

# Internal Keyways and Broaching

By an anonymous user

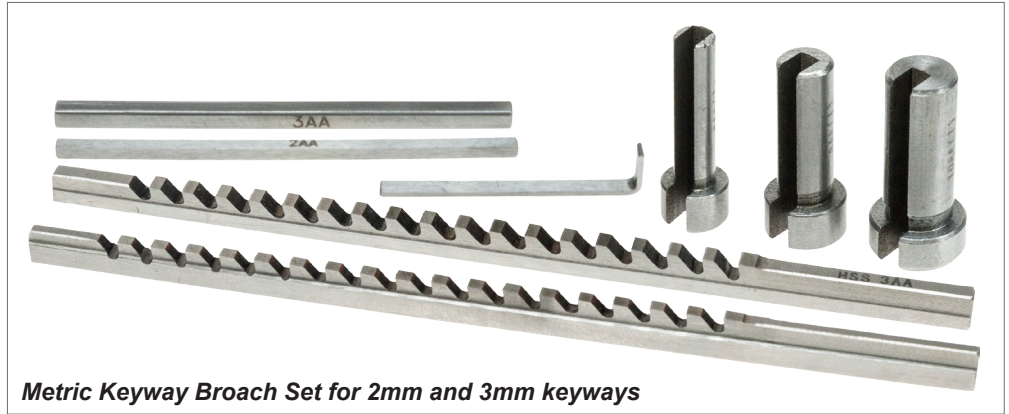
## Introduction

In the various spheres of Model Engineering the need for an internal keyway varies enormously. Locomotives in general do not use them, although there is an increasing use of them in the larger gauges for driving wheel alignment, (quartering). Koppel designed and built by Ken Swan is the exception that proves the rule, there being a profusion of keyways used on this locomotive. Traction engines on the other hand have quite a large number of keyways and splines in comparison. The Flywheel is usually fitted with a tapered Gib Key, then further along the crankshaft there are the splines associated with the gear change cluster, plus various single keyways used to key the gears as they transmit the drive to the Hind Wheels.

There are also keyways in the rear axle to key the Differential, the plain driving flange when no differential is fitted and the usual Winding Drum. W. J. Hughes in his book on constructing the Allchin traction engine describes in detail the manufacture of a special cutter to cut the splines on the crankshaft as well as to manufacture the Broach to produce the mating splines in the change Gear Cluster. L. C. Mason on the other hand in his book on constructing the Minnie traction engine produces his internal keyway for the change gear cluster by Silver Soldering a slotted sleeve into the gear cluster bore.

Model tractors which are powered by internal combustion engines are another source of a myriad keyways depending on the scale in which the tractor is being built. The gearbox which is usually but not always 3 speed plus reverse has a number of gears which need to slide in order to change the gearing but they also need to be keyed to the shaft to transmit the drive. This again depending on the scale of the tractor can be a simple one off feathered key or a multi-tooth spline. The halfshafts where they go into the differential pinions will need to have a similar arrangement to the gears in the gearbox and on the other end of the halfshaft the wheels again need some form of spline or key arrangement.

Depending upon which field of Model Engineering the reader pursues the need for internal keyways varies quite considerably. For my own part the prospect of building a working Tractor model presented a requirement for a large number of keyways to be cut. In the past most of my internal keyways have been just one-offs for workshop equipment and as such have been dealt with by racking a boring bar holding a suitable width cutter back and forth while applying a cut with the crossslide. There have been several designs for lever operated slotting devices to fit to the lathe topslide over the years and it was looking increasingly likely that now was a time to make one such device. However, talking to Arc Euro



Trade about the pending project and the requirement to cut multiple internal keyways just in general conversation, the offer was made to trial a set of Keyway Broaches that the vendor was thinking of adding to his inventory.

## Push Type Broaches

The Broach sets under consideration are both of the push type in that they require an arbor press to provide the motive of force. The drawback with the larger of the two sets is that the length of the broach dictates the need for an arbor press with a large amount of daylight, in other words the distance from the Ram face to the Anvil face needs to be quite large.

For my part the smaller set #60 which cuts 2mm and 3mm wide keyways was just the ticket, it comes with three guide bushes 6, 8, and 10mm diameter which means either of the two broaches can be used in each guide. Included in the box was an "L Shaped" shim which I have always assumed is for deepening the finished keyway by inserting this between the back of the broach and the internal face of the guide after the first pass. Depending on how far through the broach is then passed on the second cut with the shim in place will determine the amount of extra depth produced, obviously if the broach is passed completely through, the keyway

depth will be increased by the thickness of the shim. Whilst I had no requirement to use this shim, the manufacture of smaller thickness shims would not be that difficult and would make the oversize in depth of keyway more easily controllable.

Two pieces of ground square stock 2mm and 3mm are also included in the box. This presented a quandary as to what these two pieces are for; my initial thoughts were that they were just pieces of key steel for use as keys. Whilst this may be the case I however had a better use for them, but more on this later.

The larger broach set #70 cuts keyways 4, 5, 6 and 8mm wide, there are also guide bushes that cover 12 to 30mm diameter holes. Unlike the smaller set where both broaches are the same size on the back or "guide face" the larger set has the 4 & 5mm wide broaches such that they can only be used in guide bushes, 12, 14, 15 and 16mm diameter. While the broaches which are 6 & 8mm wide are used in guide bushes 18, 19, 20, 22, 24, 25, 26, 28 and 30mm diameter. Once again, the L Shaped shims and the sample key stock are included in the set. At first glance, the restriction of usage as regards which width broach fits into which sleeve may be regarded as a problem but if a bit of lateral thinking is applied, then new guide bushes turned up from mild steel to suit the job in



**Metric Keyway Broach Set for 4mm, 5mm, 6mm and 8mm keyways**



hand to take the desired broach will, in actual fact greatly increase the flexibility of the set.

## Setting Up and Precautions

Push broaches do from time to time get a bad press, (pun not intended), as regards breakage, when these reports occur we seldom get told all the details, that is to say the circumstances which were prevailing when the breakage occurred.

Having used an hydraulic broaching machine in my apprenticeship days whereby the broach was pulled through the work and in later years the push type broaches on a Jones and Shipman Broach Press, which has a reduction gearing to apply the necessary force, I have not experienced any difficulty as long as some simple rules are followed.

For one thing the work should at every opportunity be clamped to the press being used, that way the part cannot shift while the broach is being pushed through. Secondly, attention needs to be paid to the thickness of the component relative to the pitch of the broach teeth.

## Minimum Length of Cut

If a moment is taken to consider what exactly happens when the broach passes through a thin disc all will become clear. For example, say this disc is 3mm and that the pitch of the teeth on the broach is 5mm. It will soon be realised that the moment the first tooth of the broach passes through our disc it will in all probability drop until the next tooth touches the disc. The broach, during its fall has an opportunity to shift forwards as our thin disc slides down the back-face of the tooth then drops into the space between the teeth in the broach. If the operator is not prepared for this sudden surge then in all probability the broach will tip to an odd angle, jam and break, as the line of force being transmitted by the press is no longer acting directly down the axis of the broach.

The rule to overcome this occurrence is to simply fit a sacrificial ring of the same material, with the same size bore above the disc. In our example above, if the sacrificial ring was made 8 mm thick, giving a total thickness of 11 mm then there will always be one tooth in engagement and the broach will have little tendency to tip. Even when doing such a thin disc it still needs to be clamped down. Just because the broach is new does not guarantee the end of the broach is square, it always pays to check with a known good engineers square.

## Back-Off!

Lastly while pushing the broach through it pays from time to time during the cutting operation just to back off the pressure on the ram, allowing some daylight between the two, this then ensures that should there be any bending of the broach taking place during the broaching operation, the broach has chance to realign itself with the press ram face squarely.

As with all engineering activities, the condition of the machine tool or in this case the arbor press needs to be scrutinised. The

ram needs to be square on the end face, which face wants to be parallel to the anvil face; the ram also wants to be perpendicular to the anvil in both planes. The line of action of the ram wants to be perpendicular to the base; should it be pushing off a few degrees in either plane then this will not do the broach any favours. To this end there needs to be the minimum of play between the ram and the press casting.

## Clamping

Some provision to clamp the work down wants to be sorted out before the actual keyway is required, as Sod's Law dictates the broaching operation will be attempted without this with probably dire results. Attention also needs to be paid to ensure when setting the part up to be broached that the broach on exiting the part does not touch the sides of the arbor press beneath the part and last but by no means least, is that there is a hole beneath the arbor press for the broach to pass through.

This last requirement necessitated using my own arbor press laid on its back in the bench vice which accounts for the peculiar setup in the photographs.

## Cutting Multiple Keyways

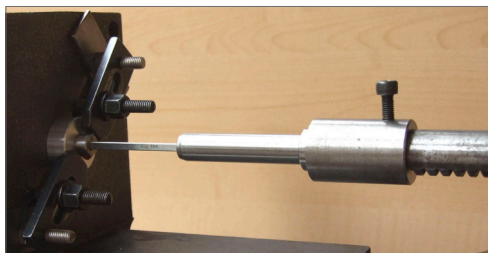
Having decided to trial the broaches my thoughts turned to some of the components that were likely to be made and in particular the halfshaft to differential pinion attachment, which in my case requires an 8mm diameter half shaft with 4 splines.

I must admit to being a little sceptical of whether my intended approach would work so I decided to make a sample joint. The idea was to broach the first 2mm wide keyway using the standard guide bush; Figure 1 shows this first operation completed and the setup.



**Fig 1. Cutting the first keyway**

Shown laid on the back face of the arbor press is an extension piece for the ram to get the required travel, just in case any reader should wonder what this is.



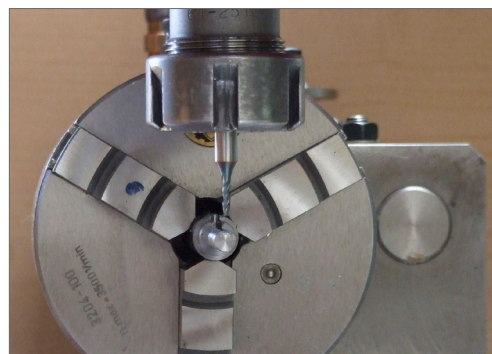
**Fig 2. Using the extension to the Arbor Press Ram to finish pushing the Broach through.**



**Fig 3. The first Keyway finished**

Then, substituting the standard guide bush for one which has been custom made with the same size broach guide slot but with an additional 2mm wide shallow slot at 90° to the broach guide slot.

Figures 4 & 5 show this guide bush being manufactured, with the diameter of the guide bush being 6mm diameter and the width of the broach guide slot being 3.25mm wide there is not a lot of room left to machine a standard 2mm wide by 1 mm deep keyway slot.



**Fig 4. Milling the shallow 2mm wide keyway**

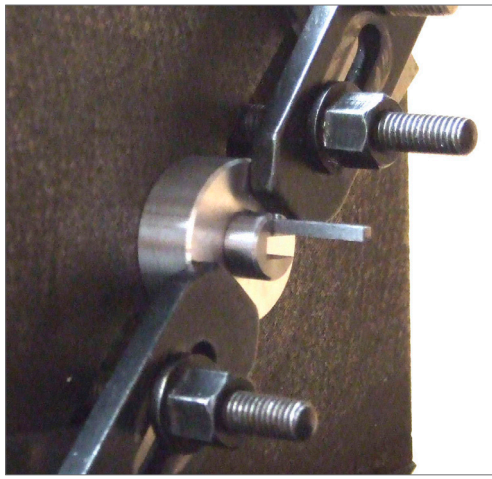


**Fig 5. Machining the Broach slot 90 degrees to the shallow 2 mm keyway**

This is where a little juggling of dimensions comes into play; the keyway produced by the broach in the part is 1.25mm deep the stock keyway material supplied with the kit was 1.99mm the one way and a dead 2mm the other way. Thus if I machined a slot in the side of my guide bush 0.85mm deep there would be 0.1mm clearance at the top of the keyway material supplied when inserted in the first keyway.

Figure 6 shows the custom guide in position being located off the first slot using the piece of keyway material supplied in the kit and hence my comment earlier with regards to



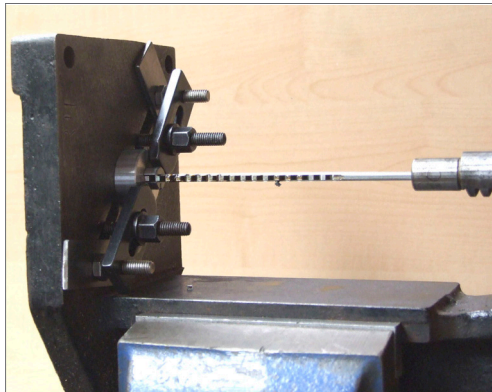


**Fig 6. 2 mm wide Key fitted to new Broach guide**

the use of this piece of material, (it is too good to use for keys).

### Proper Lubrication

Cutting the keyways follows the notes laid out earlier and the use of a cutting oil or compound is essential, the type dependent on the material being broached \*, Rock Oil Maxcut No.5 tapping & cutting fluid (170-150-00100) and Molyslip MCC (170-100-10100) are available from ARC. Unless there is a requirement to do a lot of keyways, I for one cannot see the need to go to the expense of special broaching fluids for the average model engineering requirement.



**Fig 7. Cutting the last Keyway**

The resultant 4 tooth spline is shown in Figure 8, but were the splines equally spaced or was there an accumulative error? There was only one way to find out and that was to make a dummy mating part.



**Fig 8. The finished item with 4 keyways**

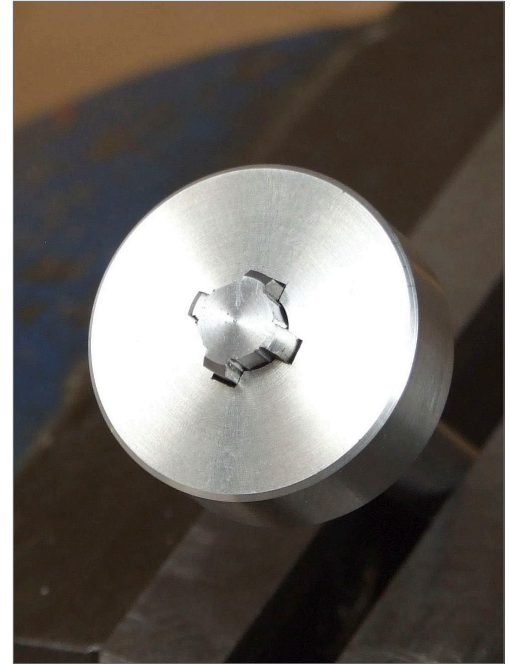
### Checking the Keyways

A piece of 8 mm diameter bar was gripped in the dividing head and using a 1.5 mm wide Woodruff cutter the 4 tooth male spline was produced. No attempt was made to make the root of the spline circular to match the



**Fig 9. Milling the mating part using a 1.5mm wide Woodruff cutter**

6mm reamed hole in the female spline, that is not to say it cannot be done as this can quite easily be achieved using the Woodruff cutter, but for the moment I was more interested in checking the radial displacement of the 4 splines in the female half. My fears were unfounded as can be seen in Figure 10 showing the two parts fitted together.



**Fig 10. The moment of truth both parts slide together with no shake**

### Conclusion

It will soon be realised that this approach to multi-tooth splines can be easily applied to the larger set of broaches, the only limiting factor is the size of the broach in relationship to the diameter of the guide bush, I have supplied a drawing that shows this limitation.

Having completed all my parts for the tractor requiring internal keyways the trial was over and the sets of broaches were remained intact with no breakages, which just goes to show that with a little care there is little to fear.

### \* Lubrication and Cutting Fluids Guidance

Broach lubrication is crucial to tool life and the quality of the finish produced. Lubrication enables chips to slide freely and curl in the tooth gullets minimizing frictional heat. This reduces Broach wear and prevents build up on the cutting edge of the teeth. Push-type keyway broaches, *regardless of the material to be broached*, require lubrication on the back side of the broach in order to reduce friction. Various materials require different lubricants:

Mild Steel - A good quality cutting oil or water soluble coolant brushed on the teeth and back side of the Broach. ① ② ③

Tough Steels such as Nickel Alloys - A good grade of cutting oil or compound. ① ③

Brass - Typically is broached dry, but requires lubrication for the backside of the Broach. ①

Bronze - Works well with an oil or soluble oil. ① ②

Cast Iron - Is almost always broached dry, but requires lubrication for the backside of the Broach. ①

Aluminum - Straight paraffin may be used, but special lubricants are available. ① ②

#### Suggested Lubricants:

- ① 170-150-00100 Rock Oil MAXCUT No.5 Tapping & Cutting Fluid,
- ② 170-150-00200 Rock Oil MAXSYN SLF Semi Synthetic Cutting Fluid (water soluble)
- ③ 170-100-10100 Molyslip MCC Molybdenised Metalworking Compound

