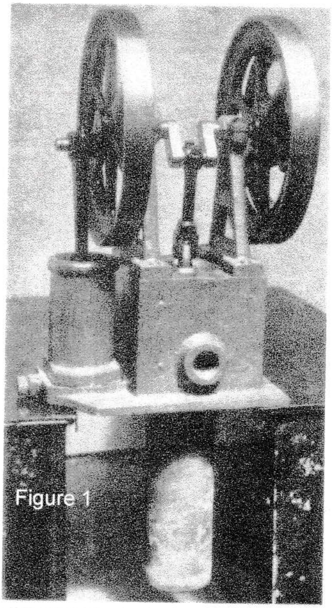
THE HEINRICI HOT AIR ENGINE

Norman Barber



A small Heinrici engine, having a power cylinder 30 mm. bore, with furnace removed to show air chamber.

This engine is based on the well-known design originated by 'Artificer' and serialised in Model Engineer magazine in 1940. The design was subsequently revised and presented by Edgar T. Westbury in his book "Practical Notes on Hot Air Engines", also published in 1940. Strictly speaking the engine is a replica rather than a model since it is to the same dimensions as the prototype (Figure 1) which it is believed was the smallest in the range manufactured by Heinrici.

The engine being exhibited differs in construction from the prototype in that no castings are employed, all parts being fabricated or machined from the solid - a method of construction suggested by Westbury should castings not be available. (Castings and materials were not as readily available in 1940 as they are today!)

The main body is fabricated from square hollow section and mild steel plate for the outer part of the water jacket and a brass inner tube forming the upper part of the air chamber. The power cylinder is mild steel with a cast iron piston provided with labyrinth grooves to assist sealing. The original design specified copper tube for the displacer but this has been changed to thin walled aluminium tube to minimise the out of balance loads, which are quite considerable. The design of the air chamber has also been modified, the specified copper tube being replaced with thin walled stainless steel with a copper end cap brazed to the hot end

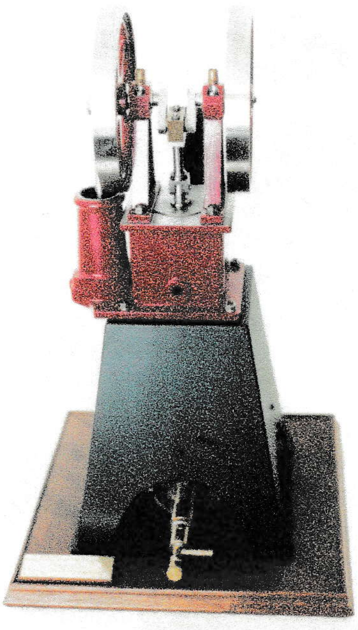
Figure 2

(Figure 2). This arrangement minimises the heat conduction between hot and cold ends of the air chamber whilst ensuring the minimum resistance to heat transfer from the heat source to the working fluid. In practice it is doubtful whether any significant advantage is gained by the use of a copper end since the main resistance to heat transfer is across the metal / gas interface, but the theory is OK!

The crankshaft is machined from solid. Flywheels are also machined from steel discs and locate on tapered seats on the ends of the crankshaft. This arrangement ensures that the wheels run true, there being no danger of offsets due to loads from keys or grub screws.

The furnace is fabricated from mild steel sheet, the edges being machined to the appropriate angle and silver brazed. The chamber is lined with a heat resisting mill board (not asbestos!). The burner is designed to operate from the small gas cylinders supplied for use with portable gas torches.

The engine runs well and so far the cooling water jacket has never been used "in anger". No doubt it would be required for continuous running and for maximum power output but for demonstrations of half an hour or so has proved unnecessary.



themselves. Mainly three-colour signals will be used, the train passing over a sensor will automatically control the colour shown. The two pedestrian level crossings will have two-colour signals with flashing lights and sirens to warn pedestrians of an approaching train. Most of the groundwork has been completed. The twenty four volt power circuit is already in place and a multi-core cable is now be run to each signal. Each signal post will have it's own control box, and depending on the direction of running, one of two sockets on the outside of the box will be used, the signal facing the appropriate direction. The signal posts are de-mountable for security reasons. It is planned to have the system in operation by the Easter weekend.
On Jan. 2nd, at "The January Crank Up" the L&BR carried two hundred and thirty one passengers, the proceeds are to be donated to the Asian tsunami appeal. An idea very popular with all of our passengers.

WHEEL FIXING WITH LOCTITE

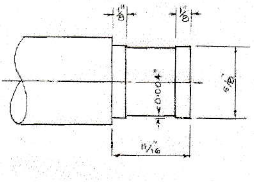
Norman Barber

Traditionally locomotive wheels have been fitted to their axles using an interference fit, usually assembled with the aid of the bench vice as a press. The procedure has a couple of potential snags, one of which is the risk of splitting the wheel hub if the interference is overdone. Another is the risk of slight quartering errors between wheel sets - no second chances once the assembly has been completed! I confess to having a rather conservative approach to new technology and it took me some years to come to terms with the idea of gluing metal parts together as an alternative to traditional fixing methods. When I came to fit the wheels of my Maid of Kent I discovered that the wheel sets were too large to fit into my bench vice for pressing. I was faced with making, buying or borrowing suitable equipment for the job or adopting an alternative assembly technique - Loctite! I had had some experience of this product in industrial applications and saw no reason why it should not be satisfactory. Other people used it, so why shouldn't I? One answer to that question was that I knew of cases where wheels fitted in this way had come off! I decided to do some tests of my own to check that any procedure which I adopted could yield a satisfactory bond between wheel and axle. The results of these tests may be of interest to others.

Two sets of experiments were carried out. In each case the test components comprised a cast iron block of approximately the same outside dimensions as the wheel hub and the same thickness as the wheel together with a stub axle having a wheel seat machined to the design proposed for the locomotive. The first series of tests consisted of fitting the stub axle to the dummy wheel boss using Loctite 603 and measuring the torque required to break the bond after allowing a 24 hour curing period. The shear stress in the bond at the failure torque was calculated and compared with the published strength for the adhesive. The second series of tests involved a number of stub axles, pressed into the dummy wheel hub in traditional manner. Again, the torque required to slip the axle in the hub was measured. The degree of interference was increased in successive tests until the dummy wheel hub was split. Finally, the theoretical slip torque and the tensile stress in the hub were calculated for the interference fits tested. The results of the tests were as follows:

Loctite Fixing.

The wheel seat design adopted for the tests is shown in the accompanying diagram. The lands at each end of the seat were machined to a light (hand) push fit. Three tests were conducted with very consistent results, the torque to break the bond being 50 lbs.ft., 50 lbs.ft. and 52.5 lbs.ft. respectively. A few simple calculations show that 50 lbs.ft. torque corresponds to a shear stress at the join (based on the surface area of the relieved portion of the wheel seat) of 2235 lbs/sq.inch. Examination of the joint after failure showed that the distribution of the Loctite had not been perfect. It was estimated that in each case only 75% of the relieved area had been filled with adhesive.



This suggests a shear stress at failure of 2235/0.75 = 2980 lbs./sq.inch. The shear stress for Loctite 601 (virtualy the same as 603, which is slightly more oil tolerant) is quoted in Tubal Cain's Model Engineers Handbook as in the range 2540 - 3260 lbs./ sq.inch. The results of the tests were therefore as might have been predicted and confirmed that the design and execution of the joint were satisfactory.

2. Press Fit

Three press fit tests were conducted with interference of 0.001, 0.002 and 0.003 inch. The beak out torque for the 0.001" interference case was 25 lbs.ft. and for the 0.002" interference was 50 lbs.ft. The 0.003" interference resulted in splitting the dummy wheel hub.

3. Theoretical treatment

The theoretical prediction of break away torque is, of course, dependent among other things on the coefficient of friction assumed between the cast iron hub and steel wheel seat. For the present exercise a coefficient of friction of 0.1 was assumed. This resulted in a predicted break away torque some 80% higher than the measured figures, suggesting that the actual coefficient of friction is considerably lower than assumed or, more probably, that very small local machining inaccuracies or surface finish imperfections resulted in a less than perfect fit. The tensile stress in the hub is estimated as 7.7 tons/sq.inch with an interference of 0.001 inch. This stress is directly proportional to the interference up to the yield point of the hub material. In the case of cast iron plastic deformation will be virtually zero and the proportionality can be assumed to extend to the point of failure. Thus the tensile stress with 0.003 inch interference will be of the order 23 tons/sq.inch and it is not surprising that the hub split, grey cast iron having an ultimate tensile stress typically in the range 12 to 17 tons /sq. inch.

Conclusions and Comment

It must be recognised that the size of the samples used in these tests, particularly the press fit tests, was too small to provide anything more than an indication of the relative merits of the techniques employed. Quantitative comparison of the results obtained using the two fixing methods would be unjustified. The results tend to confirm, however that the use of Loctite can be expected to provide at least as good a bond between wheel and axle as the more traditional press fit. I found that one of the joys of using Loctite was the ease of quartering the driving and coupled wheel sets. This was carried out in-situ in the chassis rather than dealing with each wheel set individually. More of this at some other time, however.

The wheel seat dimensions adopted for the Loctite assembly were based on the manufacturers recommendation of a 0.1 mm (0.004") gap between the mating parts. The definition of 'gap' seems to be open to interpretation, however. I interpreted it as the distance between the surfaces being bonded. I note from literature distributed at a recent Club meeting that, although a 'gap' of 0.1 mm is specified a diametric clearance of 0.1 mm is also specified. This results in a 'gap' of 0.1 mm if the male component is offset to touch the side of the hole on one side but only 0,05 mm 'gap' if the components are concentric!

Having convinced myself that I should move with the times and use this new fangled material (lets face it, it's only been around for about twenty years!) I have become a Loctite convert. I shall still fit French keys in the driving and coupled wheels, however - just in case!

EARLY ENGLISH PLOUGHING INTO THE BEGINNINGS OF STEAM PLOUGHING

Peter Ratcliffe

Part 2

In the middle of the famous, an inventor - Lt Halkett RN - devised his 'Guideway Steam Agriculture' 1858. The system comprised two steam engines with locomotive boilers mounted on double-flanged wheels riding on individual rails, the distance spanned by the gantry and rails some 50 feet. Halkett's original Guideway System was applied to cultivators, harrows and other small tools attached to the underside of the gantry by chains. The system was clearly workable in all weather conditions but being highly specialised suffered the problem of location. The idea of a Guideway System or power operated implements, etc from positively located rails has been applied about the world ever since. It must be seen that Halkett's first gantry system when engaged in ploughing as the work would necessarily commence from one side of the guideway or gantry presenting initially a very biased or unequal loading to the gantry rendering Halkett's first system unequal to the job of ploughing. The modifications necessitated placing the individual engines without the gantry on rails at right -angles to the work in hand and pulling a turnwrist plough by wire between the two engines. Following this development the pattern would have been set for conventional balance-plough work but by 1858, or later, steel wire in quantity and cheaply had not arrived and continual failures of the cable as bedevilled Lord Willoughby and others led to Halkett abandoning his original gantry system. Subsequently, the principle was modified by a Mr Grafton and it would appear the Guideway System continued on rails but for ploughing, a belt-driven windlass was employed between the then two independent englnes.

Principally, Guideways in the new world carried irrigation systems which were ultimately developed into centre pivot where from a fixed point rotated wheeled units extended upon each other and powered by the water passing through motors or turbines driving them. A centre pivot system could carry over an area equal to 'circular' square mile or 640 acres. Equally parallel Guideway irrigation systems with interval supports are widely used to irrigate, fertilise and control crops on large areas of level land.

Into the Space Age the evidence of the circular Guideway System can be seen from space where cereal crops are grown in the Arabian desert to provide grain for milling and animal feed for the dairy herds and a high standard of living for the Saudis. The Guideway principle is of such great importance that today most farm activities require correct spacing and marking of crops to prevent overlap or 'misses'. Fundamentally in the late 1950s it was appreciated when sowing seed to omit sowing a row at specified intervals

DRILLING CROSS HOLES THE EASY WAY

Geoff King

One of the tasks a model engineer eventually has to do is to drill a hole centrally across a shaft or other component. This is not an easy task to do which is why there has been umpteen jigs for the task in Model Engineer over the years. This is how I did it recently, no measuring, no difficult making of jigs, and absolutely accurate. It can not be off centre.
A block of metal [steel is probably best] about 2" x 2"x 4" long is faced up square on both ends and then drilled through about 3/8" diameter. This block is then bolted down square across the cross slide of the lathe with a tee nut and bolt. A slot drill is then put into the lathe chuck and a slot is machined in across the block using light cuts to avoid any push over of the cutter. Several different sizes can be done if needed [8 faces are available] say 1/8", 1/4", 3/8", 1/2"and 5/8". Your work holder is now finished and ready for use after deburring the slots.
The component to be cross drilled is now clamped in the appropriate size slot with a tool makers clamp or similar. The work must not touch the bottom of the slot and for preference the slot width chosen should be half to three quarters the diameter of the work, but this is not critical. A centre drill is now put in the lathe chuck and the work is now centred, and then followed through with the finished size drill. The hole drilled MUST be across the centre as the slot locating the work was machined from the chuck. Even if the milling cutter cut oversize this does not matter.
No accurate measuring has been needed and an exact result every time.
If you need a vee shaped slot for drilling across a square shaft from comer to comer use a counter sink cutter as an end mill to open out the slot to a 90 degree vee.
Do not move the block to another lathe as the centre height may well not be the same from lathe to lathe.