10.5.4 Making Steel Things

Introduction

Yes, I know - this is supposed to be about swords. Nevertheless I will digress from the topic for a short. time. Swords are fascinating objects for many reasons; good ones and not-so-good ones. But fascinating things are often not very useful, consider for example atomic bombs, black holes, Lamborghinis, Las Vegas, opera, or (insert "it girl" of your choice). So let's take a little time out and look at a few useful iron or steel objects here.
In order to get an idea of what people really wanted from their iron monger, let's look at what was going on in **Schmalkalden** around 1740. Schmalkalden is described in the link; it was a center for mostly "civilian" iron and steel products for a long time.

- There were around 1000 artisans working with iron and steel in the town; for 912 of them I will give details:

No. Artisans	% (rounded)	Product
200	22	Knife (blades)
180	20	Nails
80	9	Awls (for shoe makers, general leather / heavy cloth working)
70	8	Locks, padlocks
60	7	Horseshoes, simple weaponry
50	5	Tongs, hammers, other tools
50	5	*pair of snuffers*, scales, fittings
50	5	Gun barrels, small arms
40	4	Files
30	3	Chains
20	2	Scissors
20	2	Special knifes
15	2	Special locks for doors etc.
10	1	Curry combs for horses
10	1	(Pitch) forks
8	1	Jew's harps
5	0.5	Pans, kettles
5	0.5	Special needles for shoemakers, sailmakers, ...
5	0.5	Hammers
2	0.2	Thimbles
2	0,2	Tools for blood-letting
Source: Buchwald		

Quite amazing, isn't it? Eight jew's harp makers, whatever that is? A very simple and affordable instrument (see below) that needed some good springy steel. Don't forget that in those good old times the only music most people enjoyed was the one they made themselves.
Did you notice that major products are missing on this list? Normal **needles** for example. Considering that very close to 100 % of all females were constantly making and mending clothes, needles were major items in these times. Not to mention farm / gardening implements like scythes, sickles, pitchforks, plowshares, coulters, spades, shovels, and so on.
Obviously that stuff came from other specialized places, just as swords and armor.

Jew's harp (German: Maultrommel=mouth drum) and how you play it

- It is not surprising that knifes are on the top of the list. Everybody needed a knife all the time as a matter of course. While a knife blade could be just as complex as a sword blade, they usually weren't. Damaging or breaking your knife was not a life-and-death matter. You got a new one (possibly making it yourself from a piece of scrap) or you had it fixed.
  It is, perhaps, a bit surprising that nails are No 2. So let's start with these unassuming things.

Nails and Screws

Just think of raising big wooden constructions like houses, barns or boats without nails. You can't have a decent crucifixion either without these implements. As long as most of humankind made things from wood, including the ships Columbus used for not finding India, the ships Vasco da Gama employed for actually finding it, and all the ships used for centuries by all and sundry to bring the goodies robbed from India, America and so on back home, nails were of paramount importance. They still are.
Same thing, just much later, for their cousins: screws, rivets, clamps - you name it. Modern life is unthinkable without that stuff

- So make a nail. Actually not just one but lots. Forging nails from a piece of iron with a hammer in your smithy is not so easy, especially if you want relatively small ones with standard sizes. Going down in size you reach a point where you are better of by making wires first and than use cut-to-length pieces on which you put a "head".
  That makes clear that making the head is the problem.

Old nails
More Roman nails (large format)

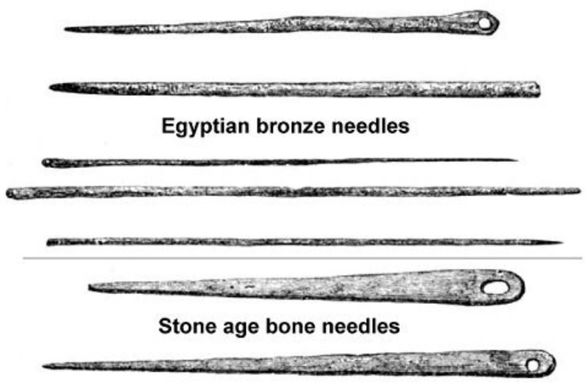
Source: Roman nails of Inchtuthil; a Roman legionary fortress in England, where 7000 kg of nails have been found. The nails from around 1500 were found by Thorsten Straub with a metal detector in Germany.

To make a long story short: Nails were hand-forged from thin wrought iron rods with square cross sections until about 1800. A tip was drawn out, then the rod was cut a bit above the thinner parts, stuck into a suitable hole on the anvil followed by flattening the thicker part into the head. In the picture above the Roman smith did far better than the medieval one, who either didn't have the skill or didn't care in this case. Maybe the Roman guy used the iron oboli for that.
I'm not going into the modern methods starting around 1800, when using wires to make "cut nails" in some machines more or less automatically took over.

- Let's stop the nailing business now and go on to screwing. Whenever you do that from now on, consider first how you, personally, would have made that screw. Think!
  I'm rather sure you are going to screw up on this. Screwing around with all types of screws (wood screw, machine screw, set screw, ...) is far easier than to make one.
  You need a machine - some kind of lathe - for doing this, and that's why screws only came up at the end of the 17th century. Screwing and screwing up, however, are much older techniques.

Needles and Awls

Needles are some of the oldest tools of humankind. A bit larger and without an eyelet you have an awl. With properly cut spiral grooves you have a drill but that had to wait.



Ancient needles. The real ones are bronze needles from the Heraklion museum

Needles, awls, and so on, needless to say, should be made from hard steel. That's not so easy, especially if you want to make small ones with an eyelet.

- One idea thus was to make needles from wrought iron and then to turn it into steel. Another one - for finer needles - was to use steel wire, anneal it to soften it, work it, and harden it again.
  The only point I want to make is that producing a needle was an extremely laborious process. Not only did you have to work on a fine scale, with tiny hammers, punches, etc. you had to go through many steps before just one needle was made.
  Since there are all kinds of needles for all kinds of jobs, not to mention awls and other related stuff, artisans specialized on just one basic type: needles for sewing, sailmaking, shoemaking; needles for surgeons, glovers, bag makers, bookbinders. And so on. The Schmalkalden crowd was not doing much needlewise, just some of the rougher stuff. Schmalkalden wives such had to needle their husbands to go and exchange some of their stuff for good sewing needles from the specialists elsewhere.

Wire

Wires are extremely useful, especially for electricity. Having thin gold or silver wires helps in making fancy jewelry. But iron and steel wires are also useful. Not just for the hilt of your sword but for many other things. Foremost, perhaps, is the making of **chain mail** or just normal chains. More important for most people, however are the normal things you make from wires: nails, needles, pins, awls, fish hook, sieves, musical instruments, suspension bridges, elevators, cranes, sailing boats, ...

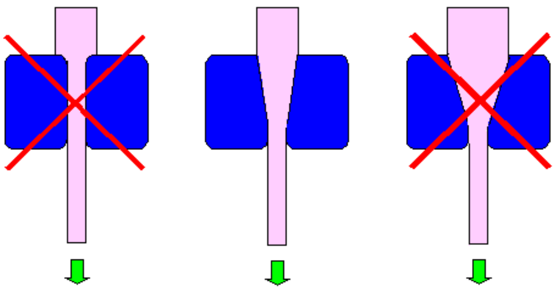
Mail shirt remains; Berlin area, around 300 AD
Pictures of Roman Chain mail

Source: Photographed in Berlin, Neues Museum

Chain mail failure. The mail was medieval in this case.

Source: Photographed in the Stockholm museum

- How does one make a wire with some given diameter? I'm rather sure that more than 99 % of all humans living now do not have the faintest idea. The all should go an visit the w**ire museum in Altena**, Germany. There you will find out.
  You do it by **drawing a wire** with a larger diameter through a **die**. You start with a relatively thick forged "wire" that is as uniform and free from slag as you can make it. Than you draw it through a die, decreasing its diameter and thus making it longer automatically. Then you repeat the process with a somewhat smaller die. Then you repeat the process with a somewhat smaller die. .....
  Wire drawing is a marvelously simple process **-** provided you do a lot of things just right.

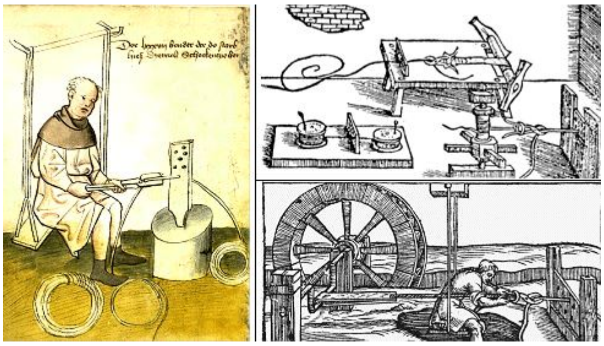


Wire drawing. Only the middle approach is "just right"

- The force you draw with must not be too large. More specifically, the stress employed (force per cross-sectional area of the wire) must be lower than the yield stress. Otherwise you are just pulling out the wire just formed.
- The die must have an opening that tapers with just the right angle (around 20^{o} in most cases). Wrong angle and the permissible drawing forces will not be sufficient to do anything.
- The reduction in the wire diameter can only be modest. A factor of 1.4 is already quite large. If you want fine wires you must do it in many steps, each time reducing the diameter just a bit

The points made above follow from experience but also from (rather involved) modern theory. They are not negotiable. In addition, there are also some practical concerns:

- Your die should be very hard with a polished surface in order to reduce friction. You are also well advised to use some suitable lubricant while drawing.
- The drawing forces may be considerable. A yield stress of 200 MPa (wrought iron) calls for a drawing stress of around 100 MPa. For a 2 mm diameter wire this transforms to a force of $(200 \cdot 10^{6}) \cdot (3.14 \cdot 10^{-6})$ $(N/m^{2}) \cdot (m^{2})$=614 N ∝ 60 kg. In other words: You must pull with almost "all your weight" or use some machinery as shown below.



Wire drawing

Source: Left: unidentified old book in Nürnberg museum library; Right: Biringuccio 1540 woodcuts showing use of "machinery" for wire drawing.

For making dies you use the hardest steel available. Precision was everything and it is no accident that the term "die maker" is still the name for professionals who can make all kinds of precision tools.
Wire pulling was skilled and very hard, not to mention boring work! Of course, the process of wire drawing deformed or cold-worked the material and thus some work-hardening occurred. Some post-treatment of the wire may have been required. And so on and so forth. Nevertheless, wire drawing is an old art. The Vikings did it and probably other and older cultures, too. Here are some old dies:

Old dies for wire drawing
Left to right: Magdalenenberg, Kärnten, Austria (the "Noricum"), around 50 AD; Vikings, Haithabu, Germany, around 1000 AD; Vikings, Oslo, Norway, around 1000 AD

Source: Photographed in the "Deutsches Drahtmuseum" (German wire museum) in Altena, Germany

Farming Implements: Scythes, Sickles, Plowshares

A farm then (and now) needs a lot of iron / steel implements. Hinges and latches, knifes and general tools, rings for the nose of the steer and all the other gear around animals, and so on and so forth. All this stuff could be made by the local black smith from the wrought iron he procured from the nearest smelter.
But there were also a few special things that needed expert makers and special iron / steel. For example:

- Scythes and sickles
- Plowshares and coulters.
- Pitchforks, spades, rakes.

A scythe looks simple but is a complex tool. If somebody gives you a scythe and you try to mow your lawn with it your wife will roll on the ground in helpless mirth until she needs to call the ambulance to take you away. It takes some practice to use a scythe but throughout the millennia most people could do it quite well. That is because most people were involved with agriculture and then a good scythe (and sickle) is absolutely essential.
The blade of a scythe needs to meet pretty much all of the requirements of a sword blade and then some. It must not cost a fortune but it needn't be good for showing off either. Most important, re-sharpening must be easy, and it should be amenable to minor and major repair. The black smith across the road from my parents house spend quite some time ***whetting*** the scythes of the local farmers during summer and fall.
Scythes were seeing hard use far more often than swords. A week of mowing probably meant more wear and tear for the blade than many swords saw during the life time of their owners. About the same is true for **sickles** . They relate to scythes like knifes to swords.
The best steel was used by specialized scythe makers, and making the blade was a laborious process:

Career of a scythe blade in 15 stages

Source: Museum exhibit; undisclosed

- Scythes have been in use for some time; here is a picture from 850 AD:

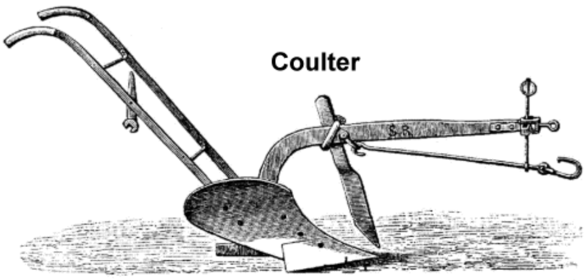
Illustrating the idea of "July" in 850 AD

Source: a martyrology in verse written by the monk Wandelbert in 848.

- Some scythe smiths even used composite technology. A cut was made into a block of softer iron and a piece of hard steel inserted. Then the blade was drawn out. That is, of course, also the way to make a katana, a Japanese sword. And that is why scythes make good weapons, too. War scythes were regular scythes adapted for combat by re-attaching the blade parallel to the haft. War scythes were widely used by Polish and Lithuanian peasants during revolts in the 18th and 19th century, here is an example.. Scythe swords were also made but only one seems to have survived.
  - Scythes, like swords, are hardly used anymore, They have been made obsolete by big mechanical things that can mow down far more grass or people than one expert swinging a scythe or sword. As far as they have survived, however, they have hardly changed, witness these two modern blades, hand-forged by some artful modern blacksmith.

Modern scythe blades

- Finally we hit the big question. What, exactly, is a **coulter**? Maybe you should know, it's in the Bible, after all. The question is if you ever gave a plow a good look? Here is a rather basic one:



A plow with a coulter
The second picture is a detail from a Pete Bruegel painting from around 1527 entitled "The val van Icarus" shown in the Brussel museum

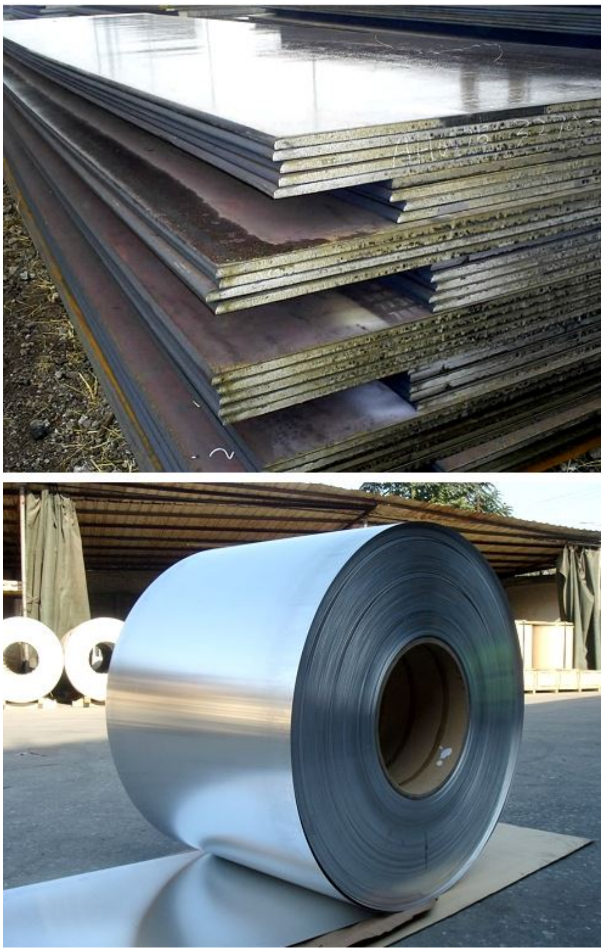
- A coulter needs to cut through the earth! That is a rather abrasive stuff with embedded very hard stones. You can't easily think of something more demanding for a slender piece of metal. When we make coulters we get rather close to sword making once more. We might actually make one from a sword!

Horse Shoes

- I just mention horseshoes because they demonstrate the development of another specialization: farriers had to be both, experienced blacksmiths and veterinarians, knowing a lot about the anatomy and physiology of horses' feet. The word comes from French "ferrier"=iron guy or blacksmith.
  - Protecting horses feet by some metal contraption is quite old. The Romans employed some "hipposandal" that wasn't nailed down, however. It might have been the Celts who first used nailed-on horse shoes; first clear archeological records are from the tomb of the 5th century King Childeric in France.
- The farrier had to fit each shoe individually. Since horses are not overly fond of being shoed, he has to work quickly and without making mistakes. Putting in a nail the wrong way could kill a horse, and badly fitting shoes are just as bad for a horse as for you. Horse shoes should be made from mild steel and that doesn't make the job easier.
  A lot of farriers were needed in times when horses provided for the only means of transportation and most of drawing power. If you use an oxen-drawn wagon, chances are that your oxens were shoed, too.

Sheet Metal and Plate

- Nowadays a steel mill poduces a lot of plate and huge coils of sheet metal; see below. The plates may end up as parts of a ship, the coils of shiny steel will turn into car body parts. Continous casting and a lot of roller milling are the processes that come to mind for making this stuff.
  Here are examples:



Steel plates and coil

- Does this mean that there was no need for plate and sheet metal before 1850 (iron ships) or 1900 (cars)?. Not quite. Armor of all kinds, your war-wear as the fashion industry, no doubt, would call it today, started as sheet metal just like your car body.

A knight and his horse in sheet metal war-wear
Large picture
Source: Photographed in the Metropolitan

It was **Henry Cort** (1741 (?) – 1800), the inventor of puddling, who also invented the **rolling** of iron / steel. In 1783 he got a patent for a grooved rolling mill and from then on the use of rolling to produce all kinds of shapes was open. You needed plenty of power from a steam engine for driving the rolls, and very good steel for the making the rolls, so once more an invention feeds on itself since without puddling steel you couldn't make those things.
How was plate and sheet metal made before this?

With a hammer in a forge, of course. Up to about 1300 sheets were hammered out by hand, then increasingly with a water-wheel driven power-hammer. Standardized sizes emerged in some places. In the Oberpfalz (North Bavaria) the sheet size was about (25 × 32) cm^2, coming in three thickness variants:

- Dünneisen (thin iron); 0,46 mm, 290 g.
- Bodenblech (bottom sheet); 0.81 mm, 508 g
- Pfanneisen (pan iron); 2 mm, 1250 g

That is some amazing precision for working with a hammer! The process was rather involved with some annealing in between. Here some circle closes. That's what Çrockü and Nölüdyæ, the stone-age types did, when they first worked native copper.
The names above give us some idea what plates and sheets were needed for. The pan iron was used for making pans. But not ordinary cooking pans but large (riveted together) salt pans for boiling brine in order to produce the all-important salt!
The thinner sheets were used for all kind of things (including armor) but mostly for making **tinplate**, "galvanized" sheets, so to say, except that the tin coating was produced by dipping the "pickeled" iron sheet in liquid tin and not by electroplating. Tin plates were a German monopoly, very popular with all and sundry since the end of the 15th century; you still find it in "**tin cans**". German tinplate was even threatening the English ***pewter*** (≈ 90 % tin plus Cu, Sb, Bi,...) industry and measures were demanded. But the Germans could keep their secret for quite some time until English spies in 1667 got hold of the process.