CENTER OF ATTENTION

WHY BUELL PUTS SO MUCH THOUGHT AND EFFORT INTO: MASS CENTRALIZATION

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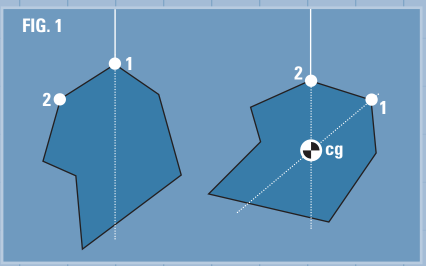
You've probably read the term a hundred times, and you may have heard it a few dozen more, but do you really know what is meant by the benefits of "mass centralization"? This is such an important concept for Buell, yet we have spent very little time explaining the nuts and bolts of it to our enthusiasts. So, when FUELL® asked Buell Engineering for another technical article, we thought this might be just what the doctor ordered.

So, what is mass centralization? You can probably paint a clear picture in your mind of Buell engineers trying to pack the mass of the vehicle as close to a center as possible. But, what is this center? And, why do we want mass centralization? Let's begin by addressing the first question.

Finding the cg of a Body

What is the center (cg)? The "center of mass" is basically the point about which the mass of the body is evenly distributed. On a planet such as ours, where gravity by its very nature acts on a body in direct proportion to its mass, the center of mass coincides with the center of gravity. This is helpful in providing an easy way to find this center, since by definition the center of gravity ("cg") is the point about which a body is in equilibrium in all positions.

FIG. 1



So, how does one find this center? Fundamentally, as shown in Fig. 1, it's as simple as hanging the body from two points (one at a time) and finding the point about which the projected string lines intersect. This works because the body can only reach equilibrium if the center of mass lies directly below the attachment point of the string. Okay, you say, but where should this point be?

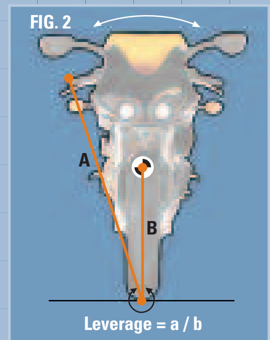
Much research has been conducted with regard to the ideal location of a motorcycle's center of mass. Here we'll try to present the basic concepts that this research has yielded. Let's first discuss the ideal height. For this, we'll take a two-dimensional frontal view of the motorcycle, as in Fig. 2.

Effects of Height of a Bike's cg

Picture the bike as an upside down pendulum rotating about the ground. When the rider provides an input to the handlebar, the road will react to this input at the front tire's contact patch and transmit the load back to the vehicle causing it to lean (we'll leave the in-depth discussion of counter-steering for another day). The leverage that the rider has to the road is dependent on the width of the handlebars and the distance that the front tire's contact patch "trails" the intersection of the bike's steering axis and the ground. The important concept here is that this input leverage, for a given bike, is a fixed number.

Let's then simplify this concept by creating a fictitious fixed lever between the rider's hand and the ground, whose length is a fixed value "a," as shown in Fig. 2. This lever will then be used by the rider to pivot the bike's mass about the ground. Hence, the leverage that the rider has on the bike's mass will be the fulcrum of his input lever vs. distance ("b") between the pivot and the bike's center of mass. Since his input lever is fixed, the closer this center of mass is to the ground, the more leverage he'll exert on it. This is why bikes with a low cg feel so easy to flick around; the rider has good leverage to start, stop, and reverse the roll motion of the vehicle.

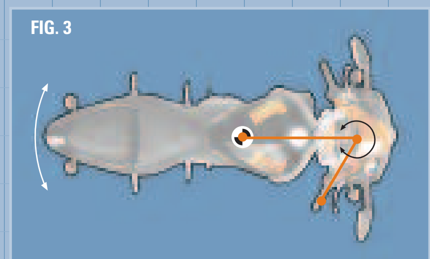
FIG. 2



Effects of Longitudinal Placement of Bike's cg

What about the location fore-and-aft? This is slightly more complicated, but we can once again try to look at it in simple terms. For this, consider a two-dimensional top view of the bike, as in Fig. 3. Once again, the rider's input has a fixed leverage to the ground at the front tire's contact patch, but what of the bike's cg? Basically, you can view it like this: the farther back the bike's cg, the more the bike itself will try to drive the vehicle as opposed to the rider. This is why, as you shift the cg of the bike back by overloading its rear, the bike will want to weave more easily – it simply has more leverage to the steering input point of the bike. Have you noticed that packing cargo on your tankbag makes the bike more responsive to your input vs. packing it in saddlebags? Furthermore, since you are feeding the input to the ground via the front tire, you want this contact patch to be firmly planted to ensure that it engages the ground as directly as possible.

FIG. 3

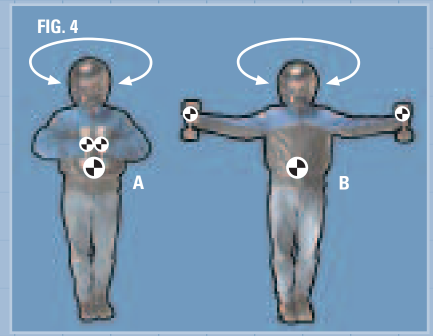


So, what do you think happens when a bike is designed with its heavy exhaust system hanging off the tailsection (high and rearwards)? Isn't it obvious that it should be mounted at the lowest and most forward location on the vehicle? It is to Buell.

Why Mass Centralization?

Okay, so the center of mass of the bike wants to be low and forward, but what about its distribution? The concept of mass distribution is known as the object's mass moment of inertia. Look at it like this: take two dumbbells and hold them in your hands tightly against your chest and try spinning your whole body as in Fig. 4a (It's fun to do this with skates!). Next, try it again with your arms extended out to your sides as in Fig. 4b. You'll find that you can spin (and stop the spinning) a lot easier with the mass close to your body (and hence, close to your cg). Note that the mass did not change, nor did the center of mass. What changed was the distribution of the mass about this center.

FIG. 4



Mass Distribution Effects on Vehicle Roll Related to Muffler cg Location(s)

Now let's look at the mass distribution about the center of mass of a motorcycle and see what makes sense. Let's again start with a two-dimensional frontal view of the bike and consider that the rider wants to make the bike lean or roll about the ground. We'll call the line connecting the front and rear tire contact patches the "roll axis." Once again, thinking back to the skater example, in order to start and stop the bike's roll about this axis, you want the bike's dumbbells to be as close as possible to the ground (which is where the cg wants to be). So, as we did before, let's consider a bike with its mufflers mounted to the tailsection vs. a Buell, as in Fig. 5. Which do you think will be more flickable?

FIG. 5

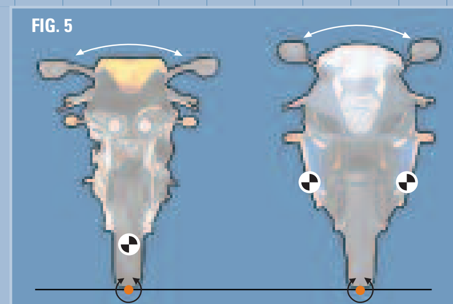
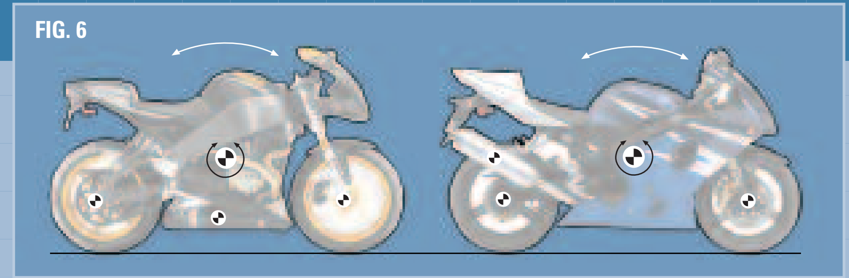


FIG. 6



Mass Distribution Effects on Vehicle Pitch Related to Muffler cg Location(s) and Wheel Weight Values

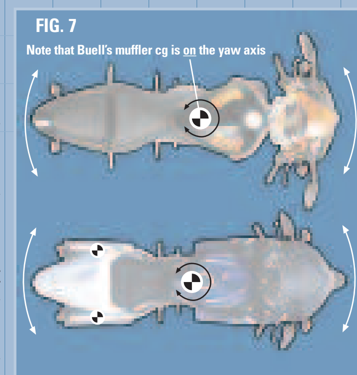
Now, let's move to a two-dimensional side view, as in Fig. 6. When the vehicle goes over bumps, it wants to pitch about its cg – that is, about a "pitch axis" through the cg that would be coming out of the page in this figure. You can imagine that if the bike's dumbbells are far from this axis, the vehicle will have a poor suspension response, since once it starts pitching it will become difficult to make it stop.

So, do you really think it makes sense for the mufflers to be mounted to the tailsection? What about the wheels? Beyond the advantages of the low unsprung weight (which we covered in a previous article), what do you think of the wheels as dumbbells in this figure? If you can't put them in the center, shouldn't they be as light as possible? Follow this logic and you can see why we pick a fairing bracket in magnesium as being more important than an engine cover in magnesium!

Mass Distribution Effects on Vehicle Yaw Related to Muffler cg Location(s)

Finally, let's examine a two-dimensional top view. The reason you want a vehicle to lean or roll is because you want it to turn, and, at speed, bikes only turn when they're leaning. Yet, this turning motion is an animal of its own and it's known as "yaw." Just like pitching, the vehicle yaws about its cg (about a "yaw axis") – and the closer the dumbbells are to the cg, the more readily it turns. You know where we're going with this. I don't even need to ask the question, just take a look at Fig. 7.

FIG. 7



Of course, this concept can be extended to every component on the vehicle. Hence, we hope you now understand why Buell takes mass centralization so seriously. With an optimally placed cg, the more we concentrate the bike's mass about this point, the better it will respond to your input (roll), to the turning intent of the roll (yaw), and to the road's input (pitch). And the better the vehicle responds to you and the road, the happier you will be. Enjoy the ride!