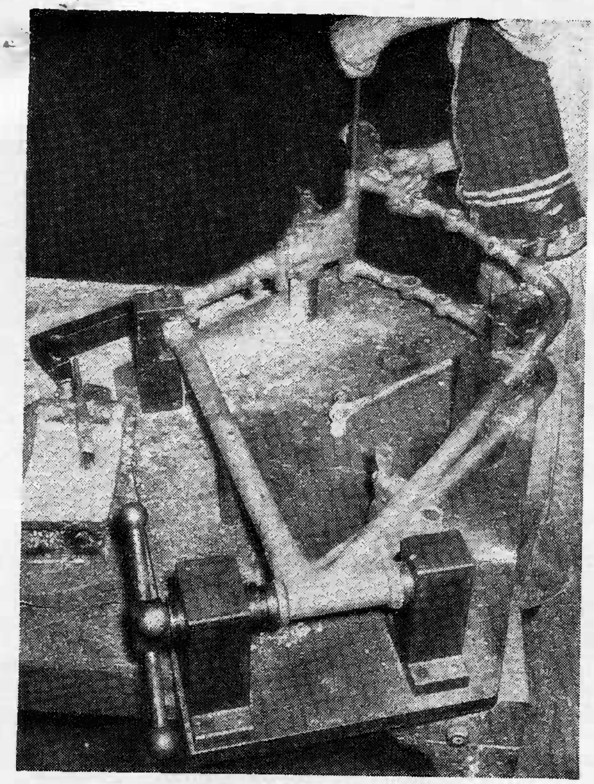


MOTORCYCLE ENGINEERING—12

Methods and Materials

Part One—Brazed Frames

By PHIL IRVING

Assembling an A.M.C. duplex frame in its jig before brazing. Locating pegs are inserted by hand pressure only; the operator's hammer may be used to tap the frame. Flux, on the left, has been applied before jigging.

WE have now surveyed many of the design features which theory and experience have shown to be necessary or desirable in the forks, frame and suspension system. This appears to be a good stage at which to consider the practical task of putting these features into metallic shape, which includes the choice of the most suitable materials and methods for uniting the various components embodied in the construction.

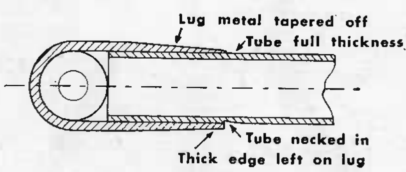
The classic (or, some might say, archaic) method of frame-building is by brazing steel tubes into lugs made from malleable cast-iron or steel, and this time-honoured procedure is still used in many factories today.

Most of the machining on the lugs consists of simple drilling or milling operations, with no extreme degree of accuracy in size or surface finish required. The lugs can be designed to accommodate any angles or changes in direction of the tubes, so that usually these can be either straight or contain, perhaps, one simple bend, while concentrations of stress can be taken care of by suitably ribbing the lugs or locally enlarging their cross-sectional area.

Brazing is a simple and cheap method of making joints. The process is to coat the parts with a flux in paste form after removing all grease and scale, assemble them in a frame-jig, drill one or perhaps two small holes in each joint to be brazed and drive in steel pegs to retain the parts in position while they are brought to a red heat on a hearth with the aid of a torch burning coal-gas and fed with compressed air. Brazing-brass, in the form of rod, is then applied to the joint at one end, and when molten it will penetrate right to the other end, provided the joint is at the correct temperature all through.

In the absence of a gas-torch, brazing can be done by home constructors using only a large paraffin blow-lamp on a hearth liberally heaped with coke as a backing around the joint. If no proprietary flux is available, either borax or boracic acid mixed with water can be used; in fact, boracic acid, though expensive, is the cleanest flux of all and the residual scale is easily removed.

If possible the brass should always be applied to the *lowest* part of the joint, whereupon it will flow *upwards* by capillary action, pushing the lighter flux ahead of it; if it is applied at the top, it has to flow downwards in the opposite direction to the natural flow of the flux and the result may be a joint which is incompletely brazed although the brass may have appeared to run right through. For a similar reason the brass should be fed in only at one end; if it is fed at both ends, flux will be trapped in the centre of the joint.



Good filing practice is shown above the centre line—bad, causing a sharp change of section, below it.

With fork-ends or other lugs which have blind holes, it is common practice to load each hole with a mixture of flux and granulated brass called "spelter;" the joint is then heated until brass is seen to exude from the end of the lug. In order to facilitate handling and to prevent the lightly pinned joints from moving, it is usual to braze such small lugs to their mating tubes as individual sub-assemblies before finally assembling the lot in the frame-jig; this also enables a batch of components to be brazed at one time.

Reference has been made in an earlier article to the liability of brazed or welded frames to finish up either distorted or with internal stresses in the tubes through unequal expansion during final jointing. This must be guarded against in duplex frames by arranging the heating sequence so that the tubes are always at the same temperature at both sides of the central plane, which they will not be if the joints along one side are completed while those on the other are not.

For pinning preparatory to brazing, frames and forks are assembled in jigs, with the lugs accurately located by hardened bars or pins fitting into hardened bushes. These jigs are sometimes built up on heavy cast-iron tables with the frame lying horizontal. Alternatively, they may be constructed to hold the frame vertical which, though a more costly form of jig to make, is preferable because there is less liability for the frame to sag when being pinned.

Brazing is also accomplished with oxy-acetylene torches, using one of the easy-flowing copper alloys specially developed for this purpose. Torch-brazing can be facilitated by the use of roll-over jigs which can be turned as the job proceeds to give better access to the joints.

All brazed frames must be checked for alignment and trued-up if necessary after cooling, this process demanding a tolerable degree of "know-how" if it is to be done quickly and accurately. The important points to check are the positions relative to the centre-line of the steering-head and pivot-bearing brackets, and the squareness of the latter to the centre plane in all directions. The smallest error in the second particular will result in a machine which has an inherent tendency to run to one side; the same point applies, of course, to the rear forks.

One trouble with brass as a jointing material is that it has the extraordinary property of penetrating into the steel itself with such rapidity that if a tube is heated and then bent when coated with molten brass it will break clean through. This is the reason why, when a damaged tube is being unbrazed from a lug, it often breaks off and leaves a piece inside if handled at all roughly. Therefore when a frame is being "set" the heat must always be kept well away from any areas covered with brass or bronze, otherwise an incipient but quite unsuspected crack may occur with the probability of subsequent complete failure due to stress-concentration in the weakened area.

However carefully it is made, a brazed joint always requires to be cleaned-up by shot-blasting and filing to remove scale and any excess brass, especially if the frame is

Malleable iron is a peculiar material. Its ultimate tensile strength of around 24 tons/sq. in. is low compared to that of mild steel at 35 tons, but it is not very notch-sensitive; that is to say, it is not so likely to develop fatigue-cracks from local stress concentrations or surface defects as are stronger and harder materials. It can be cast in thicknesses down to $\frac{1}{8}$ in., and made in hollow or ribbed sections, according to requirements. It machines easily, either wet or dry.

Malleable castings are made first of all in "white" iron, an extremely hard and brittle material, and then subjected to a lengthy annealing process by which most of the combined carbon is either removed or converted into small graphite flakes. Distortion is likely to occur to some extent during annealing unless the parts are fairly simple and straightforward.

Unfortunately for the "special" builder, this manufacturing cycle almost precludes the use of malleable cast-iron for "one-off" castings, unless he is able to utilize some existing design, but one way out of this situation is to use monel instead. Monel is a "natural" alloy of nickel and copper of equivalent strength, and can be machined and brazed just as easily as malleable iron.

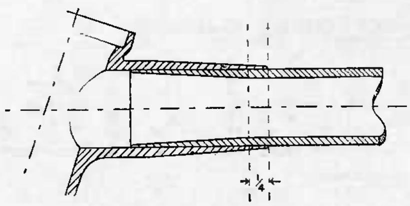
for fork-ends, because these highly stressed components require only one fairly small short hole to accept the fork-tube, and consequently the waste of material involved is so slight that it can be accepted.

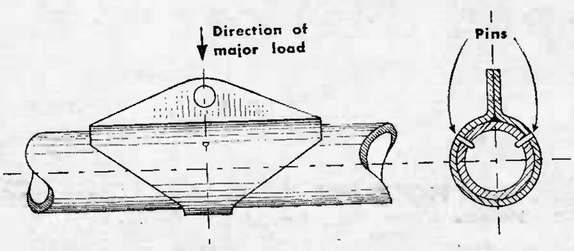
Occasionally simple lugs (such as those which form the forward ends of the side members of a built-up fork) can be machined from bar stock, with the ends either bored to fit outside the tubes or turned to fit inside them, holes being drilled centrally to avoid an abrupt change of section and to save a little weight. This procedure permits the use of a tapered tube at the expense of machining the spigot to a corresponding taper as well, whereas if the hole or spigot is parallel the last inch or so of the tube must also be parallel.

Incidentally, about two to five "thou" clearance should be provided between lug and tube. If there is less than this, it may be difficult to line up the components in the building jig when small errors are present; if more, there is the possibility that voids may form in the joint due to the brass tending, through capillary action, to drift towards the areas where the gap is smaller.

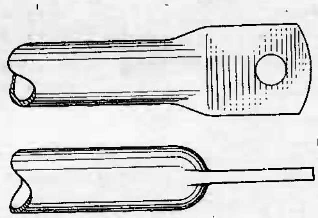
Brass is very "hot-short" just below its solidification temperature. Consequently all joints should be allowed to cool sufficiently for the brass to set before they are moved; otherwise the strength of the joint may be affected.

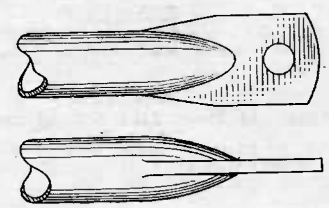
In several instances, the use of lugs may be avoided by trapping—that is, flattening—the tubes, which are subsequently drilled or punched for bolt-holes. The weakest point of a trapped tube is just where the flat section commences, and it is likely to break if subjected to much strain or vibration at right-angles to the flat portion.





(Above) Section through part of a steering-head joint, showing taper-boring of the top tube end. (Right) A brazed wrap-round lug in side elevation and section.





Trapped tube ends. That on the right has a more gradual change of section giving greater strength under side loads.

to be rust-proofed before enamelling, as rust-proofing by Bonderizing or similar processes does not "take" on yellow metals and consequently the bond between such metals and the primary coat of enamel will not be the same as it is on the surface of the steel.

Frames can be either ruined or improved by filing, according to the skill or carelessness of the operator and the time spent. Sometimes, in a misguided endeavour to remove every vestige of visible brass, the tube is severely "necked" at its most vulnerable spot, just where it leaves the lug, whereas it is preferable to leave a small fillet at this point (Fig. 1). In fact any scratches or deep file marks are focal points from which fatigue failure can start.

Conversely, tapering the lug metal down to a thin edge is beneficial in so far as it avoids a sudden change of section and achieves a smoother transmission of stress from tube to lug, with a profitable saving in weight. Another method of achieving these desirable aims is to scarf or cut the lug at an angle, or fish-tail the ends by cutting out two deep V-notches.

When heavy-gauge or butted tubes are used, a small saving in weight can be effected by taper-boring the ends to a depth about a quarter of an inch less than the amount which lies within the lug; this is never done commercially, but on racing frames it is possible to eliminate several ounces of weight by this method, with no loss in resistance to failure (Fig. 2).

In fact, it is frequently used for experimental or show models when time is at a premium.

Lugs are sometimes made from sheet steel, blanked out and folded to shape, but these are usually in thin-gauge material suitable only for the lighter class of frame. Lugs for the attachment of components such as oil tanks may be made from sheet or strip, bent into a circle with two ears which are in contact when the lug is pinned to the tube; after brazing, the ears will be united by the brass (Fig. 3). Where heavier loads are to be expected, the stress can be spread over the tube by making the lug much wider, tapering and scarfing the ends to eliminate useless weight.

For heavier application and higher stresses, steel forgings are often employed; but as forgings cannot be cored like castings, but must be made solid, it would be a very expensive proposition to use them as raw material for, say, conventional head-lugs, since that would entail buying about twice as much steel as the finished part required and then going to the further expense of drilling or machining the excess metal away. Forged steel is, however, a good material

One way of reducing the "notch effect" which is the prime cause of this type of failure is to flatten the tube in dies so that the change from round to flat section takes place over a finite distance, instead of abruptly, as it would if the tube were merely to be flattened in a vice (Fig. 4). Another method is to double-up the thickness by sliding a second short piece of tube over the main one, then trapping the assembly and finally brazing the lot together. This makes quite a strong construction and is especially suitable for lightweight fork-ends in which slots are to be cut to provide axle adjustment.

Materials for Tubes

Round, cold-drawn steel tube is by far the commonest form employed for brazed frames because of its simplicity in working and the ease of machining the lugs.

There are several grades suitable for brazing by the hearth or gas-torch method. In the accompanying table, reproduced by courtesy of the Reynolds Tube Co., Ltd., they are referred to as "qualities," but this term is rather misleading, as it gives the impression that " A " quality is superior to " B." Actually most production frames are made from " B " quality, which is a low-carbon, stable mild steel that can be brazed or welded by any method; whereas " A " quality, with a higher carbon content, cannot be arc-welded or even gas-welded with safety because local hardening and embrittlement occur due to self-quenching as the heat flows to the adjacent cold metal. It is, however, an excellent material for normal hearth-brazed frames.

It will be seen from the table that " B " quality tubing loses much of its " as-drawn " strength after brazing. This is because the higher figure is due to work-hardening of the steel during the drawing process, and the annealing which takes place during brazing removes the effects of cold working. In the fully annealed state, to which tubes must be reduced if any tight bends are to be formed, the strength is reduced still further, and in this quality there is no possibility of restoring it by subsequent heat-treatment—even if such a course were possible on a complicated structure like a frame, which would inevitably distort beyond redemption. Where possible, therefore, bends which require full annealing should be avoided, and in fact there is rarely any necessity for them if the design is correct in the first place.

The chrome-molybdenum tubing termed " 531 " (a symbol derived from its chemical composition) is the strongest tubing available in the commercial range. It is quite suitable for ordinary brazing and loses very little of its " as-drawn " strength thereby. Even when fully annealed, it is almost as strong as " B " quality at its best, and this enables much lighter-gauge tubing to be used without decrease of strength. It must be remembered, though, that Young's modulus, which is a factor used in determining the deflection of a component under load, is almost constant at the figure of 30,000,000 for tension or compression and at 12,000,000 for torsion for *all* steels, *irrespective of their actual strength*—so that, size for size, a " 531 " tube is no stiffer than one of any other composition. However, as has been shown previously, a small increase in diameter increases the strength of a tube very greatly, and the best way of utilizing " 531 " is by specifying large diameters to maintain rigidity and light gauges to reduce the weight.

Next week—Welding and Bronzing

Quality	MINIMUM MECHANICAL PROPERTIES					
	" As drawn "			*After brazing or welding*		*Fully annealed*
	Yield stress tons/sq. in.	*Ultimate stress tons/sq. in.*	*Elongation on 2-in. gauge length*	*Yield stress tons/sq. in.*	*Ultimate stress tons/sq. in.*	*Yield stress tons/sq. in.*
" B "	26	28	12%	17	24	11
" A "	28	35	10%	25	30	22
" H.M."	40	45	10%	25	30	22
" C.M."	40	45	10%	30	35	25
" 531 "	45	50	10%	40	45	25