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REF: Wheels, Brakes & Tires

Brake System Upgrades

Master Cylinder and Caliper Relationship

Calculating M/C to Caliper Ratio

- First get the area of the master cylinder pistons. The area of a circle is the amount of space the circle covers. [1)]
  - The formula for calculating the area of a circle is $A = \pi r^2$ where pi (π) equals 3.14 and the radius ® is half the diameter.
  - Or 3.14 x (r x r) = piston area (for one piston).
- The pressure is arrived at by Pascals law. [2)]
  - F (force) = P (pressure) X A (area) or P (pressure) = F (force) ÷ A (area).
  - So with a 10 lbs force at the 5/8“ break lever, we get P = 10 ÷ 0.306640625 where P = 32.6 PSI.
    You would then multiply 32.6 by the area of the piston in the brake caliper to find the actual pressure applied to the disc by each brake piston.

Master Cylinder to Wheel Cylinder Ratio

Conversions:

- 7/16” = 11.1125mm
- 1/2“ = 12.7mm
- 9/16” = 14.2875mm
- 5/8“ = 15.875mm
- 3/4” = 19.05mm
- 1-3/8“ = 34.9mm
- 1-3/4” = 44.5mm
- 1-7/8“ = 47.6mm

- General rule of thumb when swapping master cylinders is: [3)]
  - Bigger M/C = More pressure required to compress brake lever, less lever travel.
    The MoCo reduced pressure at the caliper in dual discs systems with a larger master cylinder piston.
  - Smaller M/C = Less pressure required, more lever travel.
    If the area of the master cylinder piston is reduced, the pressure at the caliper increases.
    A smaller master cylinder piston used in a dual disc system would make it too easy to lock up the brakes and make for an unsafe system.

Below is a reprint from vintagebrake.com.
[4)]

> While attending Vintage Days West, and thoroughly enjoying it, I was reminded that many of the people I had occasion to talk to, lacked an understanding of the importance of master cylinder to wheel cylinder ratios. This critical ratio is of paramount importance in determining “feel”. It has been my experience that there is a “sweet spot” in the range. I like ratios in the 27:1 range-2 finger power brakes, feeling some line and/or caliper flex. 23:1 is at the other end of the spectrum-firm. Ratios lower than 20:1 can result a feel so “wooden” as to have a toggle switch effect: nothing happens until the wheel locks. Disc and wheel diameters must be taken into consideration. A 10 inch disc working against a 19” wheel just doesn't have the leverage ratio that a 13 inch disc working a 17“ wheel does. The hand lever ratio counts too: witness the adjustable master cylinders from Lockheed and Brembo.
>
> A case in point: I had a complaint from a racer about Ferodo CP901- a compound renown for its great feel. His comment was that they worked poorly until the wheel locked. He had been thrown on the ground twice. Intrigued, I inquired as to the application. “Yamaha RD350” he replied. A red flag went up. CP901 was not available for the 48mm Yamaha caliper. I asked “How that could that be?” He had up-graded his braking system with the 41mm Lockheed unit, but was unaware that a master cylinder change was in order. A stock RD 350 has an already poor ratio of 18.3 :1, and with Lockheed, became an unhealthy 13.3 :1. The “sweet spot” formula said a change to a 11 or 12mm master cylinder was in order: my personal preference and recommendation would have been an 11mm. He was able to switch to a 1/2” , and although not ideal, he was keeping the rubber side down.
>
> For 2 piston opposed calipers, I like ratios in the 27:1 range, feeling some line and caliper flex. For a firmer lever, use 23:1. I think ratios lower than 23:1 produce a lever feel so “wooden” as to have little, if any feel. Combine “low” leverage ratios with sticky pads, and unpredictable lockup is the result. The high effort required at the lever also results in undesired input to the bars. Single piston calipers are much happier in the 14:1 to 12:1 range. Disc and wheel diameters, as well as hand lever ratios, must be considered.

From sml1226 of the XLFORUM [5)]

> The ratio charts don't exactly tell you precisely what you need, but it does provide what you need to match your master cylinder to your calipers.
> It does NOT tell you the effect on stopping power, and it doesn't consider your rotor, wheel diameter or bike's weight, all of which affect braking.
> Larger wheels are harder to stop. Larger rotors make stopping easier.
> Lighter bikes are easier to stop. The math for the full picture is far more complicated than the math done in the chart.
> **The “ideal” ratio of 27:1 is taken from the opinion of multiple people speaking about this pairing**.
> Despite being “ideal” you need to figure out your own “ideal”.
> Soften it up by raising the ratio. Firm it up by lowering it.
> The best, safest brakes, are ones that you are confident with. Do NOT assume anyone's ratio is better if you love the way your brakes feel.
> My suggestion is to find a bike with brakes you like and aim for that ratio.

Got the Caliper But What Size Master Cylinder to Use?

There will be a range of master cylinder diameters which will work for a given set of brake pistons.
A small master piston will be light to pull on, but will feel spongy and may not give full braking before the lever hits the bars.
A large master piston will feel wooden, and will only give full braking if you squeeze very hard.
Between these two is the optimum where the lever is neither spongy nor wooden, and gives enough to lock the tire.

Most caliper manufacturers specify the recommended size master cylinder for the calipers they sell.
They've already done the engineering for you.
If it's not specified in their ads, you can always call them and ask.
However, sometimes you'll have mismatched parts buying a used bike.
If the brakes don't feel right even after a rebuild and knowing for sure you have all the air out of the system, this information may help.

Below is some information for the finding a M/C bore size for your calipers.
You'll need to find the area of the piston(s) for the intended caliper used. The area is proportional to the square of the diameter.
I.E, going from 2 caliper pistons to 4 caliper pistons (doubling the area), the diameter of the M/C should be multiplied by sqrt(2) = 1.4, not doubled.

Example;
A stock setup with a 1/2“ master and a single caliper with (2)-27mm pucks has a ratio of (9.03:1).
If you want to upgrade to a 2 caliper (4)-27mm system using the same 1/2” master, the ratio would now be (19.44:1).
That would be more of a touchy feel, easier to lock the brakes, possible lever hitting the bars before pressure builds sufficiently.

If you want it closer to what the factory ratio or maybe just a little more pressure but not real touchy, you could use a 11/16“ bore master.
That puts the ratio at (9.55:1). You get less heat buildup with more pistons and slightly higher ratio.
The Moco actually used a 14mm master with the (4)-27mm dual caliper setup with a ratio of (14.87:1).

Using the master to caliper ratio chart below, you can see the ratios between the stock setup and what you want to upgrade to.
You need to know the stock ratios (or what you have been using) to know the affects of the upgrade setup.

For instance;
A 1998 XL1200S came factory with dual brakes with a 11/16” master and (2) 39mm single piston calipers on the front.
A 2000 XL1200S came factory with dual brakes with a 11/16“ master and (2) (4x33mm) 4 piston calipers on the front.
By the chart below, the 1998's M/C to caliper ratio is (9.97:1) and the 2000's ratio is (28.65:1).
That's quite a difference for very similar bikes and one reason why the 2000-2003 brakes are said to be so much better.
The master cylinder is the same between the two.
And following the chart, you can see that even if you went to a 3/4” (app 19mm) bore master instead, the ratio is still (24.11:1).
But you'll have less lever travel. It's always a tradeoff.

Master Cylinder to Wheel Cylinder Ratio Chart

Example for the table below;
Area of a 10mm bore M/C = 78.54 mm² (3.14 x r² (5 x 5, or 25mm) = 78.54).
Area of a 28mm dia. caliper piston = 615.44 mm² (3.14 x r² (14 x 14, or 196mm) = 615.44).
The ratio between the 28mm caliper piston and the 10mm master cylinder is 7.84 to 1, (615.44 / 78.54 = 7.84).

Figures in the table have been rounded up.
Their importance is only of a general process of selecting a master cylinder / caliper combination.

( ) = Number of active pistons. [6)]

Diameter	**M/C →**	**10mm**	**11mm**	**12mm**	**1/2“**	**13mm**	**14mm**	**9/16”**	**15mm**	**5/8“**	**16mm**	**11/16”**	**19mm**
Caliper ↓	Area-MM²	78.54	95.03	113.10	126.68	132.73	153.94	158.29	176.72	197.93	201.06	239.60	283.63
27mm	572.27	7.29	6.02	5.06	4.52	4.31	3.72	3.61	3.23	2.89	2.85	2.39	2.02
27mm (2)	1144.53	14.57	12.04	10.12	9.03	8.62	7.43	7.23	6.48	5.72	5.69	4.78	4.04
27mm (4)	2289.06	29.15	24.09	20.24	18.07	17.25	14.87	14.46	12.95	11.56	11.38	9.55	8.07
28mm	615.44	7.84	6.48	5.44	4.86	4.64	4.00	3.89	3.48	3.11	3.06	2.57	2.17
28mm (2)	1231.51	15.68	12.96	10.89	9.72	9.28	8.00	7.78	6.97	6.22	6.13	5.14	4.34

Diameter	M/C →	10mm	11mm	12mm	1/2“	13mm	14mm	9/16”	15mm	5/8“	16mm	11/16”	19mm
28mm (4)	2463.01	31.36	25.92	21.78	19.44	18.56	16.00	15.56	13.94	12.44	12.25	10.28	8.69
30mm	706.86	9.00	7.44	6.25	5.58	5.33	4.59	4.47	4.00	3.57	3.52	2.95	2.49
30mm (2)	1413.72	18.00	14.88	12.50	11.16	10.65	9.18	8.93	8.00	7.14	7.03	5.90	4.99
30mm (4)	2827.44	36.00	29.75	25.00	22.32	21.30	18.37	17.86	16.00	14.28	14.06	11.81	9.97
32mm	804.25	10.24	8.46	7.11	6.35	6.06	5.22	5.08	4.55	4.06	4.00	3.36	2.84
32mm (2)	1608.50	20.48	16.93	14.22	12.70	12.12	10.45	10.16	9.10	8.13	8.00	6.72	5.67
32mm (4)	3217.00	40.96	33.85	28.44	25.39	24.24	20.90	20.32	18.20	16.25	16.00	13.43	11.35
33mm	854.87	10.88	9.00	7.56	6.75	6.44	5.55	5.40	4.83	4.32	4.25	3.57	3.01
33mm (2)	1709.73	21.77	17.99	15.12	13.50	12.88	11.11	10.80	9.67	8.64	8.50	7.14	6.03
33mm (4)	3419.46	43.54	35.98	30.23	26.99	25.76	22.21	21.60	19.35	17.28	17.00	14.27	12.06
33mm (8)	6838.92	87.08	78.97	60.47	53.99	51.53	44.43	43.20	38.7	34.55	34.01	28.65	24.11
35mm	962.12	12.25	10.12	8.51	7.59	7.25	6.25	6.08	5.44	4.86	4.79	4.02	3.39
35mm (2)	1924.23	24.50	20.25	17.01	15.19	14.50	12.50	12.16	10.89	9.72	9.57	8.03	6.79
38mm	1134.12	14.44	11.93	10.03	8.95	8.54	7.37	7.16	6.42	5.73	5.64	4.74	4.00
38mm (2)	2268.24	28.88	23.87	20.06	17.91	17.09	14.73	14.33	12.84	11.46	11.28	9.47	8.00
38mm (4)	4536.47	57.76	47.74	40.11	35.81	34.18	29.47	28.66	25.67	22.92	22.56	18.94	16.00
39mm	1193.99	15,20	12.57	10.57	9.42	9.00	7.76	7.54	6.76	6.03	5.94	4.98	4.21
39mm (2)	2387.97	30.40	25.13	21.11	18.85	17.99	15.51	15.09	13.51	12.06	11.88	9.97	8.42
41mm	1320.26	16.81	13.89	11.67	10.42	9.95	8.58	8.34	7.47	6.67	6.57	5.51	4.66
41mm (2)	2640.51	33.62	27.79	23.35	20.84	19.89	17.15	16.68	14.94	13.34	13.13	11.03	9.31
41mm (4)	5281.03	67.24	55.57	46.69	41.69	39.79	34.31	33.36	29.88	26.68	26.27	22.05	18.63
44mm (2)	3041.07	38.72	32.00	26.89	24.01	22.91	19.76	19.21	17.21	15.36	15.13	12.70	10.73
48mm	1809.56	23.04	19.04	16.00	14.28	13.63	11.76	11.43	10.24	9.14	9.00	7.56	6.38
48mm (2)	3619.12	46.08	38.08	32.00	28.57	27.27	23.51	22.86	20.48	18.28	18.00	15.11	12.76
48mm (4)	7238.25	92.16	76.17	64.00	57.14	54.53	47.02	45.73	40.96	36.57	36.00	30.22	25.53
50mm	1963.50	25.00	20.66	17.36	15.50	14.79	12.76	12.40	11.11	9.92	9.77	8.20	6.93
50mm (2)	3927.00	50.00	41.32	34.72	31.00	29.59	25.51	24.81	22.22	19.84	19.53	16.40	13.85
50mm (4)	7854.00	100.00	82.64	69.44	62.00	59.17	51.02	49.62	44.44	39.68	39.06	32.79	27.70

Non Sportster HD Master Cylinders

- List of (Non Sportster) HD Front Master Cylinders
- VROD Brembo Caliper Install on 2007 883L
- XR1200 brakes on a 2007 1200R

Brembo Calipers

4 Piston Brembo

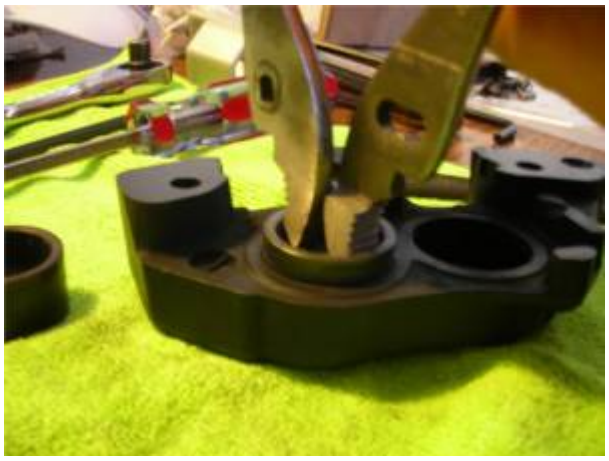
Rebuilding

No one should be afraid of rebuilding a brake caliper. They are one of the most simple components you will find on a motorcycle.
Two halves, a few pistons and a variety of O-rings. Simply order a rebuild kit for your caliper and buy some fresh brake fluid.
The caliper below is a 4-piston Brembo commonly found on V-rods, Touring models and (in our case) Sportsters which have been upgraded/modified.
The steps listed are roughly the same for a sliding 2-piston caliper with the obvious exception of splitting the caliper halves.
*As always, wear eye protection!

1. Drain all the brake fluid from your system.
2. Remove the brake line and loosen the bolts which hold the caliper together while it's still mounted to the bike.
   This way you have both hands free and the leverage needed to loosen the bolts.
3. Now remove the caliper from the fork/swing arm and remove the brake pads.
   Finish removing the bolts from the caliper, taking care to note which holes they were in.
   Lay the two halves out on your work table.
4. You can remove the pistons with several different methods. One way is to use a spray nozzle attached to an air compressor and shoot air into the fluid transfer holes.
   This method can be very effect but also very dangerous. If you aren't careful you can fire a piston across the shop/garage causing serious injury and/or death (as Harley loves to print over and over in the service manual).
   Or you can remove the pistons with either a pair of conventional pliers or reverse/spreader pliers.
   To do this with a pair of regular pliers simply take the fastening bolt out and flip the plier handles around backwards.
   This allows you to grasp the inside of the piston firmly, then twist while pulling upwards.
   The piston can be stubborn to remove at times.
5. Once all of the pistons have been removed use a wooden pick to remove the O-rings from inside the piston chambers.
   There are two for each piston.

6. Now use parts cleaner/brake cleaner to wash out all of the passages and piston chambers. Towel dry and then allow to air dry.
   You should also thoroughly clean and inspect the pistons and piston chambers. The pistons should have a smooth, polished surface.
   Small scratches can sometimes be buffed out, if not you must replace the piston.
   Nicks and scratches on the piston will tear the O-rings and cause failures.
7. Once dry you need to lube the O-rings and install them. Rebuild kits usually include a small packet of lubricant grease. If not, use fresh brake fluid.
8. Lube and slide the pistons back into their chambers.
9. Finally, you can now reassemble the brake caliper, making sure to install the new O-ring in the fluid transfer passage and torque the housing bolts to spec.

That’s it. There’s nothing much to it.
If you don’t already have one go buy a service manual for your bike. They are invaluable.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GMA Calipers

GMA-200E

For single disc FX and XL 1974-1977 19 in.

- Material: Billet Aluminum w Clear Anodized Finish. [10)]
- Position: Front.
- Piston Count: 2-Piston.
- Weight: 2.65 lbs.
- Master Cylinder Requirements:
  - Single disc applications: 5/8“ bore master using a 2 or 4 piston caliper.
  - Dual disc applications: Factory 11/16” bore (84 and later) or GMA 3/4“ handlebar master using a 2 or 4 piston caliper.
- Brake pads included
- Made in the U.S.A.
- **Not recommended for use with imported stainless steel rotors**.

GMA 4-pot calipers on a 1977 XLH [11)]	GMA 4-pot calipers on a 1978 XLH [12)] Custom brake lines & angled banjo adapter to make bleeding the calipers easier.
	 

Wilwood Calipers

- Wilwood GP-310 Brake Caliper on 1996 XL1200

4 Piston Wilwood

GP310 Front (1984-1999) See link here
Wilwood's GP310 motorcycle disc brake caliper has been designed and engineered for use on 1984 to 1999 Harley-Davidson Motorcycles.
Built around a 4-piston, high performance powerhouse, this billet aluminum caliper brings distinctive, bolt-on styling:
Direct leg-mounted calipers are available for all single and dual disc models (except Springer and 4-

speed FL models), as well as the 1983 XR 1000.
Piston Count: 4
Piston Area: 2.46 in²
Piston Type: Stainless
Caliper Material: Aluminum
Suggested Rotor Diameter: 11” to 11-1/2“
Rotor Width: 0.18” to 0.25“
Brake Pads:

- Wilwood Part# (6208) See link here
  - Thickness (in): .30
  - Pad Area (in²): 3.65
  - Pad Volume (in³): 0.63
- Galfer pads: [13)]
  - FD068G1054 = Organic
  - FD068G1375 = Sintered
- EBC:
  - FA95 = Organic
  - FA95HH = Sintered

A couple of handy phone numbers:
Wilwood (805) 388-1188
Galfer (800) 685-6633
Caliper Bolt Torque (per Wilwood): 22 ft-lbs

Experiences from XLFORUM Members

From Randy_rots: [14)]
What counts the most is the summary size of all the pistons. I was messing up with various calipers and master cylinders.
Here's what I found:

1. XR 5/8” MC and 2000-2003 4 pot dual calipers (~33mm piston size) - good braking power but lever travel little bit scarry (coming to close handlebars)
2. XR 5/8“ MC and Brembo 4 pot dual calipers (32mm piston size) - perfect braking power and confident lever travel (my favorite so far)
3. XL 1/2” MC and 2000-2003 4 pot single caliper (~33mm piston size) - good braking power but very similar feel as 1st setup above (lever coming to close to handlebars)
4. XL 14mm MC and 2000-2003 4 pot single caliper (not tested yet but I belive it will feel better than with 9/16“ MC since it's little smalled I.D.)
5. XL 1/2” MC and Brembo 4 pot single caliper (32mm piston size) - not tested yet but I believe it will be the best way to go

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[1] [2]
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cjburr of the XLFORUM
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