

RIFLED BARREL MAKING

Of all the components that make up the rifle it is the barrel that seems to hold the greatest mystique and mystery. Anybody with basic knowledge of engineering practice could make the action. Anybody with metal working experience and machinery could make a bolt action.

But the barrel, that is a different matter. How do you drill such a long straight hole to form the bore? How is the rifling put in? How is the shiny finish in the barrel achieved? And above all, what is that special something that differentiates a so-so barrel from a hummer?

Each operation in the making of a rifle barrel requires a special machine tool rarely found outside a barrel shop. That said, there is no real mystery in making good rifle barrels. But it does take care and attention to detail. In this article I will outline the main processes involved in turning a bar of steel into a rifled barrel, indicating where barrel makers differ in their approach.

The United States is the home of the custom barrel makers and there are literally hundreds of small barrels across the country, some still make barrels to the customer's specifications. There are also some very large barrel makers who make barrels primarily for the trade. The common denominator is that making barrels is all they do.

THE STEEL.

The barrel of any firearm is a pressure vessel with the action serving to stop up the rear end. The peak pressures involved during discharge are enormous, 50,000 pounds per square inch or more, and special steels are required to safely withstand these stresses.

Two classes of steel are currently used in rifle barrels. Most barrels for use on hunting rifles and in military firearms are made from a high alloy Chrome Molybdenum steel of the sort used in high stress components such as axle shafts. In the United States these steels are designated as 4140, 4150 and 4340 types.

In target shooting stainless barrels have for the most part supplanted the use of Chrome Moly barrels. The steel is not a true, fully austenitic stainless such as is found in cutlery. The 416 type stainless steel used in barrels is one of a group of martensitic steels which can be hardened by heat treating like regular Carbon steels. 416 stainless is more accurately described as a "free machining, rust resistant" steel having a high Chrome content, around 10%, but with sulphur added to give it good machining qualities. It is widely considered that stainless barrels will have a longer life and are more accurate than Chrome Moly barrels. If stainless barrels are "shot in" using the prescribed procedure, the barrel acquires a burnishing which almost eliminates fouling, so making stainless barrels very easy to clean.

Because stainless steel is more expensive than Chrome Moly steel and it is more difficult to black due to the Chrome content, high production makers of hunting and military rifles prefer to use Chrome Moly steels. But target shooters who want the best possible accuracy from their barrels are almost without exception choosing "stainless" barrels these days.

The tensile strength of the steel is measured as the force required to break a rod of steel having a one inch cross sectional area by pulling it from its ends. The tensile strengths of steels used for making barrels should exceed 100,000 lb per square inch giving at least a factor of two safety margins over the chamber pressures experienced during firing. But the impact strength of the steel is probably even more important, or the ability of the steel to withstand an impact without breaking. Generally speaking, the tensile strength of a steel alloy can be increased by hardening it. But as the hardness is increased, so the steel becomes more brittle and it becomes more susceptible to fracturing from a hard knock or sharp. A trade off must therefore be made of tensile strength against impact strength and for barrel steel the resultant hardness settled on is usually between 25 and 32 on the Rockwell C scale.

The heat treatment and other production processes involved in making the steel bar leave residual stresses, which can result in the bar bending as steel is removed in making the barrel. The stress can be relieved by putting the steel in an oven and taking it up to 600 C, then allowing it to cool very slowly. Barrel steel is usually double stress relieved to make absolutely sure it stays straight through the subsequent machining processes.

DRILLING

Anybody who has tried to drill a straight hole more than an inch or so deep with an ordinary twist drill will know the problem. No matter how careful you are in lining the drill up to start with the hole will wander and bend and the drill will not come out quite where you expected. So how is it possible to drill a hole several feet down a rifle barrel and for the drill to come out to within a few thousandths of an inch of the center?

The answer of course, is not to use a twist drill. Special drilling machines known as Gun Drills or Deep Hole Drills are used to drill deep accurate holes. On older Gun Drills it is the barrel is rotated at and the stationary drill is fed through it. The drill bit itself is asymmetric, cutting on one side only, and is made of Tungsten Carbide.

The bit has a hole through it and is mounted on a long steel tube with a V groove down its outside. Coolant oil is forced down the tube to cool the drill and clear the filings the drill produces. The drill only cuts on one side and the oil carries the filings up the V groove on the outside of the drill and drill shaft. The drill is designed so that the forces acting on the drill tip tend to keep it on the central axis of rotation of the barrel. The drill progresses down the barrel at about one inch a minute, so it takes about half an hour to drill a barrel. This process and the drills themselves have remained relatively unchanged for the last hundred years except that the drill tips are now made of Carbide.

The finish that the drill leaves inside the hole can be very good, but that is the exception rather than the rule. The hole is usually drilled about 5 thousandths under the size of the bore diameter and then a reamer is used to bring the hole up to size leaving a fine finish and a hole of uniform diameter from end to end.

REAMING

In most instances after the barrel has been drilled, it is reamed up to the bore size. Reaming a good hole is still something of an art. The vast majority of barrel makers that cut rifles or button rifles their barrels will ream prior to rifling. The makers of hammer forged barrels require a very fine surface finish in the bore and they invariably hone their barrels to get the required finish.

The reamer is mounted on the end of a long tube through which the coolant oil is pumped, but at far lower pressures than are used in the Gun Drill. Now it is the reamer that is rotated and the barrel is pulled over the reamer at about one inch a minute.

Over the past few years there has been a quiet revolution in reamer technology and these days most bore reamers are made of Tungsten Carbide instead of High Speed Steel. Reamers made from Carbide last at least ten times longer than HSS ones and generally leave a superior surface finish. Reamer shape has also changed. Reamers have become shorter over the past ten years and do not have pilots on them as reamers of old.

After reaming, the resultant hole has a good finish and has good dimensional uniformity along its length. The barrel is now ready for rifling.

RIFLING

There are currently three main methods by which rifling is put into the barrel:

- 1. Cut Rifling**
- 2. Button Rifling**
- 3. Hammer Rifling**

CUT RIFLING

By far the oldest method, invented in Nuremberg in around 1492, is the cut rifling technique. Cut rifling creates spiral grooves in the barrel by removing steel using some form of cutter. In its traditional form, cut rifling may be described as a single point broaching system using a "hook" cutter. The cutter rests in the cutter box, a hardened steel cylinder made so it will just fit the reamed barrel blank and which also contains the cutter raising mechanism.

The cutter box is mounted on a long steel tube, through which coolant oil is pumped, and which pulls the cutter box through the barrel to cut the groove. As it is pulled through it is also rotated at a predetermined rate to give the necessary rifling twist. A passing cut is made down each groove sequentially and each cut removes only about one ten thousandth of an inch from the groove depth.

After each passing cut the barrel is indexed around so that the next groove is presented for its passing cut. After each index cycle the cutter is raised incrementally to cut a ten thousandth deeper on the next cycle, this process being continued until the desired groove diameter is reached. It takes upwards of an hour to finish rifling a barrel by this method.

BUTTON RIFLING

Up until WW2 rifling was the most time consuming operation in making a rifle barrel and so a lot of effort was put into finding a way to speed up this process. Button rifling is a process that has been flirted with on and off by various large ordinance factories since the end of the 19th century. Today, button rifling is a cold forming process in which a Tungsten Carbide former, which is ground to have the rifling form in high relief upon it, is pulled through the drilled and reamed barrel blank. The lands on the button engrave grooves in the barrel as it is pulled through.

The machinery is quite simple. The button is mounted on a long rod of high tensile steel which is passed through the barrel blank and attached to a large hydraulic ram. The button is mounted in a "rifling head" that rotates the button at the desired pitch or twist as the button is pulled through the barrel. The process takes about a minute to complete.

These are "pull" buttons that are pulled through the barrel. There are slots cut into the button which means the button does not engrave the barrel in that area and as a result, lands are left in the barrel. The lands left by this simple rifling button tend to have raised burrs on their edges. The "sizing" button follows the "pull" button which presses the burrs back down, so leaving the land tops conforming to the bore circle as they should.

Breaking the pull-rod or pulling the button off the pull rod is a constant danger in "pull" button rifling, so there are several manufacturers who prefer to push the button through the barrel. In this version of the method the button is not attached to the rod, which simply pushes the button up the barrel under the influence of a large hydraulic ram. The trick here is to support the push-rod as it enters the barrel to stop it buckling from the huge forces involved.

There is much opinion that "pull" button rifling is best because the button is kept straight and true as it is pulled through, whereas when pushing the button through the barrel there is an inevitable tendency for the button to tip and yaw so leading to variable bore dimensions. Push-buttoning protagonists deny that this is a problem.

While the process is simple, the technology required to get good results is quite advanced which is why it was not until the middle of this century that it became a generally used technique. It was perfected in the late 1940's at the Remington factory at Ilion largely due to the efforts of Mike Walker, who used the workshop of Clyde Hart in nearby Lafayette for some of the experimental work. The button must be very hard and also tough enough not to break up under the stresses involved as it is pulled through the barrel. The lubricants used to keep the button from getting stuck in the barrel must not break down under the very high pressures involved - it takes around 10,000 pounds of force to pull a button down a barrel. The sort of lubricants used in the press moulding business are what button barrel makers pick through to see what suits, though most makers of button rifled barrels are very secretive about lubricant they use!

Button rifling in its common form is an American development and the overwhelming majority of barrels made in the US are rifled this way. Custom shops such as Hart, Lilja, Shilen and the large high production barrel makers like Douglas and Wilson Arms use the buttoning method to rifle their barrels. The technology has spread and there are a few other small custom barrel makers around the world who do

button rifling. Neville Madden (Maddco) and Dennis Tobler in Australia. Anschutz in Germany, better known for their .22 target rifles but also a large producer of hunting rifles also button their barrels.

HAMMER RIFLING

The technique of hammer forging rifle barrels was developed by Germany before WW2 because the MG42 machine gun, with 1200 rounds per minute rate of fire, positively ate barrels. The first hammer rifling machine was built in Erfurt in 1939. At the end of the war it was shipped down to Austria ahead of the advancing Russian army, where American technicians were able to get a good look at it.

In this process the barrel blank is usually somewhat shorter than the finished barrel. It is drilled and honed to a diameter large enough to allow a Tungsten Carbide mandrel, which has the rifling in high relief on it, to pass down the blank. The blank is then progressively hammered around the mandrel by opposing hammers using a process called rotary forging. The hammered blank is squeezed off the mandrel like tooth paste and finishes up 30% or so longer than it started.

Today, barrel hammering machines are built by Gesellschaft Fur Fertigungstechnik und Maschinenbau (GFM) in Steyr, Austria. They cost about a half a million dollars and can spit out a barrel every three minutes. These machines have reached a very high degree of development and are so sophisticated that they will not only hammer the rifling into the barrel, but it is also possible to chamber it and profile the outside of the barrel all in the one operation. Only large scale arms manufacturers and ordinance factories have pockets deep enough and barrel requirements insatiable enough that they can afford to buy and run such a machine.

Hammered barrels have never achieved much favor in target shooting. Whilst their proponents laud the virtues of the mirror finish of the bore and its work hardened surface, which gives long life, the barrels tend to be very variable in the uniformity of their dimensions down their length. Also, because the metal is worked completely throughout the barrel there are considerable radial stresses induced which are difficult to remove completely by the usual stress relieving methods. Stainless steels tend to work harden to a much higher degree than Chrome Molybdenum steels and so do not remain malleable enough to hammer forge. Because of this, it is difficult to make stainless barrels this way. Stainless barrels are being hammer forged, but using type 410 steel which has a lower chrome content than the regular 416 steel usually used for making barrels by other methods.

Most of the big hunting rifle makers in Europe hammer forge their barrels. Sako and Tikka in Finland, Heckler & Koch, Steyr and Sauer in Austria. Now, Ruger in the US has started making barrels using this method.

PROFILING (CONTOURING)

Profiling the barrel can be done on a regular lathe, but as the barrel is relatively very thin for its length it is not very stiff it is difficult to machine the middle part of the barrel without inducing a lot of chatter, which can ruin the finish and in bad cases even bend the barrel. Also, one is really limited to straight taper profiles achieved by offsetting the tailstock. To reproduce the curving lines of most sporter and big

bore target rifle barrels in a reasonable time requires the use of a proper profiling lathe which has a hydraulic copy attachment and a self-centering steady.

The hydraulic copy unit has a sensitive stylus which follows the shape of the pattern, which is usually mounted on a rail behind the lathe bed. As the automatic feed moves the saddle down the bed of the lathe, so the stylus follows the contours of the pattern. The cutting tool is mounted on a hydraulically actuated tool post and mimics the movements of the stylus, so reproducing the shape of the pattern.

To hold the barrel steady and stop it from vibrating a hydraulic or pneumatically operated steady follows a few inches behind the cutter. This consists of three rollers which clamp on the barrel and which are linked so that if one moves radially in or out then the others follow it. This allows the steady to adjust for the changing diameter of the barrel as the tool and steady move from the thin muzzle the thick reinforce.

When profiling a barrel a lot of metal is removed and if there is any stress in the metal then this is relieved by the removal of material. This may result in a barrel that started out as straight ending up as bent. This is not usually a problem when cut rifling a barrel as this does not induce any stress, but button rifling induces a fair amount of radial stress which is relieved by turning the barrel down. What happens then is that as you remove metal from the outside so the dimensions on the inside grow larger. If you turn a sporter barrel with a skinny muzzle from a buttoned blank then you find the barrel is bell mouthed and the bore diameter is a thou' or more bigger at the muzzle than the chamber - definitely, not good! Buttoned barrel blanks have to be stress relieved before profiling to prevent this expansion at the muzzle.

LAPPING

Lead lapping the barrel is done to polish the bore and remove machining marks and also to remove any tight spots in the barrel and make it dimensionally uniform end to end. If you were to sit down and write a top ten list of barrel makers, past or present, almost all would lap their barrels.

This process is usually done by hand, though the process is mechanized in larger shops. It also acts an inspection process for the barrel maker who can "feel" what is going on up the barrel.

First, the lapping rod (an old cleaning rod) is passed up the barrel to within about four inches of the end and then, with the barrel held vertical, molten lead is poured into the barrel. The lead freezes onto the end of the lapping rod forming a cast which precisely matches the inside form and dimensions of the barrel. The lead lap is then pushed out and smeared with lapping paste like that used for valve grinding. The lead lap is then pulled and pushed up and down the length of the barrel for several hundred strokes occasionally adding more paste or oil. Because the big particles of grit are embedded more deeply in the lead than the small particles there is an even bearing pressure from all the particles of grit onto the steel of the barrel. The net effect is to polish the barrel rather than scratch it which would leave a mat finish.

Lapping the barrel adds between one and three tenths of a thousandths to the bore and groove diameters of the barrel and is used by most small custom barrel makers as the finishing process on the inside of the barrel. Lapping a barrel will improve the performance of almost any barrel.

Generally, lapped barrels will shoot well from the word go where as the same barrel not lapped may take a thousand rounds or so until it starts performing at its best.

WHAT MAKES A BARREL ACCURATE

Some people want their barrel dimensions accurate to the nearest tenth of a thousandth. But in truth, the golden rule seems to be that the groove diameter must be same or less than the bullet diameter to get good accuracy. It does not seem to matter how much less you make it, one tenth of a thousandths or one thousandth so long as it is less.

As a general rule, barrels with shallow grooves are better than those with deep grooves because the bullet will be distorted less. Barrels with shallow grooves reach their best quicker than deep grooved barrels,- but they certainly do not last as long.

Some people say that the finish in the barrel is important and the better the finish, the better the barrel. What seems to be true is that if the finish is too good, less than 10 microinch roughness, then metal fouling tends to become a problem. It seems that in a "rough" barrel, the bullet rides on the high spots and so there is relatively little friction. But the smoother the barrel gets then the greater the surface contact with the bullet. The friction goes up and more bullet jacket gets left behind. Of course, if the barrel is too rough, then this just picks up metal and acts like sandpaper on the bullet. But there is a band of surface roughness where metal fouling is minimized which is between 10 and 20 microinches.

There have been many claims over the years that different forms of rifling profile will give better results. But so far, there is no conclusive proof that the so called concentric form almost universally used these days is any worse than any other - or any better!

What is important is that the bore and groove dimensions are uniform down the length of the barrel, that the twist rate is uniform and that the groove circle is concentric with the bore. Many think a slight choke at the muzzle end of a ten thousandth or so will improve accuracy. But bench rest shooters have shown that parallel barrels seem to win more matches than choked ones. The exception is barrels which shoot lead bullets, like .22 Rimfire barrels and air rifle barrels. These barrels definitely shoot well if there is a slight choking in the barrel. The barrel should also be completely free of stress so that as it warms up during a course of fire the barrel does not bend so leading to group shifting.

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WHICH METHOD MAKES THE BEST RIFLE BARRELS?

Like all old technologies, cut rifling is slow and requires a high level of skill to make and maintain the tooling. This makes it expensive. The other side of the coin is that the tooling is readily made with simple machine tools and is very flexible - by which I mean that a large range of twists and bore dimensions and numbers of grooves are readily achieved using the same cutter and cutter box. This makes cut rifling is an efficient way to go if you are making custom barrels in one's and two's to a customer's specific requirements and you can charge a hefty sum for your efforts. But cut rifling machines are expensive to buy and expensive to operate.

The button rifling machine is relatively simple and cheap to build, (compared to a cut rifling machine), and the buttons are also available and very cheap - in terms of tooling cost per barrel. Also, no real skill is required to pull a button down a barrel.

If it is so easy to rifle barrels using a button, why do some barrel makers persist in the difficult, time consuming art of cut rifling? As outlined above it is critical in an accurate barrel that bore and groove dimensions are uniform end to end. With buttoning a barrel it is critical to have the steel be very homogeneous and of uniform hardness along the bar. If not then the button will engrave deeper into the soft parts than the hard parts so giving varying dimensions down the barrel. The button rifled barrel maker is very much in the hands of his steel mill to supply him with uniform, homogeneous steel.

The depth of engraving of the button depends also on the thickness of the bar at the point where the button is. If the bar is thin then the metal can then just expand elastically allowing the button to pass without doing much engraving. If the bar is thick there is more resistance to the button and so it will engrave deeper. To hope to get uniform bore dimensions it is critical to pull the button through a blank which has the form of a parallel cylinder. A button rifled barrel must be rifled and then stress relieved before it is profiled. There is always the problem that any residual stresses are going to make the barrel move when profiling thus leaving you with a barrel that is bent or bell-mouthed.

The tendency of the bore dimensions of non-stress relieved buttoned barrels to expand on profiling the outside had been used by some manufactures to advantage. Barrels having bore dimensions that vary over the length can be made to shoot well if the muzzle end is the tightest part of the barrel. The bullet will then make a clean exit without gas leaking around the sides to destabilize it. When mass producing barrels it is then possible to allow a fair degree of variation in the bore and groove dimensions down the barrel, provided some choking at the muzzle is included in the manufacturing process. If the buttoned barrel blank is profiled so that the last inch or so at the muzzle end is left at a larger diameter than the rest of the barrel, the expansion of the bore dimensions will be least at the muzzle so leaving a slight choke. That is why the barrels on almost all .22 target rifles look the way they do.

Cut rifling a barrel puts no stress in the steel and so it is possible to profile the barrel after the drilling stage. Any moving around the barrel is going to be done and the barrel can be reamed and rifled after profiling. The problem of stress induced changes in bore dimensions during manufacture can be eliminated.

When making fluted barrels, the fear is always there that putting six flutes on the outside of the barrel will leave the bore shaped like a hexagon instead of round. With cut rifling, the barrel can be completely profiled and fluted after the drilling stage and then reamed and rifled. All the niggling doubts as to whether fluting the barrel will ruin it can be dispelled if it is done this way.

The exact twist of a buttoned barrel is also unpredictable. The button tends to slip in the barrel so what set out to be a 12 inch twist may end up as a 12.5 inch twist. This is not a problem if the twist is uniform, but if it varies down the barrel. If the twist rate slows then more than likely it will not shoot accurately at all.

Another problem, is that the button may not engrave as deep on one side as on the other so leaving a groove circle that is not concentric with the bore. The result is bullets leaving the barrel which are not balanced and so unstable. This becomes less of a problem if you have lots of shallow grooves instead of a few deep ones.

None of these problems arise in traditional single point cut rifling a barrel. Groove circle and bore are always very concentric. Because very little work is being done on each passing cut the twist rate is very consistent and very uniform. As a general rule button rifled barrels are not as uniform in bore dimensions straight off the machine as a cut rifled barrel. Button rifled barrels usually need a good deal more lapping than a cut rifled barrel due to this problem.

Exact dimensions are easier to achieve by cut rifling and are not dependent on the hardness or thickness or type of steel as they are in buttoning. No stress is put into the barrel by cut rifling so no stress relieving is needed.

Many people think that the superior finish in a button rifled barrel must mean it will shoot better. In the first place, the surface finish that counts is the longitudinal surface finish, down the length of the grooves. The tool marks in cut rifled barrels go in just this direction, so causing mini-lands which are quite uniform down the length of the barrel. The transverse "roughness" caused by the lands are never viewed as an impediment to accuracy, so the mini-lands left by the tool marks in cut rifled barrels will also not affect accuracy. In the second place, the final finish in the barrel is determined by the lapping. If the cut rifling barrel maker has paid attention and kept his cutter sharp to minimize tool marks, then after lapping only a very experienced eye will be able to tell the difference between the cut rifled and the button rifled barrel.

In my opinion you are more likely to get a top of the line tack driver by cut rifling a barrel than by any other method.