Tricks of Smiths

What is a trick?

When I conceived this module, I thought it would be large, possibly developing into a link hub. I was wrong. The reasons for this are manifold:

- What may appear to be a "trick" to an outsider is just business as usual for somebody who had invested a lot of time for learning the trade.
  No special tricks are required to produce, for example, a kilij blade with its complex geometry from a more or less shapeless lump of normal steel. You just have to keep it at the right temperature and hit it with the right hammer the right way in the right places for a few thousand times.
- The ancient smiths probably knew some real tricks (e.g. around pattern welding) that have been lost.
  Making a pattern welded sword with a palmette pattern, for example, was fairly routine in the 4th century AD in central Europe but would tax the ken of modern smiths. Maybe it was just hard and time consuming work, but maybe these old guys knew a trick or two for making palmette forging easier.
- Things that all smiths do routinely, like fire welding two pieces of iron / steel, are not all that well understood scientifically.
  So what's the trick here?

Maybe a better way to address the topic is to ask what kind of not-so-easy things ancient smiths obviously could do, and what "tricks" they used to do it. Here is my list:

1. Recognizing and sorting different grades of steel / iron
2. Faggoting
3. Fire welding.
4. Dealing with "wootz"

The first point overlaps with the "tricks of the smelters and miners" to some extent but I won't go into this here.

Recognizing and Sorting Different Grades of Steel / Iron

A smith had either made the iron / steel he worked with by himself in a bloomery furnace or he bought it from some supplier. In the latter case the material may have resulted from three quite different procedures:

1. From a bloom that was worked ("wrought") by some colleagues right after the smelting or from a in-between smithy that made "half products" out of bloomery iron / steel. Here are examples.
2. From cast iron that had been fined somehow. In China that happened rather early, in Europe the 15th century might be taken as the turning "point".
3. From a crucible that produced ultra-high carbon steel (UHCS) by melting a mixture of (low carbon) bloomery steel and carbon.

The bloomery iron / steel from the *first* case always contained slag inclusions. Moreover, the main alloying element might have been phosphorus and not carbon. In any case, the distribution of carbon / phosphorous in the bloom was for almost sure rather non-uniform.
We don't seem to know all that much about the *second* case. The famed Svedish "Osmund *iron*" that, surprise, turned out to be steel, is a point in case. Anyway, "finery iron / steel" might still contain slag inclusions from the way it was made, even so the cast iron it was made from was slag free. It was also likely to be rather inhomogeneous.
The crucible steel of the *third* variant was a relatively useless specialty of India / Central Asia / Persia as far as the normal smith was concerned. It had some merits for some special products (like sword blades) but was too hard, too expensive and too difficult to work with for the everyday things a smith made and maintained.
Let's not forget an old rule:

The typical smith worked mostly with wrought iron / mild steel

The typical ancient smith was a guy you knew. He lived and worked not far from you. I would guess that every town with more than 500 inhabitants had its resident black smith, often with the additional qualifications as ***farrier*** so he could shoe your horses. He certainly did not make swords.

The "*recognizing and sorting*" question thus has two parts. First, how did the normal smith deal with the task and second, what did the sword smith / specialist do?

The answer to the first part is easy: The normal smith just had his suppliers that provided him with the normal and most likely local stuff he knew. He might even have been part of the suppliers when some smelting took place and

he participated.
it didn't matter all that much if the quality of his wrought iron / mild steel fluctuated a bit for most for the products he made. It his wrought iron was not good, he could tell right away because it behaved wrong. Everybody who can wield a hammer can tell if a material is soft and ductile, hard and tough, or perfectly brittle, after all. Somebody who wielded a hammer all the time could certainly do considerably better.

The second part of the questions is what interests us. Let's first look at the Roman expert (of probably Celtic decent) who made a complex pattern welded sword around 300 AD from bloomery steel. He could work a bloom himself but more likely bought the stuff from somebody else. What he needed was:

- Steel, at best a mild carbon steel for one part of the pattern.
- Phosphorous steel for the other part. Note that two steels with different carbon concentration will *not* make a good pattern.
- Eutectoid or slightly hypereutectoid steel for the edges.

Now consider a Japanese sword smith who made a nihonto from *bloomery* steel between about 1000 AD and now. He needed:

- At least two kinds of carbon steel: low carbon and high (hypereutectoid) carbon.
- Perhaps also medium carbon - but he could make that himself if he had high and low carbon steel.

Next, let's look at the European sword smith between 800 and 1500 or so who worked with *bloomery* steel. What were his needs?

- Exactly the same as those of the Japanese guy.

What about the European sword smith after, roughly, 1500 AD who worked with steel fined from *cast iron*? His needs were similar to that of the Chinese sword smith since 500 BC or so. He had to rely on the *steel industry* to a large amount.

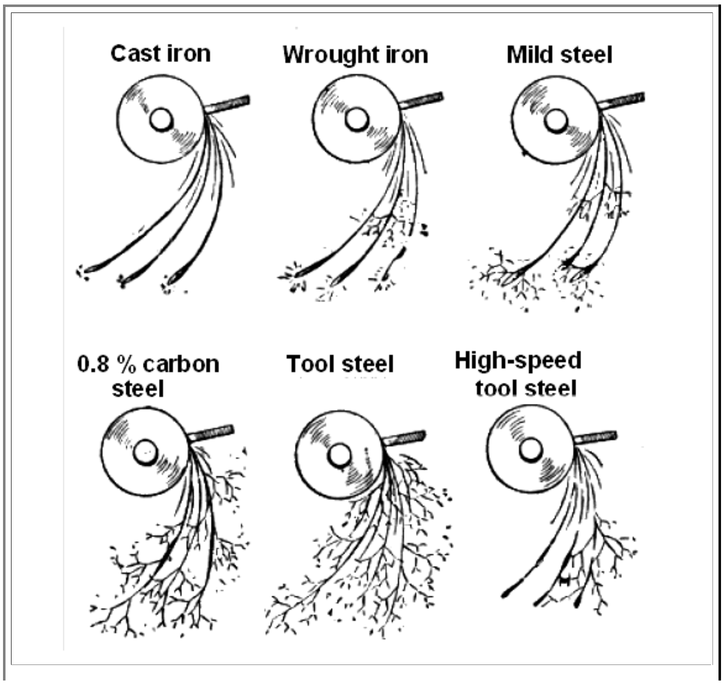
- He bought steel as needed from a reliable source

Finally, we have the Indian / Iranian smith who goes for forging a wootz blade from *crucible* steel. His needs are clear:

- He needed a couple of "good" wootz cakes (or bulat eggs). He may have made the crucible steel himself or, more likely, bought it from a reliable source.

What could a smith do to ascertain that the pieces of steel he made or acquired were the right kind? The range of tests included:

- General hardness (response to hitting with a hammer).
- Fracture behavior.
- Response to heating and quenching.
- Assessment of fracture surface structure.
- Assessment of "color" (in particular for phosphorous steel).
- Assessing the glowing "stars" flying of a the grinding wheel.



Spark test for steel types
Source: Internet; unidentified primary source.

I have described some of those tests in more detail in the chapter about Japanese blade forging because we know what Japanese blade smiths did and still do for testing the quality of their starting material. We can only guess with respect to all the other ones.

Faggoting and Fire Welding

Faggoting involves copious fire welding so I treat both of these topics in one paragraph.
The need for faggoting bloomery steel results from

- Non-uniform carbon distribution.
- Very non-uniform phosphorus distribution.
- Large extraneous defects like voids, slag inclusions, other "dirt", in a non-uniform distribution

None of this is acceptable for a high-quality blade. Variations in the phosphorous concentration, for example, will produce variations of the contrast, the difference between the bright and the dark part that makes for the pattern of a *pattern welded sword*. Variations of the carbon concentration in piled all-steel swords defy the purpose of piling. Large defects like slag inclusions may induce early fracture.

Link Faggoting illustrated

Faggoting is the only way to overcome these problems. Fold, fire-weld, stretch. Repeat ten times and you have 1024 layers now. Everything is rather uniform and some large extraneous defects have been reduced to many small defects. Some might have been removed (like voids).
So far the smith wouldn't need to resort to tricks, he just has to do his job. Tricks must come in, however, because faggoting involves copious fire welding and that is a tricky procedure for several reasons

Advanced Link Faggoting

- Fire welding needs high temperatures; not all that easily obtained in early times,
- Fire welding produces defects of its own like badly welded regions and oxide inclusions.
- At the high temperature required you always burn off some of your iron / steel.

The more you fold and fire weld, the more uniform your iron / steel will get. But with every folding and welding less iron / steel is left and the number of welding defects increases. There is thus an optimum number of foldings that depend on the quality of your starting material and in particular on your skills as smith. Here your "tricks" come into play. What do we know about these tricks?

Next to nothing. Sprinkling some "sand" (or flux) on the surfaces to be welded is a well-know trick. What that might do I have described elsewhere. Japanese smith put some rice straw or the ash of rice straw on the surfaces to be welded. What that is doing I don't know. Since rice straw is rich in SiO_2 it might be just a different way to put flux on the surface.
However, the ancients smiths must have know a trick or two that we have not yet unraveled. Suffice it to mention the so-called "white weld line" effect with its mysterious high arsenic concentration.
Only time will tell. So far there are far too few investigations in ancient (and modern) fire welding techniques and its precise working.

Putting rice straw on the steel to be folded
Nice trick. But what does it do?

Source: Internet; unidentified "forging tamahagane" commercial page

Working With Wootz Steel

The two major tricks, unknown to the European smiths who wanted to unravel the secret of the Indian / Iranian / Arabian wootz blades in the 18th / 19th century, are

1. Spheroidize your cementite in your ultra-high carbon steel (UHCS)
2. Forge at low temperatures, barely surpassing the A_1 temperature.

Look up the many "wootz" modules for details.

- So far so easy. But forging a rather brittle material at low temperatures is not easy. Deform it too much and it cracks. One trick that modern wootz smiths seem to us is to encase your UHCS steel in soft steel. You grind off the soft steel after you are done with forging.
  What kind of tricks the ancient wootz smiths had up their sleeves we don not know At least I do not know.

I have a message here.

Input (preferably from smiths) is welcome!