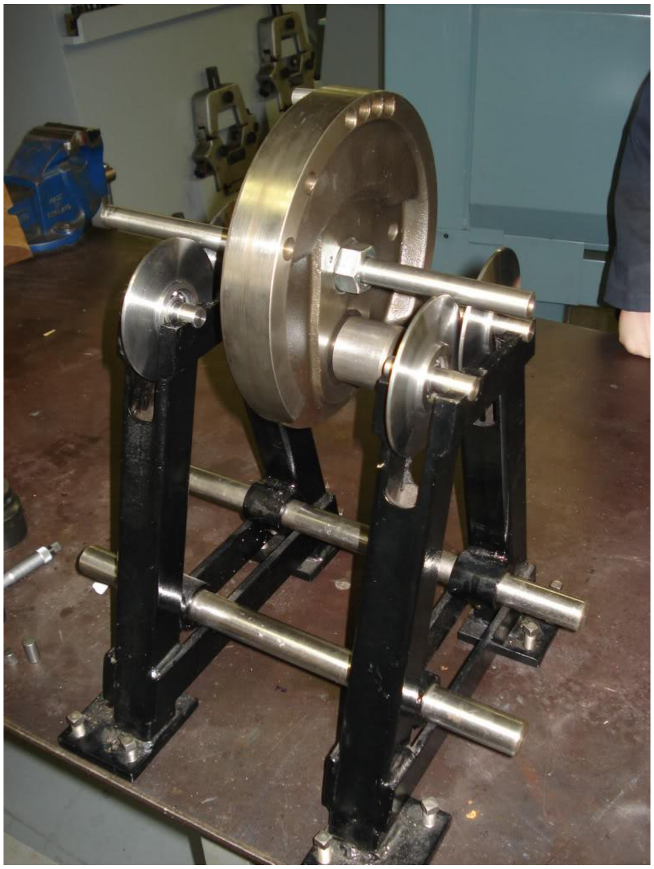
An engine that has been balance with great care using the static method is to my opinion as close as you can get it. A dynamically balanced engine is done faster when everything is set and ready but the method is not necessarily better. Remember the "compromise" in balancing a 45 degrees Harley engine.

Rule of thumb is… if the component to be balanced is no more than 4 inches wide it can be balanced on a single plane. If wider than that, it is recommended to use the dynamic balance method. This method could balance double or multiple planes at the same time. Since each Harley wheel is not that wide, they can be balanced with the static method with good success.

Those using the dynamic method have to align and true both wheels with or without connecting rods mounted on the assembly (depending on the type of balancing machine they are using). Then they need to drill the holes on the outside face of the flywheels. This method has a tendency to hold oil on the outside face of the rims and cannot escape easily due to the close gap between wheels and crankcase. Oil equals weight. If this oil cannot get out easily, this will result in an unbalanced engine…. Also, that oil will have a tendency to form bubbles and foam when forced to escape via the tight space. As a result, that oil cannot do its job well either. We're talking about cooling and lubricating that will be affected…. Again, this is my opinion.

Normally I do not include oil in my balancing formula but some do (amount of oil count as weight in some balancing formula). It is hard to figure out how much oil will count in the balancing as every engine is different in regards to volume and or scavenging the oil in the crankcase.

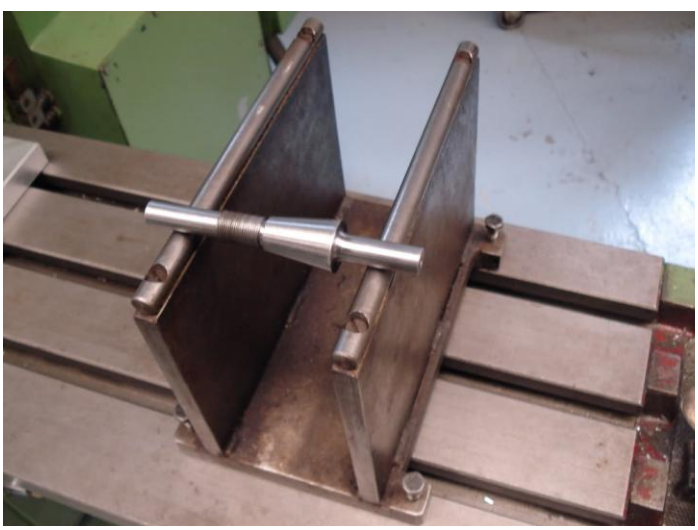
Shown here is a complete bob weight assembly for dynamic balancing. This kit is one that is custom made but could also be bought from a special supplier.



Let's continue with the story. Here is my personal static balancing stand for balancing a Harley flywheel. It is a custom stand made for that specific purpose as is all the special tooling I use in this thread.

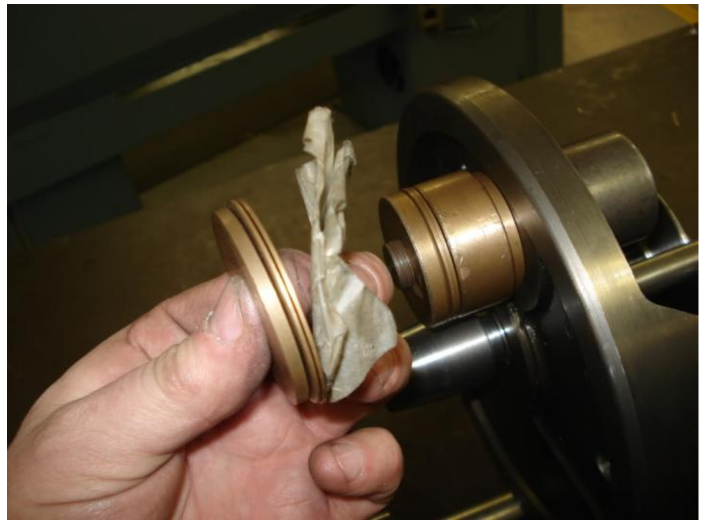
Most people who balance either in a shop or at home still use the knife edge stand like those sold by S&S. Shown here is my very first balancing stand. It looks like an S&S stand with slight improvements. I now prefer to use my newer one. A little more precise using big roller wheels with C3 bearings without oil to reduce friction. It does not take much force to make it turn.

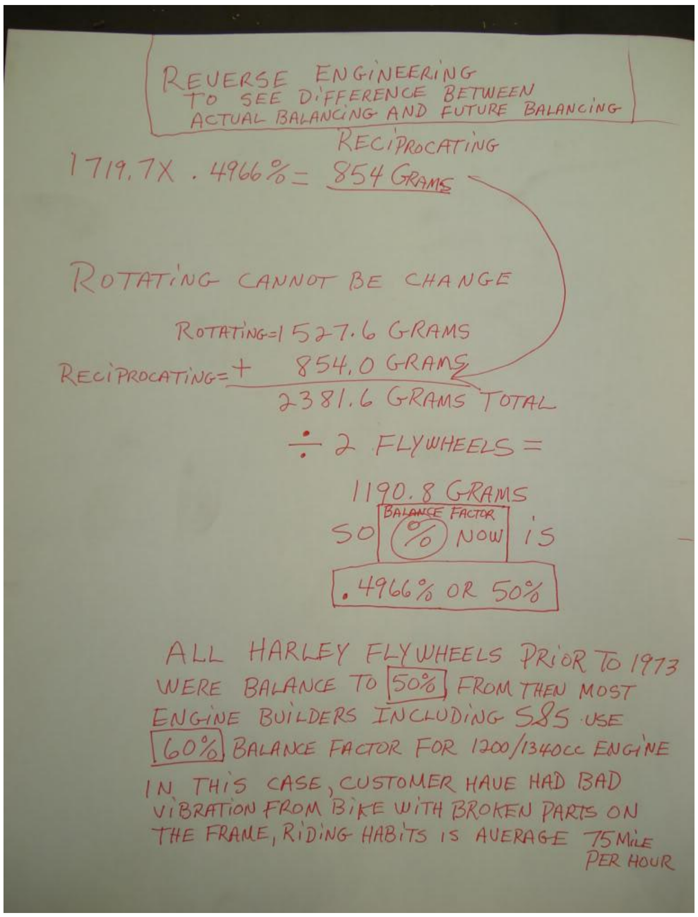
Those knife edges are cheaper to build as a manufacturer's point of view and still do the job no problem as long as they are perfectly level. In this case, a center bolt and 4 jack screws in each corner make it easy to level.



And for those who are looking to build one, another stand type that could be built at home without too much equipment is this one. I made it in the past to balance grinding wheels. Quite similar to the knife edge except for the two round rods bolted on top of steel plates. Being bolt-on pieces, they can be replaced if damaged.

Back to the balancing process: After all my calculations are done and the bob weight installed on the flywheel, I noticed a strong movement as the bob weight dropped suddenly to the bottom (remember mother earth's gravity attraction) meaning I was really out of balance. So I start taking off some of the bob weight a little at a time. Shown in the picture is what I took off and then the wheels were not moving at all meaning they were in perfect balance. Wherever you stopped the wheels they don't move.





REVERSE ENGINEERING
TO SEE DIFFERENCE BETWEEN
ACTUAL BALANCING AND FUTURE BALANCING

RECIPROCATING
1719.7X .4966% = 854 GRAMS

ROTATING CANNOT BE CHANGE

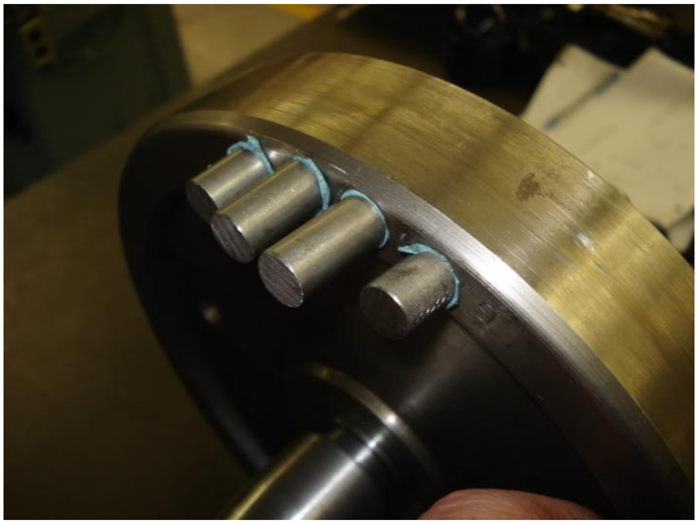
ROTATING = 1527.6 GRAMS
RECIPROCATING = + 854.0 GRAMS
2381.6 GRAMS TOTAL
÷ 2 FLYWHEELS =
1190.8 GRAMS
SO BALANCE FACTOR % NOW IS
.4966% OR 50%

ALL HARLEY FLYWHEELS PRIOR TO 1973 WERE BALANCE TO 50% FROM THEN MOST ENGINE BUILDERS INCLUDING S&S USE 60% BALANCE FACTOR FOR 1200/1340cc ENGINE

IN THIS CASE, CUSTOMER HAVE HAD BAD VIBRATION FROM BIKE WITH BROKEN PARTS ON THE FRAME, RIDING HABITS IS AVERAGE 75 MILE PER HOUR

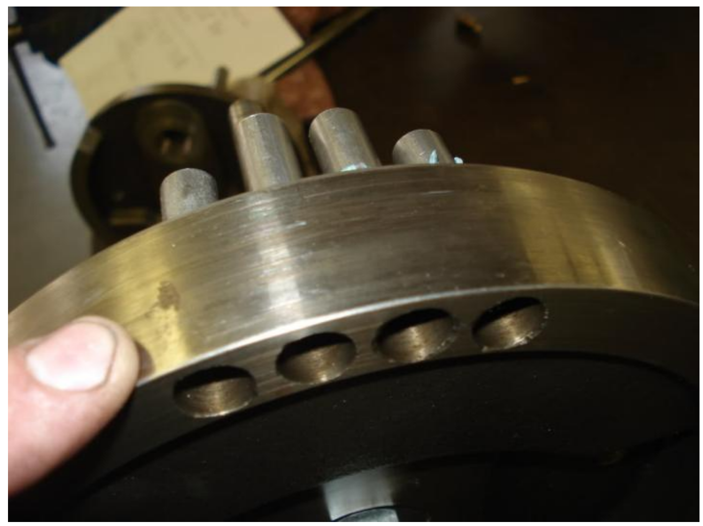
So, I weigh the remaining bob weight and find a balance factor of 0.4966 of 50%. See my calculations below.

To obtain the 60% factor I was looking for at first and to show you how much weight needs to be add on the opposite side, I simply use MACtac blue adhesive to hold things on the side of the wheels.



I use small metal plugs a 1/2” in diameter the same size of the hole that was drilled in them before.

Noticed the position of the plugs versus the previously drilled holes, I tried to match the length of holes with similar plugs on the opposite side and the wheels are now very close to balanced…at a 60% balance factor. So what happened on this specific engine? Were there changes in connecting rods and/or pistons in the past, for example? Why were those wheels so out of balance? I guess we will never know but we will correct the problem….



This is basically what needs to be added to both flywheels to have them balance to a 60% balance factor. They were off by 88.9 grams (or slightly over 3 ounces each if you prefer). At that diameter, it makes a whole lot of difference from a very unbalanced engine to a smooth running engine.

To give you an idea, just imagine if you put the total amount we just found multiplied by 2 for both wheels (179.8 grams) in a small bag and twirl it in a very short radius at the highest speed you could. It would give you an idea of what I mean by very unbalanced….and remember, you are not turning at the normal speed of an engine.

But wait! That’s not all about this engine….the reciprocating weight difference between both front and rear connecting rods should be very close to each other as well to have an engine that runs smoother. In this case there was a 19.7 gram difference. The reciprocating weight was heavier on the front cylinder. This resulted in an engine that was unbalanced because both reciprocating masses were not equal to each other. Some will neglect this portion because they say these specific type of engines run on a single crankpin so you don’t have to bother about that. I do not agree with them.

Remember that every time the engine makes a complete turn, if one piston assembly is heavier than the other, even if they are on the same rotating assembly, the piston assembly will create an unbalanced movement as the speed of the engine goes up. That will allow a noticeable vibration. You would not be able to tell from front or rear which one is the heaviest assembly but, you would still be able to feel some annoying vibration with an engine that is supposed to be balanced…

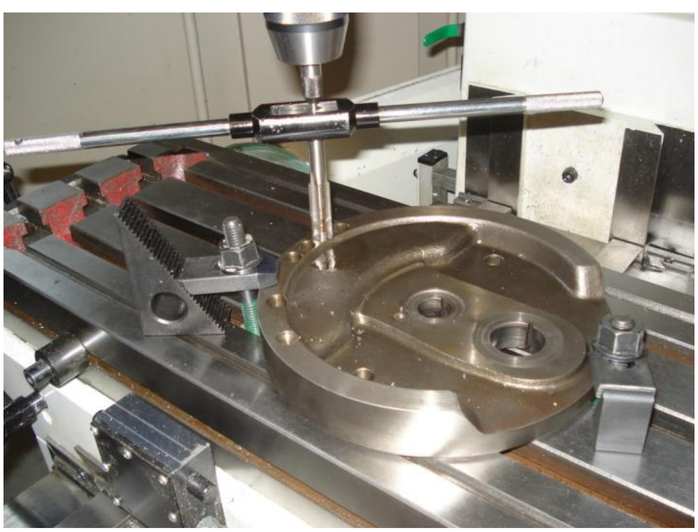
It takes more time and special care to equalize both reciprocating weight. Not everyone is willing to pay the extra difference to have it done like that?

In every engine combination with multiple cylinders all reciprocating parts should be as close to each other as possible and also as light as possible… Not only the balance factor is important but, the closer the reciprocating weight are from both the front and rear assembly, the better you will enjoy your ride in the end. In this case… a difference of 19.7 grams with the old rods.

Let’s continue with the flywheels. Those holes that were previously drill… now most of them need to be plugged. Not all, but most of them.

I am still looking to achieve what I was shooting for at first, an engine with a 60% balance factor.

Those holes were drilled 1/2” in size. I normally drill them 7/16” so I can plug them if needed to 1/2”-20 NF thread. That is a common size bolt. This time I will have to use either an M14 x 1.25 or 9/16”-18 NF bolt. The only bolt I have on hands is the 9/16” so here we go.



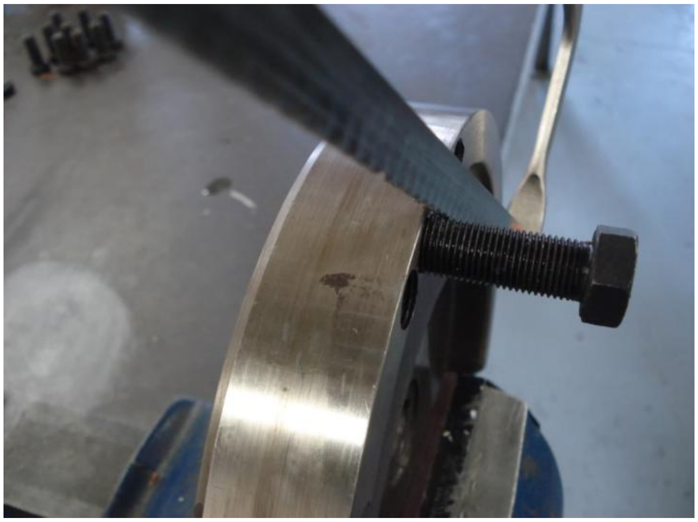
Tapping them all with 9/16”-18 NF thread then we will take care of the rest after.

Both wheels are ready for the final touch, already tapped and ready to be plug with portion of bolts. Don’t forget when doing that always use a good cleaning agent. Use primer and Loctite to make sure those threaded bolt portions will never come off.

If for example the weight of those steel bolts were not enough to counterbalance the bob weight you can use Tungsten often call “Mallory Metal”. The density of Tungsten is much more than regular metal or cast.

Even if I don’t need all of that extra weight in my own flywheels, I will try to explain to you how you can correct the problem with a solid carbide end mill. (You can also buy some Mallory Tungsten metal from a special supplier) This one I cut to length with an abrasive wheel. You press this slug in then plug the top part of the hole to make sure this tungsten slug will never come loose. You will take a small threaded portion out of a 9/16 NF bolt, to thread on top of the plug. Cut and face the rim on the lathe or simply grind the rest. This way I will have a heavy plug that will counter balance and it will never come loose.

Machining on a lathe instead of grinding the face of the flywheel makes a much cleaner job.



Remember to clean everything correctly then prime and Loctite the bolt in place before cutting them.

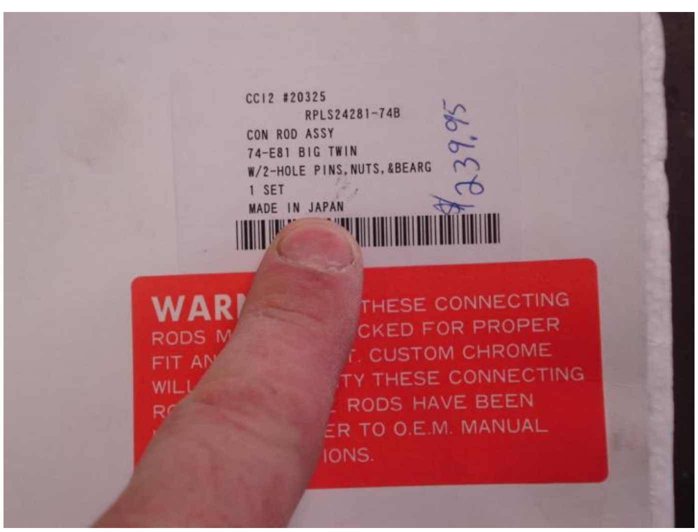
Time to continue with the balancing process: Since connecting rod bearings and the crank pin were worn out, I asked the owner of the engine to bring me new quality sets.

I just receive the new set of connecting rods to replace the old set. The new set is made in. I told him to either bring me an American or Japanese replacement rod assembly. I do not like the sets made in Taiwan or China.

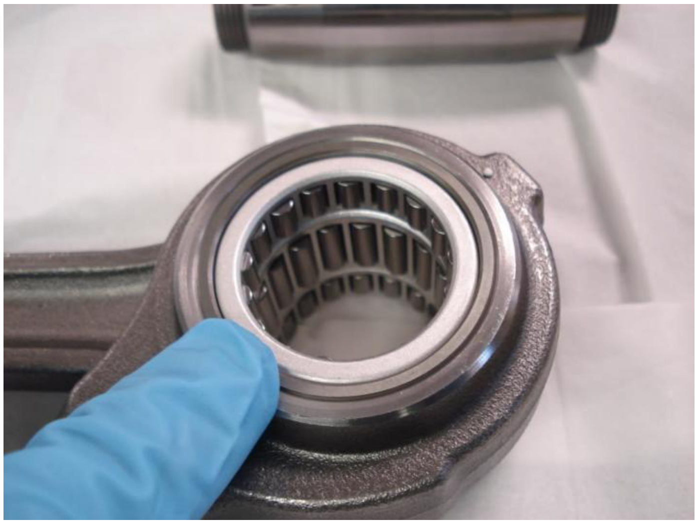
I know some would take the time to hone the male and female Big End races to except oversize roller bearings, change the crankpin & nuts and refit and hone new bronze bushing on the reciprocating end. A lot of work and most of the time not worth it. Considering the new parts are fitted (a real nice fit by the way) with all new materials and only cost $240 plus tax. If you buy parts separately combined with the time you spend doing the reconditioning, it would probably cost a lot more than that. Unless you have OEM or quality aftermarket parts and want to stick with them.

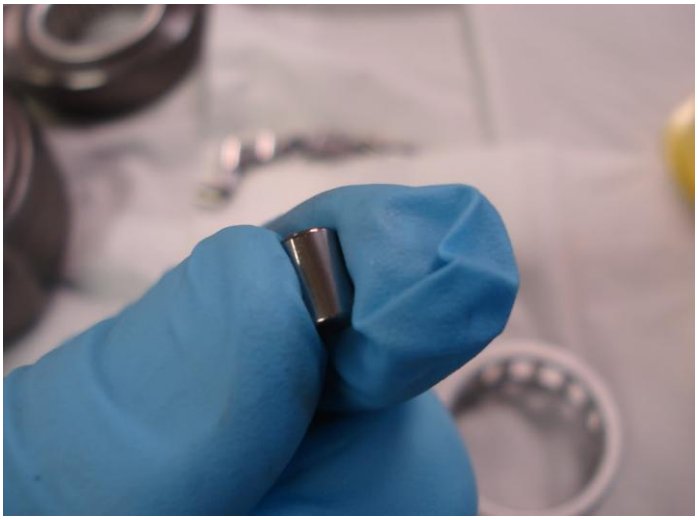
Those previous rods were replacements also and the purpose of this article was to explain how balancing is done, not fitting roller bearings in the big ends of a rod assembly.

Same replacement part number but brand new. This will save me a lot of work. Just have to complete the balancing job… But, probably a bit more work to come as you all know.

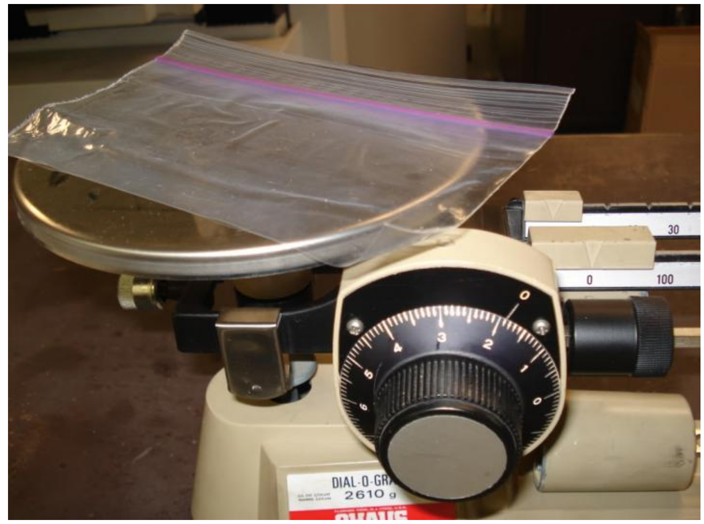


Time to take care of those new rods: To include all those parts in my new spec sheet, I have to put everything in a small Ziploc bag. Always take care not to touch clean rollers with bare hands. All roller bearings and bearings in general should not be touch with bare hands. The reason for this is acidity coming from your hands that would create a microscopic rust print. All major bearing companies have been doing research about this matter and they found that high speed roller bearings touched with bare hands turning at high speed will show microscopic sparks occurring at those exact spots they were touch causing premature wear. So, don't touch roller bearings or whatever kind of bearings with your bare hands and if you decide to do it make sure you have oil on your hands before touching them. Sometimes when I am too lazy to pick some latex glove, I clean my hands with brake cleaner. The brake cleaner makes my hands white and also very clean. Not the way to go but sure gets your hands clean… it is always better to use latex glove. Another thing… Keep those rollers away from humidity. It is very important to prevent surface rust.





Before weighting each bag of rollers there is another thing to take care. Empty bags still weigh something. In this case, 1.9 grams that needs to be subtracted from total weight of each package.



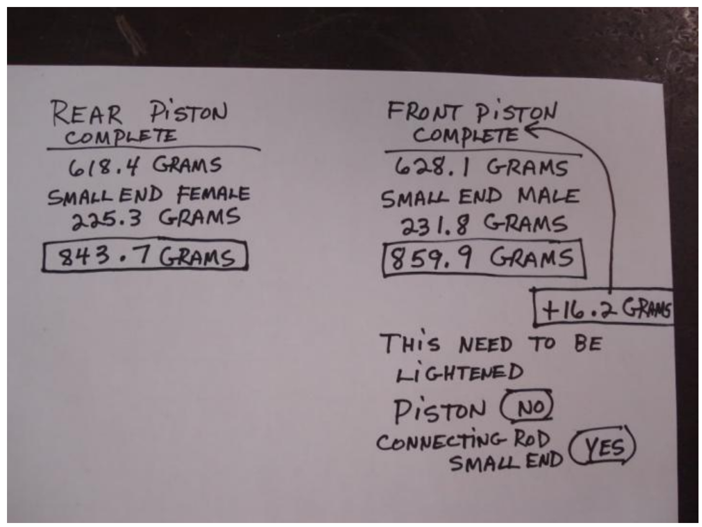
All roller bearings, male and female, placed in separate Ziploc bags and ready to be weighed.

After all small bags have been weighed it’s time to take care of both connecting rods. Weighing each end as described earlier with the previous connecting rods.

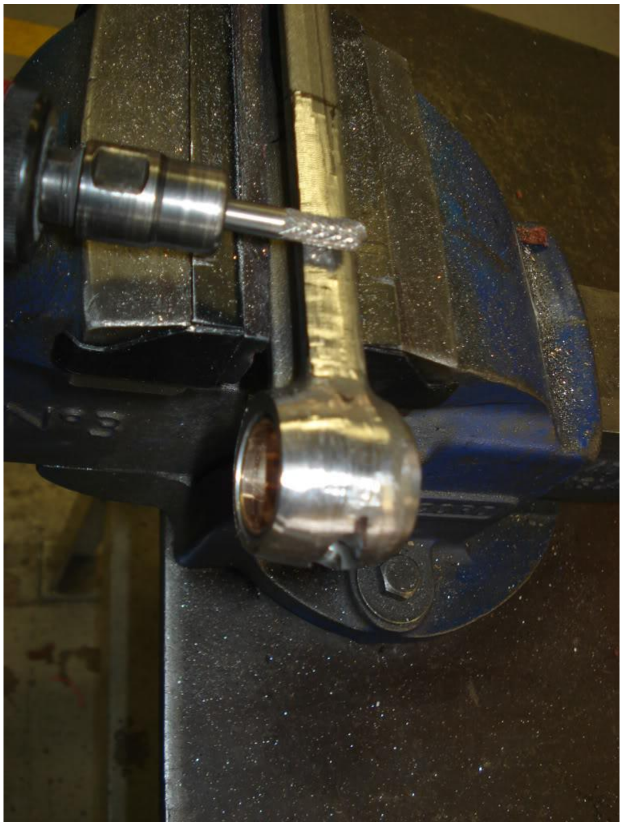
The only missing parts are pistons, rings, wrist pins and the 4 Teflon buttons. Those total weights did not change from the first weighting session since we will be using them again. Those new reciprocating parts (connecting rods) will have to be weighed again and be recalculated.

Remember when I mentioned that both reciprocating weights are important? After weighing both the front and rear reciprocating mass I found a difference of 16.2 grams. Heavier this time on the front cylinder compared to 19.7 grams heavier on the rear cylinder with the old rods.

So what needs to be done is called “equalizing the reciprocating weight.” This is done by removing weight from either the piston or the small end of the connecting rod or from both.

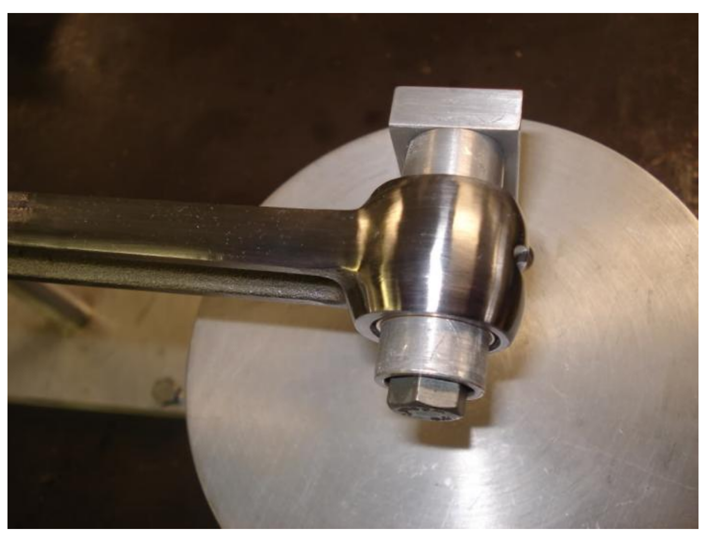


Why I decide to take the weight of the connecting rod end instead of the piston: If the customer wants to change pistons in the future to a similar part he will not change the end result by much. Also, connecting rods usually last for a longer period of time. First thing to do when doing a job like this is planning where you want to take off the material without weakening the rod itself.

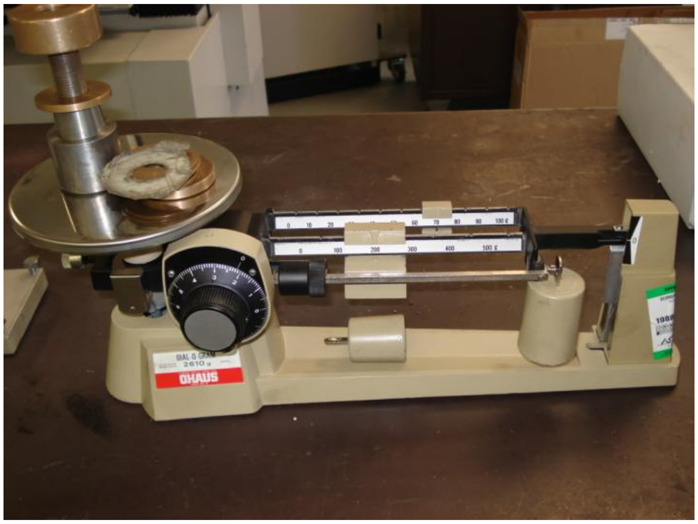


The grinding session took me about an hour in all. Grinding and weighing the male small end (you don't want to take off too much) I ended up within 0.2 grams difference between front and rear reciprocating weight, that was close enough for me.

Here a few pictures of the process from the start to final touch up.

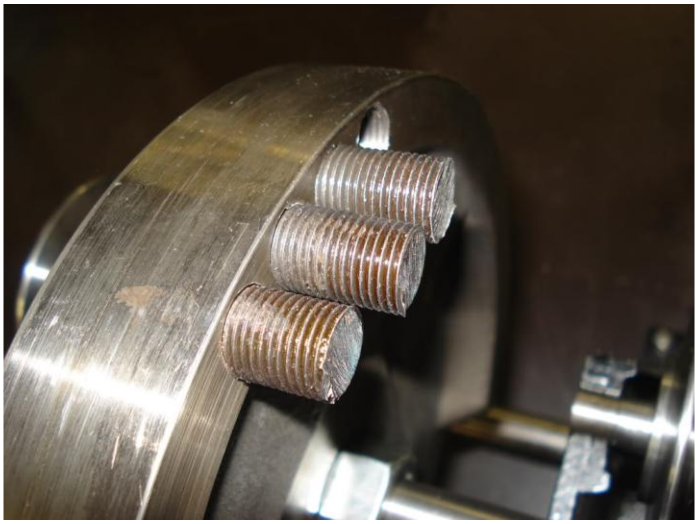


Now that both reciprocating ends are within 0.2 grams difference, it is time to prepare for the proper bob weight assembly.

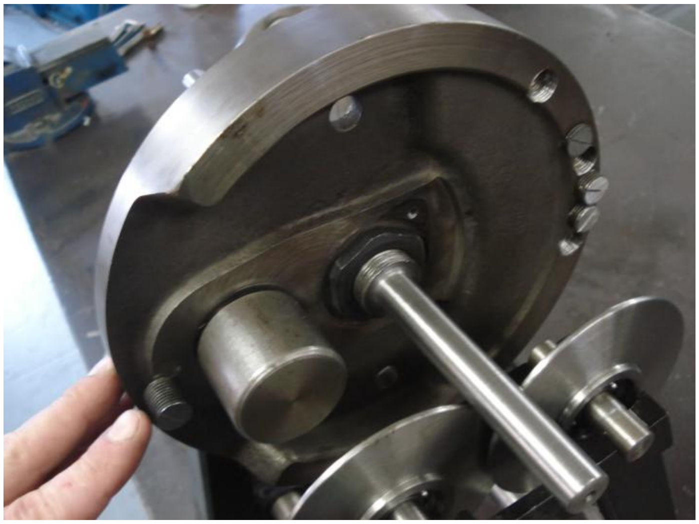


Now it’s time to take my spec sheets out and do the balancing calculations for the new parts. Check and install the correct bob weight on flywheels. I am looking at 1,272.16 grams of bob weight for each wheel.

In theory this is what needs to be added to achieve the correct balance. Not dead on but close to it. Those 3 sections were screwed in just a little.



A slot was cut in the face of each insert to make it possible to screw them in with a screwdriver. This is just to explain how the balancing is done. Those will need to be taken out again, cleaned properly, primed and Loctited in place. Then the section that is protruding will to be machine flush and final balancing can be achieved from there by drilling a very light spot at the end if necessary.



To show you how close it will be before finishing the balancing, I just added one little threaded portion on the opposite side equal the total length of the protruding portions of the 3 inserts. After I added that little piece of metal, the flywheel would stop everywhere without moving too much. The pictures are just to explain how to proceed. Most likely a small touch up hole will need to be drilled to achieve perfect balance.

Then it is time to take care of the final plugging of those holes. Both parts need to be cleaned thoroughly with brake or contact cleaner. Then prime both parts with 7649 Loctite and apply high strength Red Loctite inside the threaded portion on the flywheels.

When all inserts have been threaded in, you are ready to mount both flywheels on the lathe to machine the faces. That makes a clean finish.

At the same time I have the flywheel on the lathe I like to cut a circular line on the center of the protruding portion of the flywheel. This will be used as a guide so you can drill a nice symmetric series of holes on your next balancing job.

Here is what the plugged holes look like after the machining on the lathe. See the black spot? It is cured Red Loctite inside one hole. It is actually the threaded plug from the hole that is the closest. Normally, you leave at least 1/8” between each hole on forged wheel and 1/4” between each hole on cast wheels. As you can see, symmetry also was not taken in consideration. Those rules were not respected making this is a poor balancing job in my opinion.

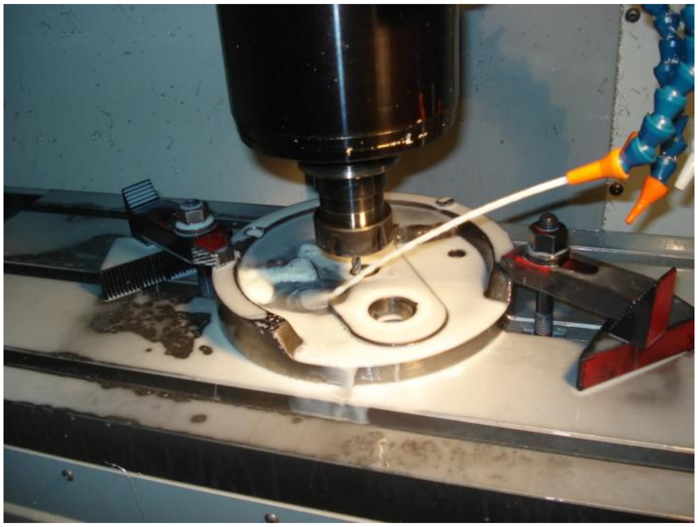
Now it is time to mount both flywheels on the balancing stand for the final touch up. Should be very little but still some fine tuning will be needed to finish both wheels. Just to give you an idea again of what needs to be drill out to achieve perfect balance… I took a small 9/16”-18 NF threaded bolt about 5/16” in length for one flywheel and about 1/8” long piece for the other flywheel on the opposite side. Both wheels were not moving at all anywhere you stopped them. See the black “X” mark that needs to be drilled opposite small weight. This is the next spot we will drill a shallow hole.

As I was mounting the bob weight for final balancing, I noticed wear on the inside face of both flywheels around where the crankpin is mounted. Another thing to take care before finishing the balancing process. I ordered a set of steel thrust washers from an earlier model and will fit them to the flywheels. One for each wheel and they will be like new again. On S&S flywheels there is no connecting rod thrust washer. The wheels are forged steel and normally don't wear out fast. This set must have some mileage on it?

Flywheels mounted on the CNC milling machine with dial indicator.

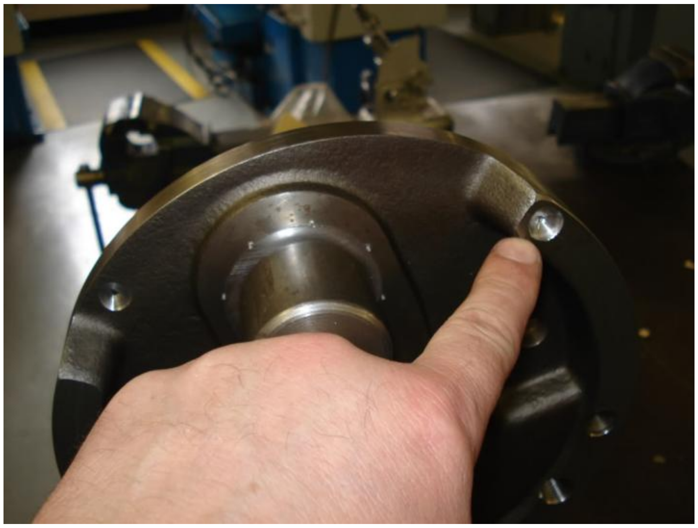
Using circular interpolation on the CNC mill makes for perfect grooves to adapt those news hardened thrust washers.

Need to use some coolant to do the machining. In the first picture I was using only a compressed air and ended up with a broken end mill.

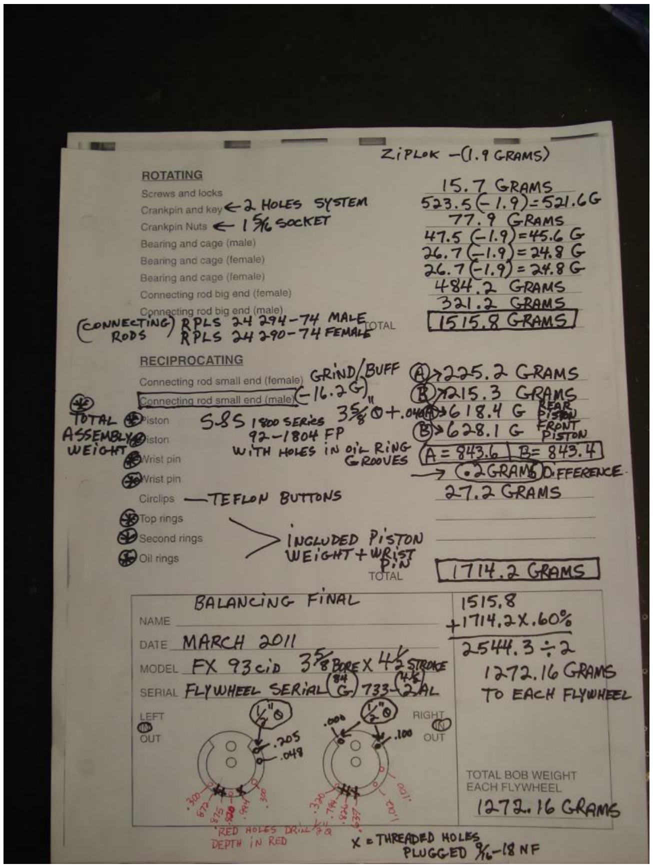


We will now take care of the final balancing: The balancing will be as close as you can have a Harley engine running. The owner will now be able to keep the rhythm and ride with his friends on their newer bikes without being severely shaken up.

Shown is the final balancing. You can see what needed to be drilled on each flywheel to have both in perfect balance. Both wheels are balanced to within 0.1 grams with this static method.



Note: The balancing stand I use in this thread has been tested with a small dab of MACtac weighting 0.1 grams and the flywheel started moving…. Accurate enough for any person doing a balancing job on a Harley engine.



ZIPLOK –(1.9 GRAMS)

ROTATING

Screws and locks	15.7 GRAMS
Crankpin and key ← 2 HOLES SYSTEM	523.5 (–1.9) = 521.6G
Crankpin Nuts ← 1 5/16 SOCKET	77.9 GRAMS
Bearing and cage (male)	47.5 (–1.9) = 45.6 G
Bearing and cage (female)	26.7 (–1.9) = 24.8 G
Bearing and cage (female)	26.7 (–1.9) = 24.8 G
Connecting rod big end (female)	484.2 GRAMS
Connecting rod big end (male)	321.2 GRAMS
(CONNECTING RODS) RPLS 24 294-74 MALE, RPLS 24 290-74 FEMALE — TOTAL	1515.8 GRAMS

RECIPROCATING

Connecting rod small end (female) GRIND/BUFF	A → 225.2 GRAMS
Connecting rod small end (male) (–16.2G)	B → 215.3 GRAMS
TOTAL ASSEMBLY WEIGHT Piston — S&S 1800 SERIES 3 5/8" Ø +.040 92-1804 FP	A → 618.4 G REAR PISTON
Piston — WITH HOLES IN OIL RING GROOVES	B → 628.1 G FRONT PISTON
Wrist pin	A = 843.6 | B = 843.4
Wrist pin	→ .2 GRAMS DIFFERENCE
Circlips — TEFLON BUTTONS	27.2 GRAMS
Top rings	
Second rings — INCLUDED PISTON WEIGHT + WRIST PIN	
Oil rings	
TOTAL	1714.2 GRAMS

BALANCING FINAL

NAME

DATE MARCH 2011

MODEL FX 93cid 3 5/8 BORE X 4 1/2 STROKE

SERIAL FLYWHEEL SERIAL (84 G) 733-(4.5 2) AL

1515.8
+1714.2 X .60%
2544.3 ÷ 2
1272.16 GRAMS TO EACH FLYWHEEL

LEFT IN OUT — 1/2" Ø — .205 — .048

RIGHT IN OUT — 1/2" Ø — .000 — .100

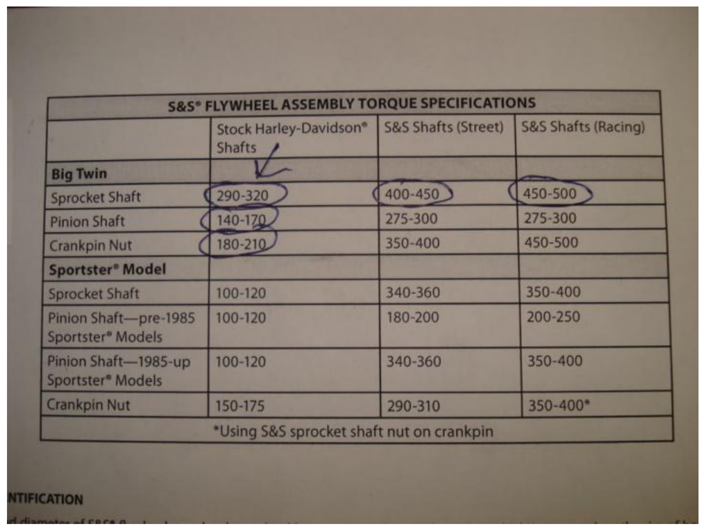
TOTAL BOB WEIGHT EACH FLYWHEEL 1272.16 GRAMS

RED HOLES DRILL 1/2" Ø DEPTH IN RED

X = THREADED HOLES PLUGGED 9/16-18 NF

Here are my final balancing sheets for future reference….and also for those who are curious.

Now we can reassemble those flywheels as a complete assembly. Shown is a torque spec sheet from S&S. On the left is with stock shaft and on the right is with an S&S shaft. I used a JIMS pinion and the OEM sprocket shaft.



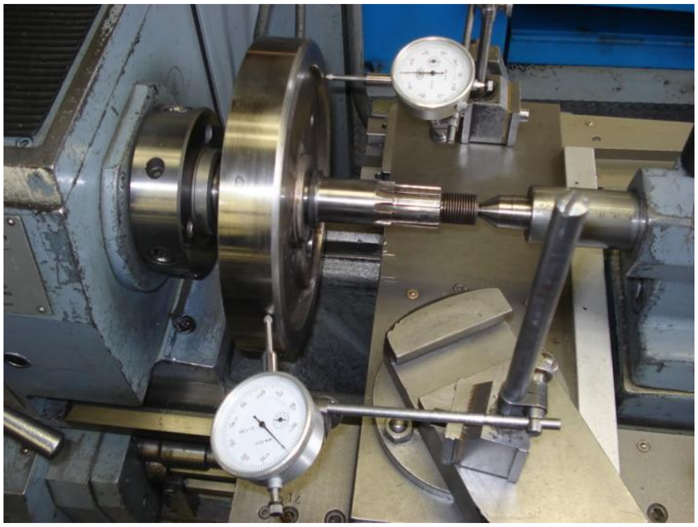
S&S® FLYWHEEL ASSEMBLY TORQUE SPECIFICATIONS

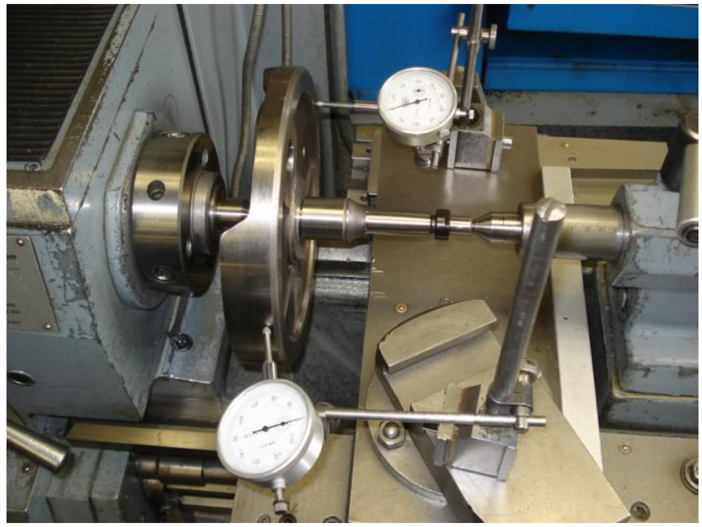
	Stock Harley-Davidson® Shafts	S&S Shafts (Street)	S&S Shafts (Racing)
Big Twin			
Sprocket Shaft	290-320	400-450	450-500
Pinion Shaft	140-170	275-300	275-300
Crankpin Nut	180-210	350-400	450-500
Sportster® Model			
Sprocket Shaft	100-120	340-360	350-400
Pinion Shaft—pre-1985 Sportster® Models	100-120	180-200	200-250
Pinion Shaft—1985-up Sportster® Models	100-120	340-360	350-400
Crankpin Nut	150-175	290-310	350-400*

*Using S&S sprocket shaft nut on crankpin

To do this, I am using the shop table with 2 holes drilled through it to accept 2 mounting bolts and a slot to clear both shafts, very solid and easy to do for anyone.

Now we can check each wheel for runout on the outside surface and on the face. All are within 0.001”. Now we are ready to finish the assembly.

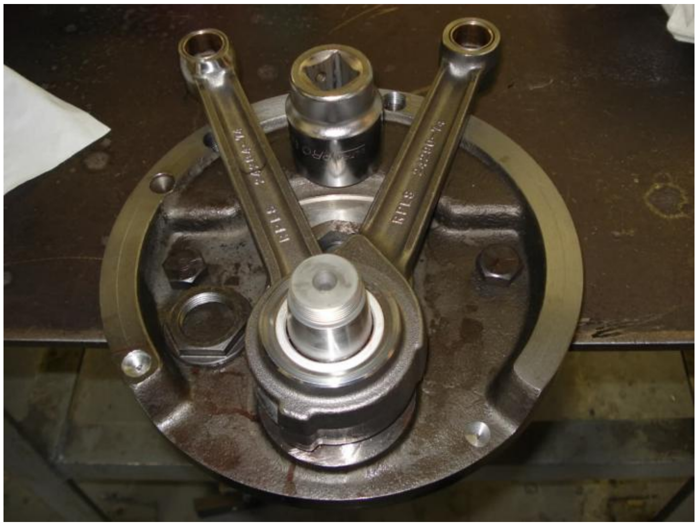




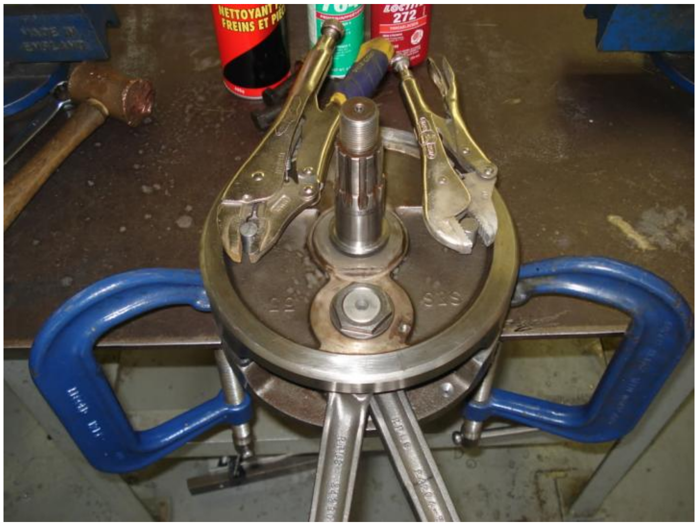
This is what you need to complete the assembly.

Torco assembly lube is a must for any engine.

Slide both connecting rods over the bearings assembly

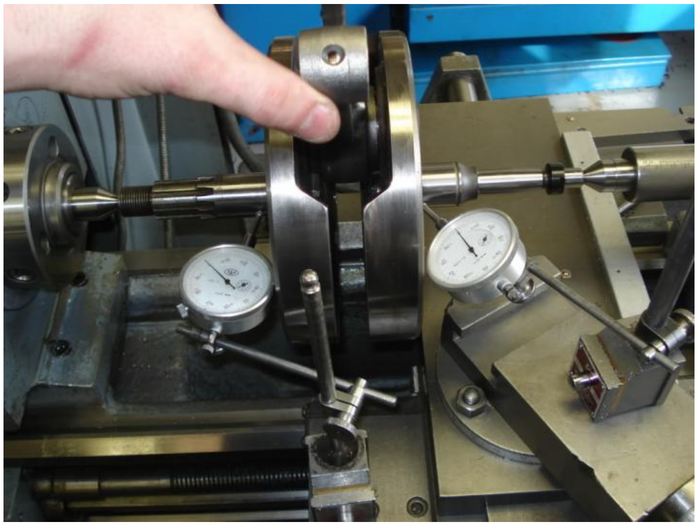


After mounting the flywheels on the lathe both wheels were off by 0.005” with torque at 175 ft lbs. Short only 35 more pounds to achieve final torque.



Note the 2 rods that are secured with vise grips. They were machined to slide with a slight drag. That way the flywheels set up quicker.

Final assembly runs within spec at 0.0000” on sprocket shaft and at 0.0002” on pinion shaft.



Another problem occurs before closing the case. Since the previous assembly was so out of balance, the inner portion of the pinion race ended up with a total out of round of 0.0035” so nothing I can do, I need to put a new race in and then line lap.

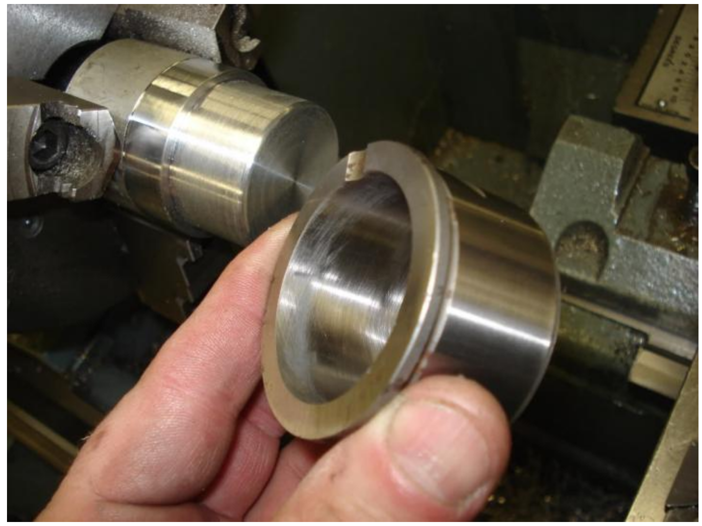
Another special tool to press the old pinion race bushing

But surprise the race does not need to be press out! I was able to push the race out with my fingers. I guess another problem is coming…?

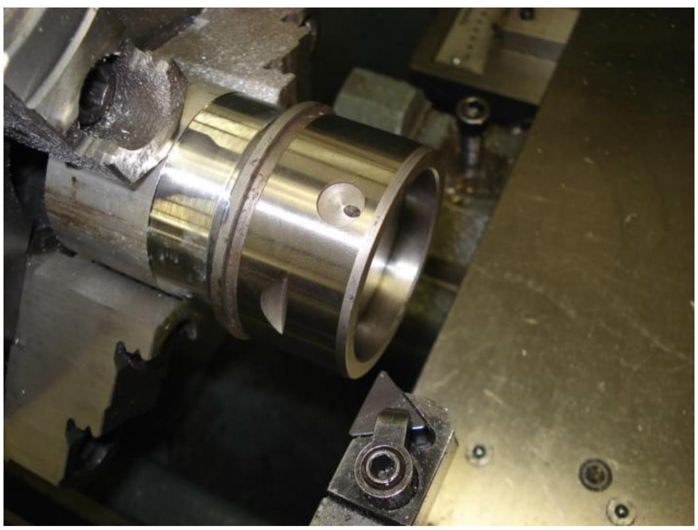
The pinion race insert is 0.001” under the bore size. Only the set screws were securing the race but the set screws were not tight. I mean barely touching. So I order an oversize race and we will then fit the new race to the case insert.

Guess what, another problem. When mounting the new oversize Eastern bearing race on a custom aluminum mandrel, I found the race was not concentric. Inside diameter was perfect but the outside diameter was off by 0.0025”. If I had measured the race and ordered the next larger size to fit as a shrink fit in the bore, I would have found a big surprise… Hard to lap something that is not on centerline with the opposite Timken bearings…. I would assume the I.D. and O.D. were concentric but it was not. There are some quality control issues from some North American companies nowadays. Quality is not always what it used to be.

The outside race was at 1.135”. I think it was a 0.005” oversize. I asked for at least 0.005” or more. I was expecting to machine the outside to make it fit anyway. So, I had enough material to remove to have the fit I was looking for at 1.1295” for a bore size of 1.127”. This will give me a 0.0025” shrink fit.



Ready to be cut with a ceramic insert.

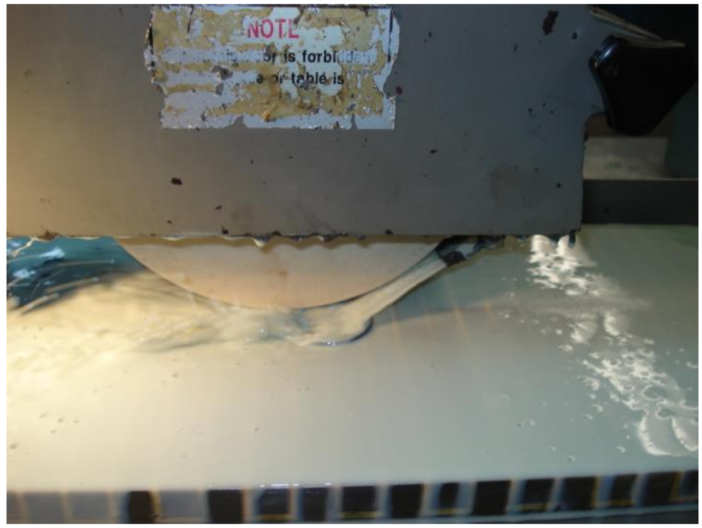


Heating the case and shrinking the pinion race before insertion.

I use snow to freeze the race to get the 1.129” to shrink 0.0005”

Time to lap the race, I use the old Timken in the opposing race for the pilot to my lapping tool. Lap the new race to final size of 1.7515”. Starting at 1.749” on each end and 1.7485” in the middle after the shrink fit. The new pinion shaft from JIMS is 1.7502” so I ordered a set of 0.0002” oversize rollers at 0.2502” to have a 0.0009” tolerance.

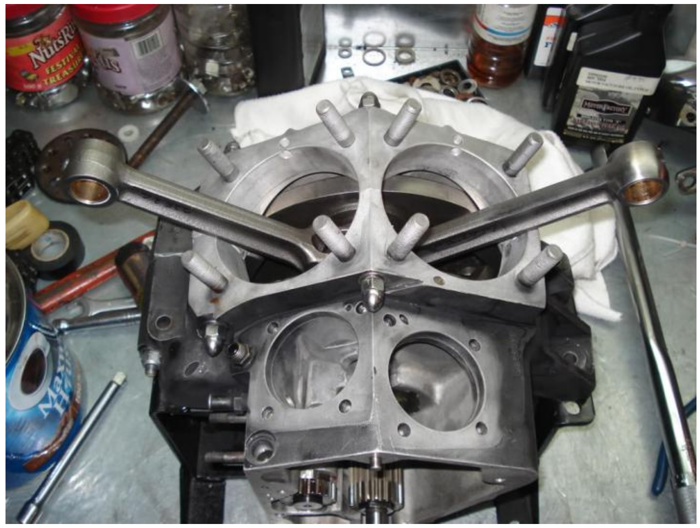
Almost done with this engine and the owner asked if I could check the Timken play for him since he did not have the tools to check it himself. Well, I said, “Yes, it is a small job when you have the proper tool”. But, guess what? Total backlash from the brand new Timken kit was at 0.009”. Way too much! Harley recommends between 0.001” to 0.006” max. So, I took the small spacer to the surface grinder and take 0.006” off it to end up at 0.100” thick instead of 0.106” thick. I end up at 0.0017” backlash. That is a nice backlash for a set up like this.



As you can see, the total backlash is now at 0.0017”. A lot better than the 0.009” we had. Again never assume. Even if the company is Timken.

Now it is time to call the owner telling him that he can come and pick up this project. The rest will be complete by him with a few phone calls to me in the meantime….

I stopped at the shop and took a couple more pictures of the flywheels now assembled in the crankcase… Getting closer!



Things I forgot to mention: I drilled a 1/4”-20 NC set screw to reduce the flow to the connecting rods. The drill I used was 3/32”. I might have drilled a little smaller but at 0.093” I would be safe. The JIMS shaft comes with a threaded hole of 1/4”-20 without a plug or reducer in the box so the hole was at over 0.200”. Too big for a pinion hole. The pump needs to build pressure.


I am sure some of you might have other methods to do a balancing job and some might disagree with the way I am doing things. I fully respect that. Remember, my main goal here was to show my students how a Harley bottom end was balanced. I have had a few more things to take care of along the way. More than I first expected for sure but, that is part of life. You live and you learn. I expect some of you might have learned something from this also.

Hope you have enjoyed this very long thread,

(saddlebagrail)

FLYWHEEL BALANCING WORK SHEET

ROTATING MASS:

Screw and Locks ________________

Crankpin and Key ________________

Crankpin Nuts ________________

Bearing And Cage (male) ________________

Bearing And Cage (female) ________________

Connecting Rod Big End (male) ________________

Connecting Rod Big End (female) ________________

TOTAL ________________

RECIPROCATING MASS:

Connecting Rod Small End (male) ________________

Connecting Rod Small End (female) ________________

Piston (front) ________________

Rings and Cir-clips (front) ________________

Wristpin (front) ________________

Piston (rear) ________________

Rings and Cir-clips (rear) ________________

Wristpin (rear) ________________

TOTAL ________________

NAME: ________________

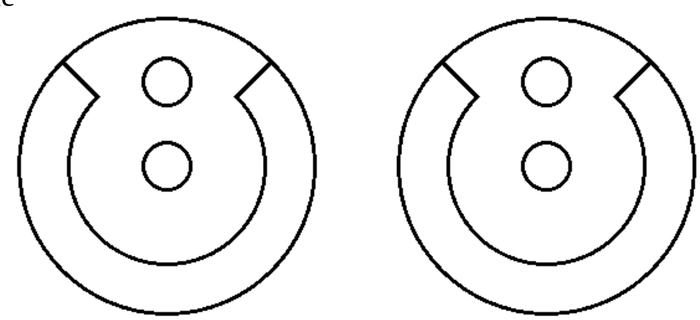
DATE: ________________

MODEL: ________________

SERIAL NO.: ________________

Left Wheel
Inside
Outside

Right Wheel
Inside
Outside



TOTAL BOB WEIGHT
PER FLYWHEEL:

____