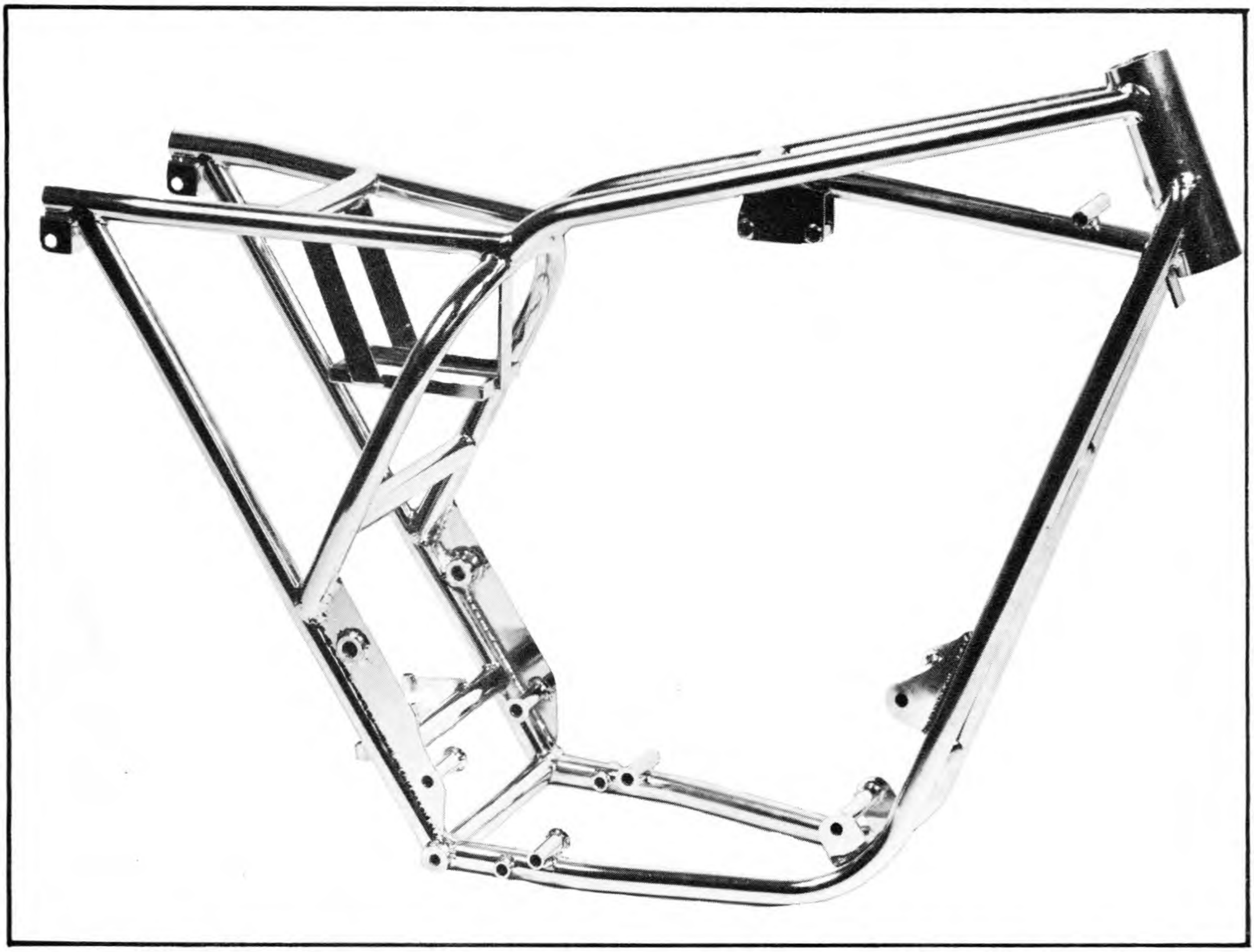
PART 3 SUSPENSION + CHASSIS



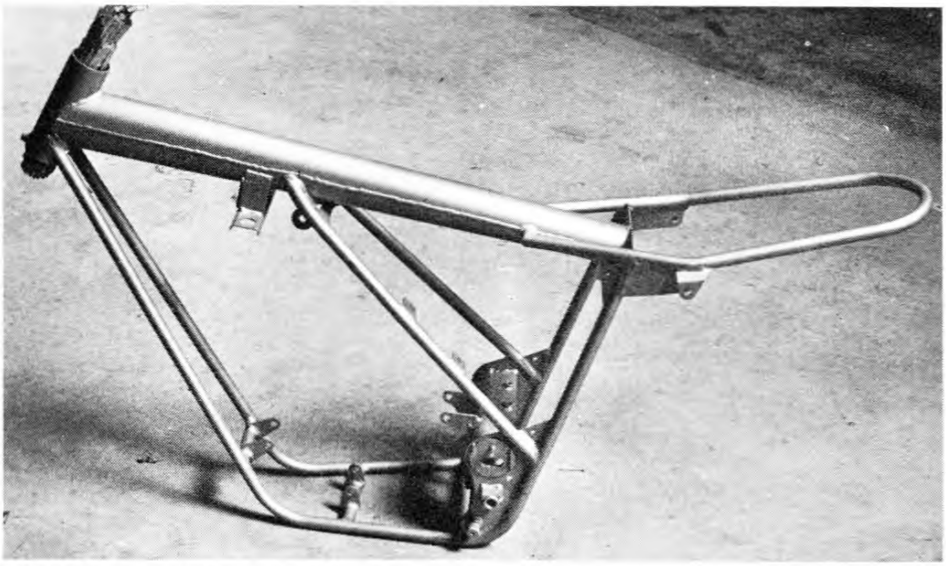
This nickle-plated frame is an example of common chassis design. Note the use of the trianglization method in the construction of this tubular double cradle frame.

The first section on handling covered in the previous two issues ran through the basics of front and rear suspension units. These two chapters actually covered the first half of handling, the second being chassis design. As with the suspension units, we will try to cover the area of the modern day chassis, their good and bad points, rather than getting into the extremely complex study of the engineering principles and theories behind them. There are a few books available (almost all British) that cover in great depth the subject of chassis and frame engineering. If you can read through these chapters on suspension units and frames and desire more, we would suggest you pick up one of these books. They are rather complex and written on an engineering level.

Generally speaking, there are three common frame designs being made today for production motorcycles. They are the tubular single and double cradle type, stamped steel monocoque (one piece) design, and backbone and banana styled frames. Each of these frame designs is a standard production item used by American, European and Oriental manufacturers. Each has its advantages and disadvantages.

In chassis design, the Europeans, in particular the British, have had the upper hand over their Oriental counterparts. Much of this is due to the experience, testing, type of riding and production differences between the two. The Europeans have always placed great emphasis on chassis design rather than engine performance as compared with the Japanese. This goes without saying for road and street machines, dual purpose and dirt bikes as well as motocrossers and road racers.

One of the prime criterion of any chassis is to be rigid and have minimal flexibility, with single and double loop cradle frames. This is accomplished by following the trianglization design pattern. By making these chassis in a series of triangles and placing stress points at the corners, it forces any stresses to push, pull or twist all three corners and not one or two. If you look at a machine bare of its external components but with the engine bolted in position, you will notice a series of triangles that are formed (sometimes overlapping) in looking from one stress point to another. Examples of these might be seen by looking at the top rear shock mount, then looking at the swing arm pivot point, and then rear wheel axle. Three stress points that form a perfect triangle. Another triangle might be the front engine mount and the upper and lower rear motor mounts. The stress here originates at the primary sprocket, but the pulling force is



In an attempt to acquire maximum strength and minimum weight, the AJS motocross frame uses a combination double cradle and semi-backbone construction.

Both Yamaha and Honda have made extensive use of the stamped steel monocoque frame design. In mass production they are cheaply made and strong, but are heavy.

placed equally on all three mounting points. Another triangle can be formed by looking at the head stock, then going down to the front engine mount, then back up to the joining section just behind the gas tank. Basically all of the double and single cradle frames, regardless of origin, are designed using the triangle system.

Stamped steel monocoque frames have become a favorite with the smaller displacement mass production Japanese machines. Probably two of the most popular lightweights ever to hit the motorcycle market made use of this type of chassis, the Honda 90 and Yamaha 80. The construction of the monocoque type frame is simple and very strong. These chassis do not require trianglization to give them strength. In constructing these frames, it requires a large number of units to justify (financially) their production, but with the huge number of motorcycles that Japanese manufacturers deal with, it proves to be quite a cost saver. These monocoque frames are assembled almost entirely by machine. They are made similar to car bodies. Two steel halves are formed in huge presses, matched together and welded at the seams with automatic machines. All of this requires very little manpower. The engines are usually *hung* from the mounting tabs of the frame and add little or no additional strength to the chassis. The big advantage is low manufacturing cost for mass production. Their disadvantage is a high weight factor and inability to modify or change the design or geometry.

The third common frame type used today is the backbone and banana type chassis. The Europeans make extensive use of these chassis for all types of machines. The design and construction of this type of chassis commonly incorporates the use of steel tubing. On the backbone type frames, a very large diameter tube running from the headstock back to the rear of the gas tank area and then down to the rear of the engine/transmission is the main supporting member. There is no other connecting

As with many European factories, the Italian made H-D Baja use the tubular backbone chassis. Note the large diameter backbone tube. Engine may or may not be used as structural member.

chassis member(s) running from the headstock down to the engine. Rather, the engine itself, by being bolted in a multitude of places, acts as one of the supporting stress members of the chassis.

The banana type frame is somewhat similar to the backbone chassis in that it uses no supporting member from the headstock down to the engine. The main supporting member(s) is a formed section(s) that runs from the headstock with a downward curve to the center of the machine, then bends back up to the rear of the chassis. From this banana shaped member other downward sections of tubing are used to mount the swing arm and engine. Some of these chassis do not

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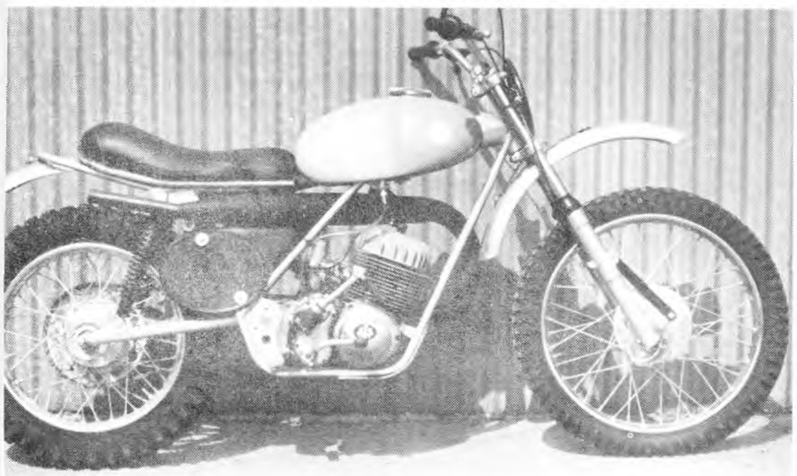
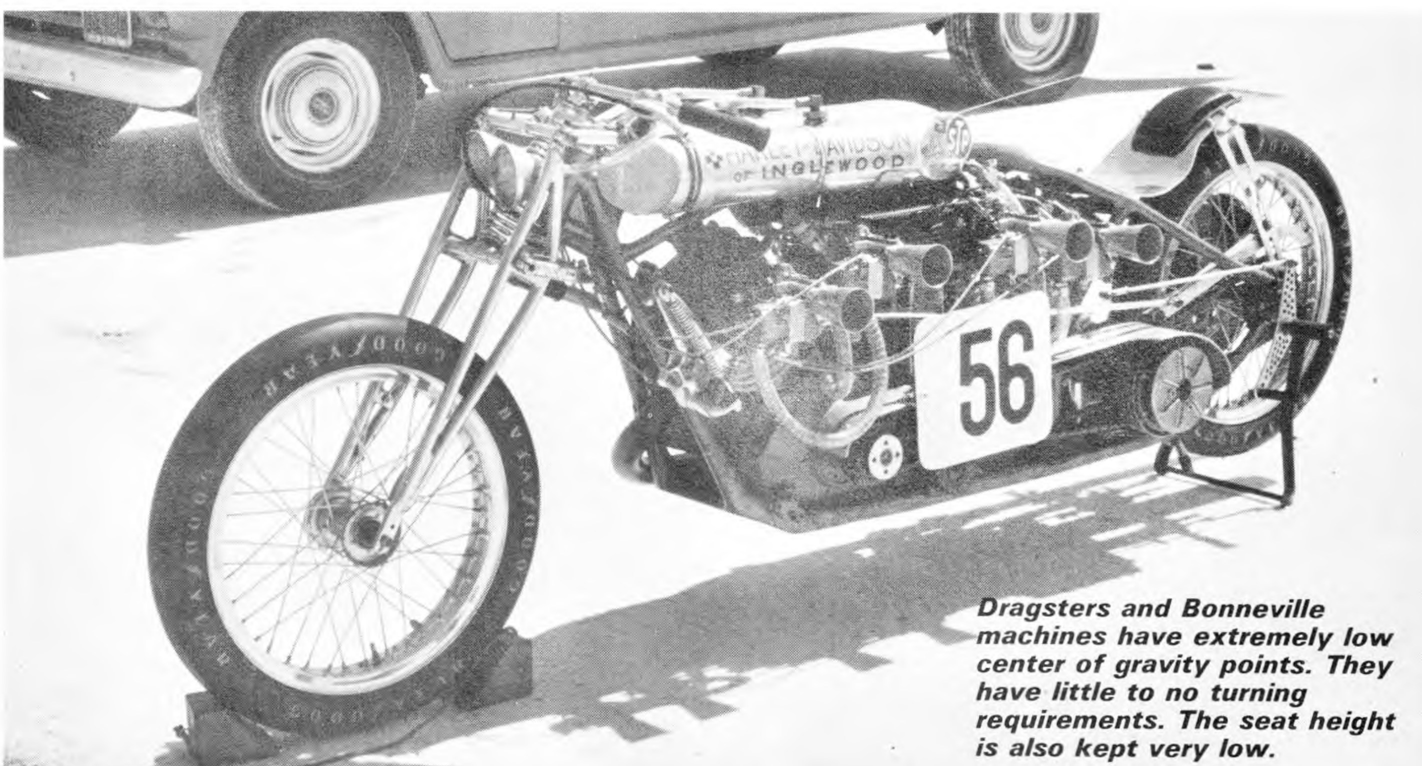
This dual purpose oriented Honda has a high center of gravity due to the location of the top heavy engine. Center of crankshaft is over two inches above axle height.



This AJS motocrosser from Britain has kept the crankshaft centerline below the axle height. Location of the foot pegs is to the rear and low, as is the position of the saddle.

This Bultaco trials machine has a high center of gravity built in intentionally. Low speeds and quick handling are desired here. Check height and rearward location of foot pegs.



Dragsters and Bonneville machines have extremely low center of gravity points. They have little to no turning requirements. The seat height is also kept very low.

CHASSIS Continued

use the engine for a supporting member and just have it hanging from the frame.

Disregarding the various suspension units, the handling characteristics of a motorcycle are directly determined by the positioning of components in relation to headstock angle, swing arm position and length, foot peg and seat location, engine position and their relation to weight distribution and center of gravity. It is these differences that make for the great differences, generally speaking, between the Japanese and European machines.

Let's start off with the center of gravity (CG). With the complete motorcycle, this would be the single central point of balance of the motorcycle. On any machine, this is the point where you could mount a horizontal rod going sideways through the motorcycle and spin the unit like a top. The CG point is determined by two factors, one is the weight bias for and aft, and the other is the weight distribution from the ground to the top of the machine. It's the variation of these two figures that controls and differentiates the general handling characteristics of a motorcycle.

Weight bias of most motorcycles will vary from 45% front and 55% rear to 40% fore and 60% aft. Generally, most street and road machines run in the area of 44% front and 56% rear. On the other hand, most off-road and motocross type machines will lean closer to a 41% front and 59% rear weight distribution balance. There are two general reasons for these variances. One: the street machine will have more components and overall weight, with much of it being on the forward section of the motorcycle. The dirt machines have less equipment and overall weight, and a fewer number of components on the front of the motorcycle. Another reason for this variation is that a street machine functions better on the road with a more equal weight bias and a more centralized CG. The dirt bike, on the other hand, is more desirable if there is close to twenty percent less weight on the front wheel than on the rear. These percentile differences may not sound like much, but in weight the figures could add up to ten or twenty pounds (more or less) on the front wheel.

How or what determines the CG and weight distribution? The CG is determined mainly by the engine, foot peg and saddle location. There are marked differences in the location of these components with the European and Japanese, as well as two and four stroke engines. Ideally, the center of gravity should be as low as is practical, i.e., the aforementioned components as close to the horizontal ground level as is practical. By having a low CG, a motorcycle will have more tendency to go forward, at slow or fast speeds, without wanting to lean or fall to one side or another. The only general exception to this rule is a trials machine where the rider is traveling at slower speeds and turning and leaning the motorcycle over and around objects.

There are two problem areas in having too low a CG. One would be the tendency of the machine not wanting to turn and it will more readily stay straight up. (A motorcycle must lean, even if just slightly, in order to turn.) The two types of machines that would favor the super low CG concept would be dragsters and Bonneville type motorcycles. These two machines virtually have no need to turn—rather, they must go straight and true.

With the specialty machines that require exceptionally high or low CG points out of the way, we will look at more conventional machines. Since different types and styles of machines

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CHASSIS Continued

will have various CG points, we'll use a common feature as a location to determine the vertical center of gravity. This point will be the center line of the crankshaft, since it is easy to visualize and locate. To further aid the location, draw a line from the center of your machine's front axle to the CL of the rear. Generally speaking, most modern day road machines (above 100cc and/or 200 pounds) should have the center line of the crankshaft either equal with, but no higher than one inch above the horizontal line running from the front axle to the rear. Anything above this figure will tend to make the machine top heavy, and below it could cause ground clearance problems when negotiating sharp corners and leaning excessively. (This may be especially true with the wider multi-cylinder-engined machines.)

The higher or taller four cycle engines will generally have the CL of the crank overlapping the horizontal axle line. An example would be Triumph, BSA, Royal Enfield and other European twins, all considered to be good handling machines. A single cylinder four stroke can and should (because of narrowness and engine height) have this CL below—as much as two inches—the axle line. Some of the finest handling machines have been the Velocette, BSA Goldstar, Norton and Matchless singles.

On the other hand, the Japanese have, for some unknown reason, kept the crankshaft centerline position as much as three inches above the axle CL. This has resulted in the motorcycle having top heavy characteristics. These show up most in road machinery, in having an unstable (reluctancy to stay straight up) feeling in cornering and at high speeds. Also, most of the Japanese machinery has more weight distributed on the front of the machine than their European counterparts. This goes for both the two and four stroke Oriental manufacturers.

The exclusion to the above general formula is the lightweight small displacement trail type motorcycles. Because of their engine and overall lightness (and smaller powerplant) they can have the crankshaft CL higher (up to two inches) above the axle CL without adversely affecting the handling. This is because the actual center of gravity for the machine is in the same area as the larger motorcycles. Also, most of these smaller machines cannot attain the speeds and are not subjected to the handling stresses as are the larger motorcycles.

This information pertains almost entirely to the position of the power

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plant and its relationship to weight distribution and center of gravity. The other determining factor of the center of gravity is the position of the foot pegs and saddle. These will change the location of the center of gravity with the rider on board. In the case of a street or road machine, the position of the saddle will play an important part in changing the CG. This is because the rider's weight is almost entirely situated here, with a small percentage on the foot pegs. Experience tells us that 31 inches is an accepted average for the best location of the saddle height from the horizontal ground level. Again, experience tells us that having the saddle height above this 31-inch figure can have adverse affects on the high speed handling because of the raised CG. On the other hand, some road racers will get the saddle height as low as 28 inches to lower the CG for improved high speed handling qualities.

With dual purpose off-road and racing motorcycles, the saddle height location is secondary in importance to the location of the foot pegs. The reason for this is that the rider's weight, especially with motocross machines, will center at the foot pegs when the rider is standing. Obviously, the CG will be greatly lowered if the rider's weight is down at the foot pegs (below the top of the engine), rather than up at the saddle. But the height of the saddle is still important as more time is spent sitting than standing.

The exception to the lower saddle height and foot peg position is a trials machine. With the trials machine there are no demands on high speed or cornering ability. Rather, the important factor is the ability of the machine to handle very quickly at low speeds. Therefore, trials machines have a high engine location and foot pegs to give maximum ground clearance and quick handling qualities. The foot pegs are commonly located above the crankshaft centerline and behind the engine/transmission assembly. The location being far rearward also places maximum weight on the rear wheel.

In this first section on chassis we have looked at the basic construction of some common motorcycle chassis configurations. The three common chassis types all have the same requirements regarding construction principles, engine and seat location, plus the position of foot pegs and their relationship to the center of gravity. Now that we have covered suspension units and general frame construction, we will next see what the last and final stages of the location and position of these units in a chassis result in. Next month's section will cover geometry of the chassis and suspension units. *Dave Holeman*