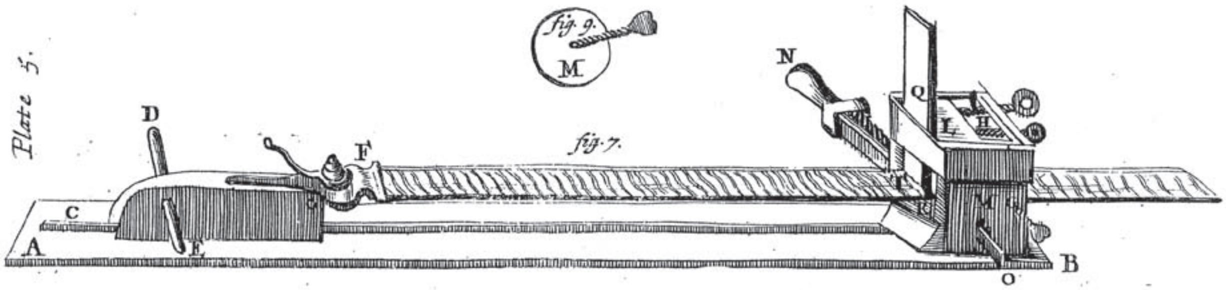

Fig. 1 "Waving Engine" from *Mechanick Exercises*, Joseph Moxon, 1678–80.

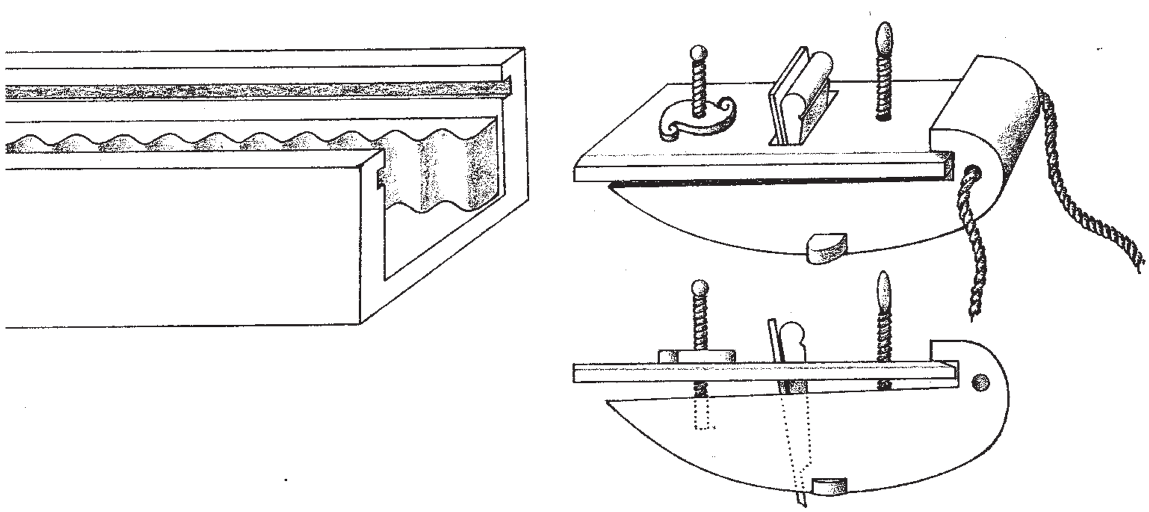

Fig. 2 Waveform molding plane and pattern-track, after an engraving in *Architectura* by Rütger Kaseman, 1630. (re-drawn by Thornton)

The History and Technology of Waveform Moldings: Reproducing and Using Moxon's "Waving Engine"

Jonathan Thornton

Abstract

Rippled or waveform moldings (French—*moulures ondées*), also called "flame moldings" (German—*flammleisten* and *wellenleisten*), have been used in furniture and picture frames since the early 17th century. Reportedly invented in Germany, they rapidly spread to other European countries. They are popularly associated with Dutch baroque frames, especially when executed in ebony and ebonized fruitwoods. Devices for making these moldings all use a pattern and follower system to duplicate a waveform onto a stock piece. The device that is discussed in this article was closely based on the engraving and description in Joseph Moxon's *Mechanick Exercises* of 1678–80. Details of construction and use of this reproduction "Waving Engine" (as Moxon called it) are given, along with examples of finished moldings and frames illustrating the tool's versatility. Scattered published descriptions of this technology show a gradually increasing complexity of the devices from the 17th century to the present. This gradual replacement of a highly skilled operator using a simple device, by a complex machine that can be run by an unskilled operator culminating in the almost complete removal of an operator in the 20th century, illustrates larger trends in craft and woodworking over the last few centuries.

Introduction

Anyone with longstanding interests in woodworking and the history and technology of picture frames could not help but be intrigued by the complex rippled moldings that are most commonly seen surrounding paintings of the Baroque period. If that person is also a maker and collector of tools, as I am, then the construction of a device to make them is a strong temptation. It was years ago now that the temptation became almost an inevitability with my discovery of an engraving of such a device in Joseph Moxon's seminal work on technology, *Mechanick Exercises*.[1] All I needed was the time, which was furnished by a semester sabbatical in 1994. I built a close reproduction of his device and have been exploring its capabilities as well as the literature on the subject ever since.

Moxon's device intrigued me for several reasons: it was neglected or misunderstood in the available literature, it appeared that it would be capable of producing a variety of complex waveforms and it was the only type of such devices that to my knowledge had not been faithfully reproduced (although a somewhat modified version had been published in *Fine Woodworking* in 1986[2]).

The device, called the "Waving Engine" by Moxon (fig. 1), works on a relatively simple principle. A stock piece is fastened to a guide or template rod carved into a waveform, and they are pulled together through a stationary cutter. As the guide rod rises and falls over a polished feeler bar, the waveform is gradually cut into the stock piece by a fixed blade. While the principle is simple, the devil is in the details.

History

Waveform moldings can be divided into two types. The German literature makes the distinction between *wellenleisten*, or moldings that undulate up and down in the vertical direction (perpendicular to the molding length) and *flammleisten*, which undulate from side to side (also in an axis perpendicular to the molding length). This distinction is apparently less linguistically rigid in English. Moxon for example describes the up and down form as "waved" moldings. Later literature has used the term "wave" to describe the horizontal undulation and "ripple" to describe the vertical form. This seems to be the clearest convention in modern English, and that is how I will describe them.

This type of wooden molding was probably first developed in Germany around 1600.[3] There appears to be agreement in contemporaneous sources that the inventor was Johann Schwanhardt,[4] a cabinet and gunstock maker who died in 1612, at which point the method seems to have been reasonably widespread. The makers of silver boxes may have been the first craftspeople to use the technique extensively.[5] Such silver boxes were often combinations of silver and ebony. Ebony is one of the woods that was extensively worked into ripple moldings. Very hard tropical woods such as ebony were newly arriving in Europe, particularly as a result of the trading activities of the Dutch East India Company after the beginning of the 17th century.[6] European craftsmen needed to develop new ways of working such timbers, and the slow scraping action of waveform molding devices would have fit the bill. Frames completely covered with rippled and waved moldings are often considered to be typically Dutch, but recent scholarship has disputed this popular opinion.[7] Such exuberant frames were most likely made in the Catholic parts of Europe; southern Germany and Flanders, and Spain.

The earliest form of a device to make waveform moldings (fig. 2) seems to have been based on cabinet and molding planes and is illustrated in a work of 1630 by a woodworker, architect and sculptor.[8] The moldings are planed into a side-to-side waveform by a plane that moves in a closed track similar to a long miter box. On the sides of the box are undulating guide strips. A peg inserted through a dado on the sole of the plane and projecting slightly out of the sides engages the guide strips and causes the plane to move in a wave motion as it is pulled down the track and over the stock piece, which is fastened into the bottom of the track. The plane itself has a screw-operated device, which increases the depth of cut by advancing the entire plane downwards. This is surely the first woodworking plane to use a screw adjust of any kind, as such mechanisms were not widely used until the late 19th century.[9]

This wriggling plane of 1630 appears to be capable of only the side-to-side action, and so would have produced wavy moldings or *flammleisten*. The method for making wavefrom moldings of all sorts appears to have been fundamentally rethought during the first half of the 17th century, resulting in devices in which the blade is stationary and the stock piece and template bars are the moving elements. The simplest of such devices is a frame holding both a blade and a feeler bar mounted on the end of a screw-feed pressure block. The guide bar and the stock piece are both pulled through this frame by the worker without any additional guides or adjustments. An apparatus like this, residing in an Austrian folk-life museum, was described by Hans Mayerl[10] and reconstructed by him. He appears to have been unaware of Moxon's description and illustration, which represents a more developed version of this same general method.

The technological developments did not end with the device described by Moxon. By the third quarter of the 17th century, machines to do this job had become even more sophisticated, particularly in France. Instead of the work-piece and guide templates being pulled through the cutter head by hand, they were cranked under a fixed blade by means of a cogwheel that engages a rack lying on the underside of a moving bed. The blade is spring loaded, so that it can be gradually screwed

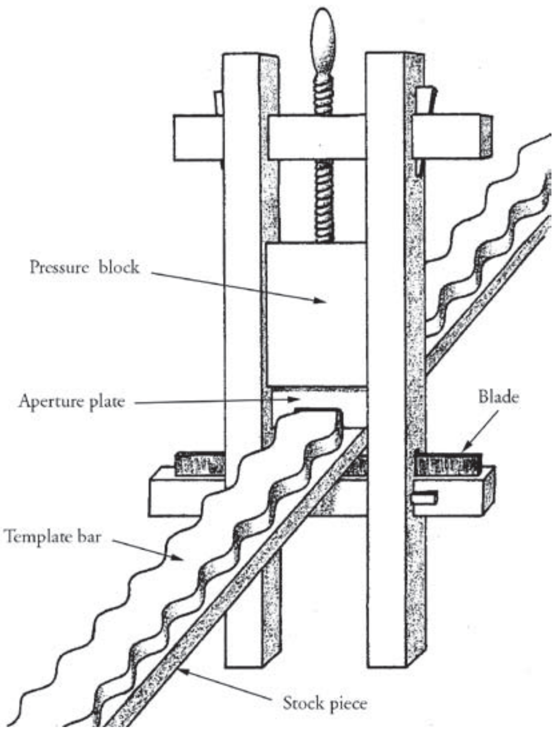

Fig. 3 **An early type of device for making waveform moldings, after Hans Mayerl, 1975. (re-drawn by Thornton)**

downwards to take progressively deeper cuts. The type of machine that would predominate during the 18th century was first illustrated and discussed by the French writer Andre Felibien in 1676.[11] The method continued in use with only minor variations for over one hundred years. Machines similar to that of Felibien are to be found in the work on cabinet making by Roubo[12] as well as in the Diderot Encyclopedia,[13] both during roughly the same time period (second half of the 18th century). It is versions of this machine that have been reproduced and used by a few modern experimenters. I am aware of those by Cornelis Van Horne[14] in this country, and van Soestbergen[15] in the Netherlands. Interestingly, while Moxon certainly knew of the work by Felibien, and based his engraving of cabinet maker's tools on Felibien's illustration,[16] he chose to show an earlier type of the ripple molding machine, one he probably learned of during his earlier years in Holland.

Joseph Moxon was the son of the radical Puritan printer James Moxon, who was exiled to Holland with his family from 1637–43. Joseph learned the printing trade from his father, and pursued it on his own after he returned to England. In addition to printing, he made and sold globes and instruments for mathematics and navigation. He designed and cut type, and wrote the first book on the art of printing.[17] With these various activities, Moxon became of necessity something of a jack-of-all-trades. He writes as one who has seen or done all of the things he describes. It is for this reason that his works were so influential in an age when as Francis Bacon said, it was "esteemed a kinde of dishonour to descend to enquirie or Meditation upon Matters Mechanicall."[18] Ephraim Chambers refers to Moxon's influence in his practical Encyclopedia of 1728, and the Diderot Encyclopedia began as a translation of Chambers. It is reasonably certain that Moxon described the work methods and tools of practicing craftsmen, and this was revolutionary for his time. It is not known however, whether the "Waving Engine" that he describes and illustrates is based on memory or his own current practice.

Making the Machine

The illustration of the device that Moxon provides (from a plate almost certainly engraved by himself) presents a few problems of interpretation, and Moxon's description, while fairly thorough omits some important information. My intent was to

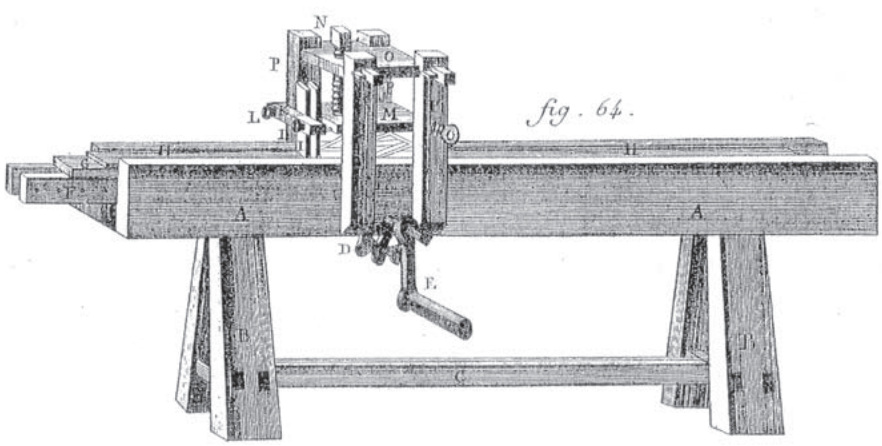

Fig. 4 **Complex machine for making waveform moldings, from the *Encyclopedia* of Diderot and d'Alembert, 1751–87.**

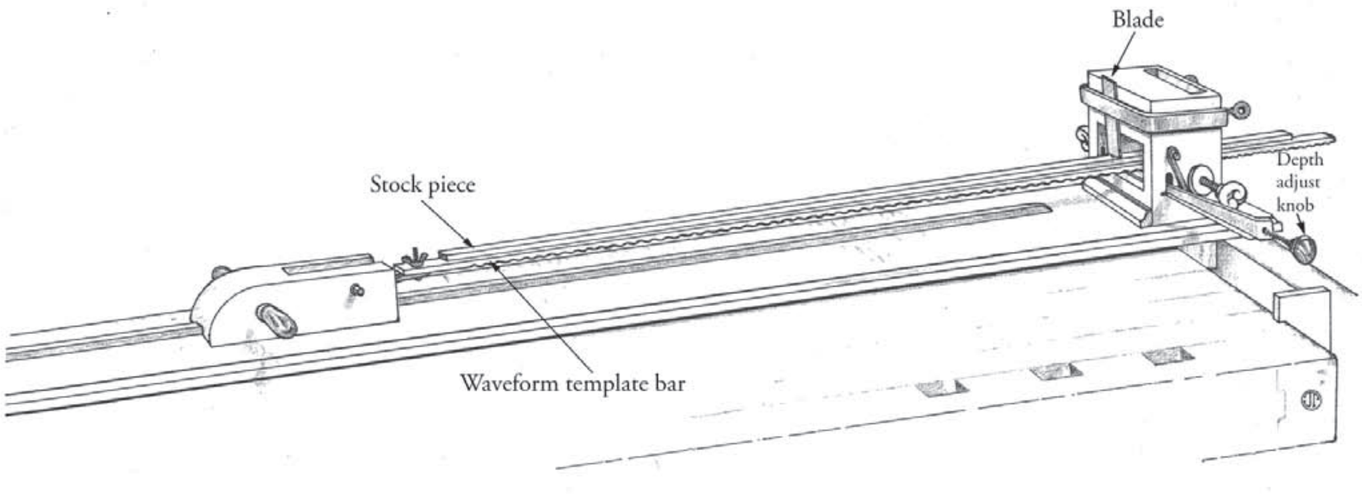

Fig. 5 **Overall view of a reproduction "Waving Engine" of the Moxon type. (drawing by Thornton)**

make Moxon's "engine" to his specifications, and if modifications had to be made, the reproduction itself would tell me what to do, and not my own second-guessing.

> "The Waving Engine…hath a long ſquare Plank…All along the length of this Plank, on the middle between the two sides, runs a Rabbet…Upon this Rabbet rides a Block with a Groove in its under side…the Groove in the Block is made fit to receive the Rabbet on the Plank." (Joseph Moxon)

I made the plank from quarter sawn sycamore (lacewood). The rabbet I made from hard sugar maple, likewise the block that rides on it. This is the block that pulls both the patterned template and the stock piece through the cutter head. Moxon attaches these elements to the block with a "Vice, ſomewhat larger than a great Hand-vice…." In considering this, I made the only major deviation from Moxon's machine. I didn't see how a fixed vice could easily follow the up-and-down motion of the guide rod ("rack") and stock ("riglet"), let alone the gradual raising of these strips as the molding was cut. I suspect that simple looseness of fit allowed Moxon's machine to accommodate these movements. In place of the hand-vice, I forged a tongue with a hinged box-joint (mortise and tenon) much like the joint in a pair of pliers. The tongue would move to accommodate any adjustment upwards. The tongue itself was fastened into the block with a rod, which threads through it and also penetrates the block (at an angle—the purpose of which I will make clear). By means of this rod, I can adjust the attachment point to accommodate different widths of stock. In addition, I placed a support rod and knob under the end of the tongue and likewise threaded into the block, so that I could raise the attachment tongue correspondingly as the strips rose. This modification does not alter Moxon's method in any important way, while making the machine easier to use.

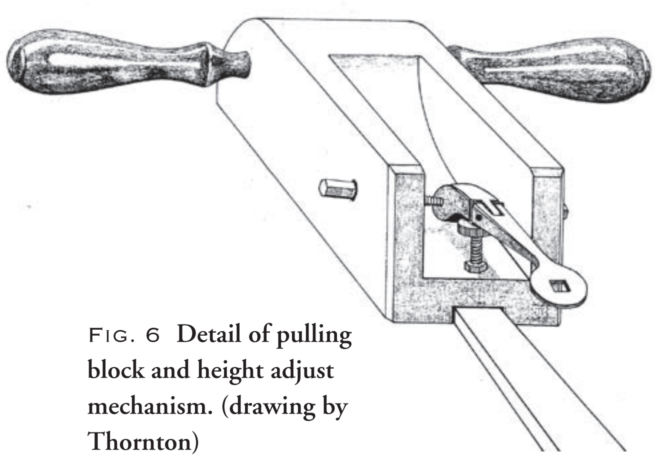

Fig. 6 **Detail of pulling block and height adjust mechanism. (drawing by Thornton)**

> "At the farther end of the Plank is erected a ſquare ſtrong piece of Wood…This square piece hath a ſquare wide Morteſs in it on the Top…upon the top of this is a ſtrong ſquare flat Iron Coller…"

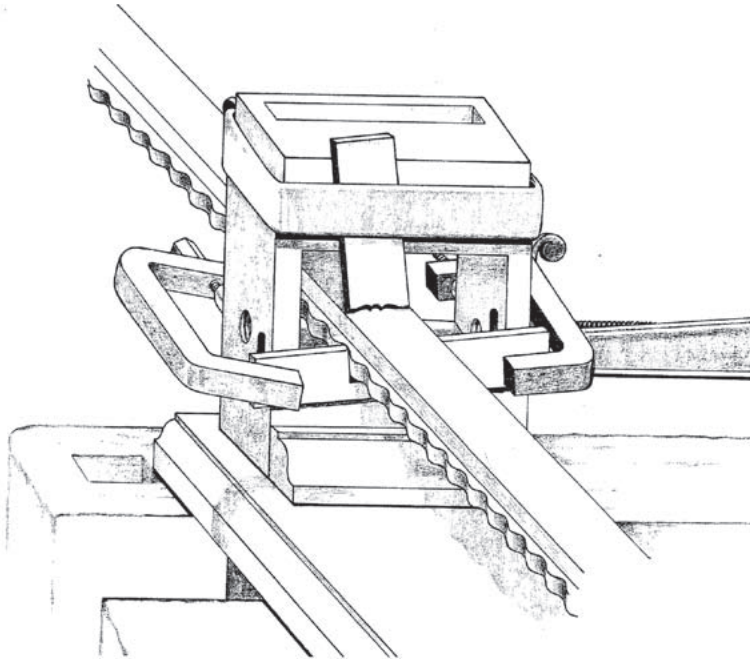

Fig. 7 **Detail of cutter-head and slide-board clamped into the end-vise of a cabinet makers workbench. The device is set up to make a side-to-side (*flammleisten*) waveform molding. (drawing by Thornton)**

This is the business end of Moxon's device which I call the "cutter head." My upright block was made of a single piece of maple, with the appropriate mortises as described. I added two projecting through-tenons to fasten the block into the plank, so that they could be gripped by the end-vise of my workbench when the machine was in use, and allow me to easily disassemble the machine when it was not. The purpose of the collar is to clamp the fixed scraper-type blade perpendicular to the stock piece. My collar was forged from mild steel, as were the screws that tighten it on the block. Like Moxon, I forged perforated disks on the ends of the screws, so that a bar could be inserted to tighten them with lever action. It is important that the blade not move while in use.

Moxon is at his sketchiest when it comes to how the depth of cut is gradually increased, although the engraving seems to show what the description omits. A bar is shown penetrating the block underneath the "rack" that appears to be both tapered and furnished with a threaded rod for gradually advancing it under the work. There can be no other way to do this in a controlled way. Jutzi and Ringger in their discussion of Moxon's machine had a different interpretation.[19] They speculate that this knob, projecting out of the far side of the machine, was used manually by a helper to lift the guide rod and workpiece against the blade. Moxon however, refers to this as "a wooden screw called a Knob." He also appears to illustrate, though he does not discuss, the taper of the polished rod that is advanced by this screw-knob. It seemed clear to me what he intended: I made a steel bar with a T-shaped cross section that would slide through T-shaped slots in the block. I put the taper side up, as Moxon appears to do, and simply accounted for this cant in the rack and "riglet," by setting my attachment-tongue into the pulling block at the same angle. I captured the end of my adjusting screw-rod with a sort of clutch lever that would allow me to easily disassemble the machine, an alteration necessitated by my own tight space that again, did not alter Moxon's device in any important way. The screw-rod uses a fine thread so that I can very gradually raise the work under the cutter. In use, one or two revolutions of a rosewood knob on the end of this screw increases the depth enough for the next cutting pull. The handles on my pulling block were also made of turned and polished rosewood, press-fitted onto a steel rod, which runs through the block, again for ease of knock-down.

> "But before you draw the Rack through the Engine, you must consider the Office…of the iron screw…for by these screws, and the Rabbet and Groove, your work will be evenly gaged all the way…under the edge of the iron."

Moxon shows only one screw, though he refers to them in the plural. These screws serve to keep the work "gaged" under the blade. The end of the screw shown was fitted with a flat iron disk, that appears to be a sort of wear-plate against the moving template and workpiece, called the "rack" and "riglet" respectively by Moxon. Jutzi and Ringger speculate on two screws, one from each side, that enter at an angle. Their drawings are interpretive reconstructions as they did not build such a device. I believe that Moxon clearly shows a screw entering perpendicular to the cutter-head block. I also decided to use two screws, so that I would have greater flexibility than could be achieved with just one, though the inside surface of the cutter head could have conceivably gauged the other side of the strips. Instead of iron, I made my screws from lemon-wood (*Calycophyllum candidissimum*), a beautiful close grained relative of box-wood, and equally hard-wearing. I threaded these with the Beale® router attachment, and made decorative double volute-shaped flanges on the ends similar to the screw end shown by Moxon. I decided that locking washers were a good idea if I wanted to keep my work well "gaged." I made these from rosewood also, and placed them on the outside of my block where they are easier to get at.

My blades were made from 01 steel, a high-carbon, oil-quenching tool-steel that has low warp characteristics in hardening, and can be tempered to create a tough and hard blade. The blade "whoſe lower end is cut into the form of the Molding you intend your work ſhall have…" has a single bevel facing towards the pulling block. I filed and ground the shapes before hardening the blades. I sharpened them once on the bevel, then subsequently only on the flat side.

> "Then if you lay hold of the handles of the Block…and ſtrongly draw upon them, the Rack and Riglet will both together ſlide through the Mouth of the wooden piece… and as the rounds of the Rack rid over the round edge of the flat iron…the Riglet will on its upper ſide receive the Form of the ſeveral Waves on the under ſide of the Rack, and alſo the Form, or Molding that is on the edge of the bottom of the iron, (blade) and so the Riglet will be both molded and waved."

The final form of the moldings is dictated by the shape of the blade, by the form of the template or combined templates, and by the attachment point of the pulling block. The number of possible designs is multiplied by the addition of any of these elements, and quickly becomes astronomical. Even with my still limited stock of blades and templates, I will probably never produce all of the possibilities.

Using the Machine

I have continued to explore the capabilities of this tool in the years since I first made it, and it has provided both mental and physical exercise. In action, I hold the tongue down with my finger as I push the strips through the machine for the return stroke, then I "draw strongly" on my handles. Depending on how deep the molding is going to be, and this is dependent on the wave amplitude of the template, I will continue to make cutting strokes until the moldings are complete. I take coarse cuts (Moxon would say "rank") to start out with, but by the end, when the blade is bearing

Fig. 8 **Making a molding on the Moxon "Waving Engine."**

more-or-less continuously, the shaving needs to be thinner than paper. I can complete some molding strips in fifteen to twenty minutes, but deep moldings in a hard wood take more time.

Any wood that is hard and relatively dense will work well for the molding strips. Cherry is excellent, as are pear and maple. Many of the period moldings are executed in either ebony, or a fruitwood stained to look like ebony (ebonized). I have gotten by with poplar for molding with a gentle wave. It's best if the grain rises away from the pulling block so that the wood fibers are severed more obliquely. Earlier on, I mounted the molding strips to the "racks" or guide bars with a few dry-wall screws shortened so that they did not come through the surface of my moldings. I still had to make them relatively thick however, and they were only held firmly in a few places. Now I prefer to use the wood turner's trick of gluing the stock piece to the template with pieces of heavy brown paper. The finished molding is then taken off by splitting the paper interleaves, and scraping the glue and paper residue away.

The "racks" are made of hard maple. I have hand-carved some of them after stepping off the intervals with a divider, by using the same gouge across the grain both bevel side up and bevel side down. I have also used a pin-indexing jig on my table saw and router table T-slide like those jigs used to cut box-joints. I did this to create bars with tight waves that would have consumed a lot of time in carving. The mathematical accuracy of this method can be both an advantage and a disadvantage depending on your point of view. Historic ripple moldings have subtle variation and character.

No sanding is required on a properly cut molding. The blade leaves an almost polished surface in a wood like cherry. I also discovered that pushing the molding back through the cutter-head for the return stroke burnishes the molding against the polished bevel of the blade. Stain will greatly accentuate the wave appearance by selectively penetrating the severed wood fibers on the insides of the wave troughs.

Waveform moldings

Moxon appears to discuss and illustrate only the up-and-down rippled moldings, and not the side-to-side type called *flammleisten* in German. It is fairly easy however for his machine to be adapted for this purpose, and I had intended to do so from the start. It was in thinking about this function, that I chose to provide it with two "gauging" screws that would end in relatively narrow and rounded wooden ends—not the large wear plate shown by Moxon. Using these, a template with a side-to-side waveform could be guided through the cutter head on both edges. In use however, the side screws tended to loosen due to the extreme vibration. I solved this problem by making thin pieces of wood that had wide slots cut into one side exactly matching the width of my guide rods (fig. 7). These slips of wood are then clamped to the front of the cutter-head with two C-clamps. The guide rods slide through the aperture as the moldings are cut. The early type of device illustrated by Mayerl (fig. 3) solves this problem in a similar way.[20]

The side-to-side waveform guides can be used alone, or stacked with an up-and-down guide for a complex compound effect. The sides of these template strips need to be of absolutely consistent width, so that they will pull evenly through the machine with guides bearing on both edges. There are two methods that I have used to ensure this: In the first method I start by making a thicker bar which is waved on only one (top) side and flat on the bottom. This is done on the "Waving Engine" itself. I rip this bar down the middle perpendicular to the wave surface, and book-match the pieces back together with a glue join along the flat (formerly) undersides of the strips. Since the edges started as the same surface, they can't help but be parallel. The second method uses a guide rod for a ripple molding, but this is fastened to the piece that will become my new guide rod so that the waves are perpendicular. I run the guide rod along a V-block mounted to my router table fence, so that the router blade cuts the waves on one edge of the new waveform guide rod. With the ripple guide rod removed, I rout the other edge using

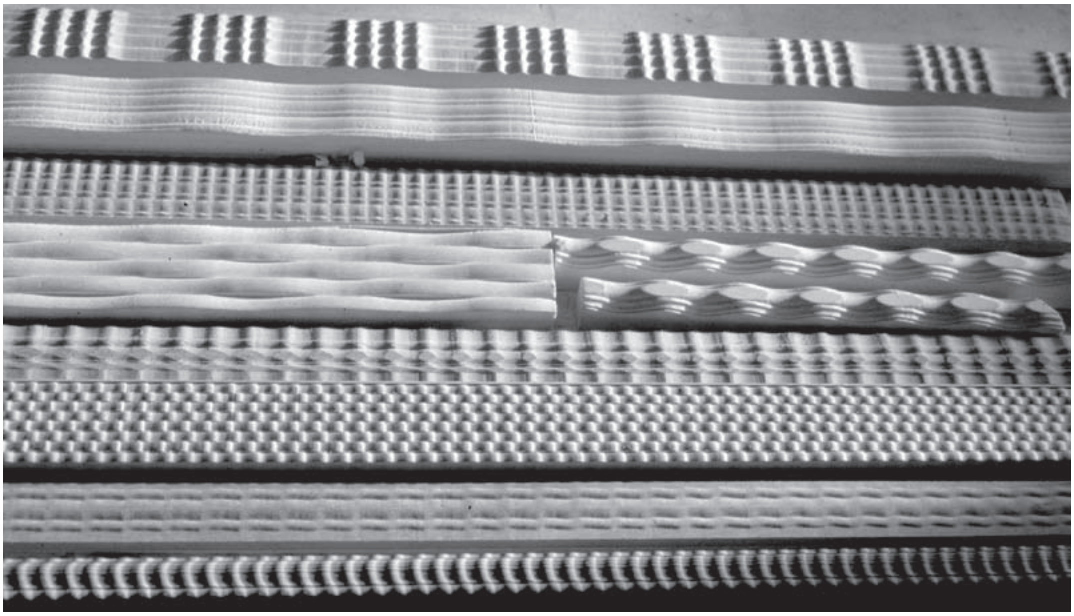

Fig. 9 **A selection of moldings made on the Moxon "Waving Engine."**

the first-routed edge as the reference against the V-block. This is efficient, but will work for large waves only, since the circumference of the router blade limits the tightness of the waveform.

Discussion

Devices of the sort typified by Moxon's machine did not come from nowhere. In essence, his waving engine uses a system of guides running against a "feeler" or "follower." Such systems were on the technological cutting edge in the late Renaissance, and were to inform ever-growing complexity in tools and machine tools right up to the present. The first such systems were used for cutting screws and ornamental twisted turnings on the lathe. The earliest illustration of such a device dates from 1480.[21] It uses a carved screw-form cranked through a follower block to impart a regular movement to the work-piece as the spiral is cut by a stationary cutter. An even more complex ornamental lathe was designed by Jacques Besson in 1579.[22] Besson was Da Vinci's successor as engineer to the French Court. His ornamental lathe uses a system of patterns and followers that either guide a moving cutter, or guide the work past a fixed cutter.

Spiral grooves were also cut into the inside of rifle barrels using similar systems. In the process of rifling a gun barrel by hand, a carved spiral fastened to a rod with a cutter on the end is pulled through a feeler guide, imparting this spiral motion to the cutter inside the barrel. Rifling can be traced to as early as the end of the 15th century.[23] It may be significant that the purported inventor of rippled moldings, Johan Schwanhardt was among other things a gunstock maker.

The use of patterns and followers introduced a particularly productive lineage in tool making and technology. Following this line of descent, the screw-cutting lathe leads to complex ornamental lathes, to riffling of guns and ripple molding machines. Other later developments that use pattern and follower systems include the Jacquard loom, the earliest mechanical computational devices, duplicating lathes and carving machines, as well as the key-card systems, which led to computers. Historically speaking, Moxon's device was near the beginning of a fruitful concept.

Another interesting historical point concerns the natural progression of the machines that were used to produce complex waveform moldings. The devices show a steady increase in complexity. Why should this be so if they all do essentially the same thing? The late 17th-century device of Felibien and the mid-18th century devices of both Diderot and Roubo are more complex machines in every way, but they are still based on pattern and follower systems. In these devices, the entire table, to which the stock piece is fixed, is cranked back and forth under a fixed blade. Machines of this sort require no skill in operation as any worker could stand and crank, whereas my own and Moxon's device require relatively more effort and finesse. It may have been that the shear demand for luxury goods during this period drove the increasingly mechanized production of waveform moldings. There were also social changes at work that de-emphasized the skills of individual master-craftsmen, in the interest of manageable and efficient production changes that have continued to the present day.

What happened to the devices that created waveform moldings can be thought of as a capsule history of woodworking—as machines have grown in complexity, the necessary skills of the operator have declined. Earlier craftsmen relied on relatively simple tools, guided by hand, eye and body skills developed over a long time and with constant practice. As Moxon himself says, "The Cunning or Sleight or Craft of the Hand cannot be taught by words, but is only gained by Practice and Exercise." A level of skill made possible by both the intellect and careful, lengthy training is replaced by reasonable care and thought, coupled with complex machines that can be set up to accomplish most tasks. Skills that are reliant on training, like those of athletes, allow complex motions to be reproduced with some degree of reliability, but they are steadily replaced by 'skills' that are more purely intellectual. Using the simplest tools successfully then has more in common with sports than the sort of jig and machine-based woodworking practiced widely today by both industrial and hobbyist woodworkers. Tools change as people change and vice versa.

The historian of design David Pye put forward another telling distinction.[24] He divides craft practices into workmanship of "chance" and of "certainty." Workmanship of chance employs techniques that can and often do result in variation in the result. To return to the sports analogy, any fan can testify that even the best training does not produce a certain result. Moxon himself in discussing the "Barbarous ſort of working which is uſed by the Natives of America" says that "they know neither of Rule, Square, or Compaſs; and what they do is done by Tedious Working, and he that has the beſt Eye at Guessing…" This sort of craft-work, barbarous to Moxon is typified in objects we now place a positive value on as being "handmade." In eras when everything was handmade however, the aim of the careful worker in the European tradition was to reduce variation by skill and increasingly, by ever more complex tools. Such perfectionism was pursued into the machine age resulting ultimately in techniques that typify workmanship of certainty. The aim of industry after all is quality control, which means the absolute reproducibility of a desirable result. The history of wave-molding devices also advances along this continuum towards ever greater certainty of result, coupled with ever decreasing skill in use.

Another recent device for making ripple moldings, as described in *Fine Woodworking* [25] serves as a modern endpoint. It was developed with no apparent knowledge of earlier machines, and so "reinvents the wheel." As a reinvention, it recapitulates the history of these devices by using a cutter-carriage, which rides over a fixed molding, as does the very earliest device. It is run with a motor, which powers a long threaded rod that carries the entire cutter carriage. With a reversing switch at each end it can be left unattended as it traverses doggedly up and down the molding. It combines the earliest and simplest concept with the convenience and perfection of the twentieth century, and with minimal input of labor. It is a sort of seventeenth century/machine-age Wave-O-Matic!

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