Examination of a moulding plane blade from Vindolanda

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ABSTRACT: This paper gives an overview of the use of the carpenter's plane in Roman civilization. A general review is made of the planes and plane irons which are known in the archaeological record. Metallographic examination is made of a Roman moulding plane blade found at Vindolanda, on Hadrian's Wall in Northumberland (NGR: NY7766). The blade was made of a laminar structure of steel and iron. The cutting edge was left unhardened, which would have made it easy to shape and maintain, whilst being hard enough to create the fine mouldings such as are found on the Roman furniture uncovered at Pompeii and Herculaneum.

Introduction

The Roman carpenter's tool kit contained many of the tools which may be found in its modern day counterpart. Some of these tools have changed very little, if at all, in the intervening time. Figure 1 shows a selection of carpenter's tools, amongst which may be recognised hammers, chisels, saw and plane. One important omission from the 'kit of tools' which includes the plane, is the file (although Aldred (1956, 231) may have regarded this more as a blacksmith's tool). The file could have been used for shaping both wood and metal. Burstall (1963, 77) reports that the file is often mentioned in classical texts, and was made from the best quality steel from Laconia. The file is an important tool, since it would be used not only for the fabrication of artefacts, but in the production and maintenance of other tools, such as plane blades.

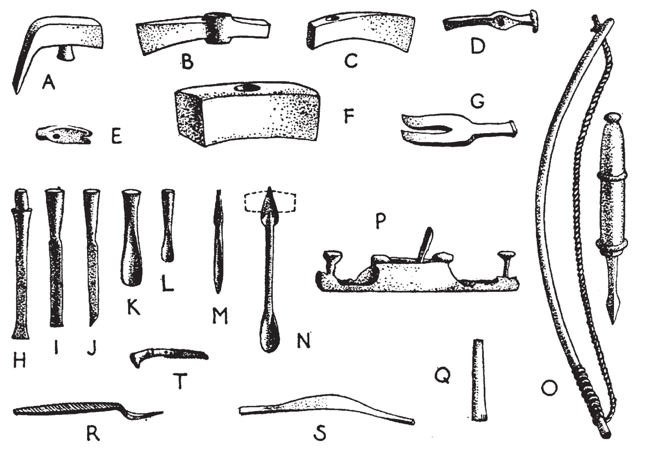

Figure 1: Tools in a Roman carpenter's kit (after Aldred 1956). A-E: hammer heads, F: wooden mallet head, G: nail lifter, H-J: socketed chisels, K-L: socketed gouges, M: spoon bit, N: auger (wooden handle shown dotted), O: bow drill, P: iron carcass of a plane, Q: moulding plane iron, R: rasp, S: draw knife, T: saw.

Moulding plane blade from Vindolanda

The moulding plane blade (find 5345), which can be dated to between AD160-180, was found with other (unspecified) artefacts in two ditches on the western side of what is presumed to be a late Antonine fort. The ditches were dug through the floors of a building dated between AD105-140, but were later backfilled and sealed to provide for a second-century construction associated with a military annexe (Blake 1999).

The iron, which is shown in Figure 2, is 122mm long, 20mm wide and 3mm thick. The cutting edge is scalloped (Fig 3a), and there is a clearance angle of 41° which would be sufficient for a blade set at 50-66° as described below. Figure 3b allows comparison of the Roman blade cutting edge with its modern equivalent; the similarities are obvious. Figure 2 shows there is some mushrooming evident at the end opposite the cutting edge, which is in keeping with use of the blade

Figure 2: Moulding plane blade from Vindolanda

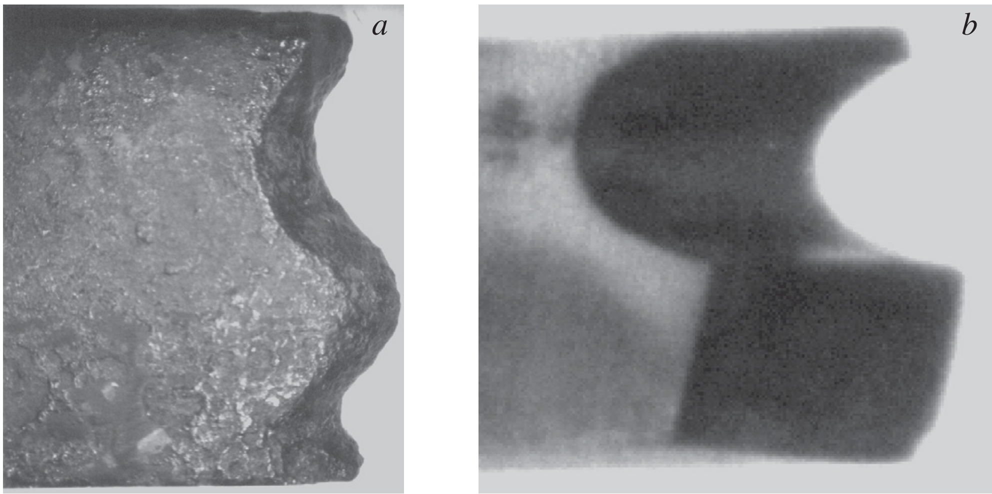

Figure 3: Close up of cutting edge for a: Roman and b: modern moulding plane blades (magnification 3x Fig 2)

in a plane. A metallographic examination was conducted to determine the composition of materials used and method of manufacture; the results are presented below.

Roman planes

Although only a few examples of Roman wood-working planes survive to this day (and none of them complete), there is sufficient information available to be fairly certain of their form and use, especially when taken in conjunction with contemporary portrayals, literary references, and the artefacts which they made (Greber 1956). It is not clear where and when the plane was invented. Petrie (1917) states that it seems fairly certain that it was from the Greek civilization rather than the Egyptian, whilst Burstall (1963) states that it was a Roman invention. What is known is that the earliest planes to have been discovered are two from Pompeii, which was founded by the Greeks.

As Greber (1956) points out in his comprehensive work on the history of the wood-working plane, there are a large number of different types of planes to satisfy the many needs of craftsmen working in wood (he lists about 50 different generic types). It is unlikely that the Roman carpenter would have had such a great number, but there would have been several, as there was a requirement for smoothing, grooving and creating mouldings, as evidenced by the furniture which has been found at Pompeii and Herculaneum (Mols 1988, 139-143).

Goodman (1964, 43) lists 13 Roman planes (or parts of Roman planes) including those listed by Greber (1956), from various sites across the Roman empire, including Silchester, Caerwent and Verulamium in Britain. The body of the planes was either made from wood (two examples), or a combination of wood and iron (11 examples). The angle at which the irons were set in the body of the plane was very consistent, ranging between 50-66° (Goodman 1964, 43). The small number of known planes makes it impossible to state whether it was more common for them to be made of wood or a combination of iron and wood, since very little wood has survived. However, with the exception of the early Pompeii planes, the form seems to have varied very little, whether made of wood or a combination of wood and iron.

Figure 4: Roman plane found at Silchester (after Goodman 1964), length 340mm.

Figure 4 shows a plane which was found at Silchester, at the bottom of a well. It can be seen that the plane has changed little in shape through the centuries. Probably the most significant difference between Roman and more modern planes is that the wedge in Roman planes is between a pin or bar and the plane iron (the cutting blade) whereas later planes have a wedge which slides within the plane body to hold the iron. This style of wedging is not recorded until the early sixteenth century, when it was shown in a drawing by Dürer (Die Melancolie - see Mercer (1929, 111) for a reproduction).

So far, we have considered planes which have been used for smoothing or creating a uniform surface (toothed irons were used for roughening surfaces prior to gluing) and therefore have a flat (symmetrical) sole. Modern moulding planes have the same principles of operation, but differ from smoothing planes in three ways:

- the pattern they create is with reference to a fixed edge. Thus the plane must be guided as it is used in order to follow a straight path; this may achieved either by a lip on the sole of the plane, or by using a 'fence'
- the sole of the moulding plane is shaped in sympathy with the cutting edge of the iron, so as to support the blade
- where the plane (blade) is asymmetrical, so too will be the plane, and it is possible that the shavings may be discharged to the side of the plane rather than through the hole in the centre of the box.

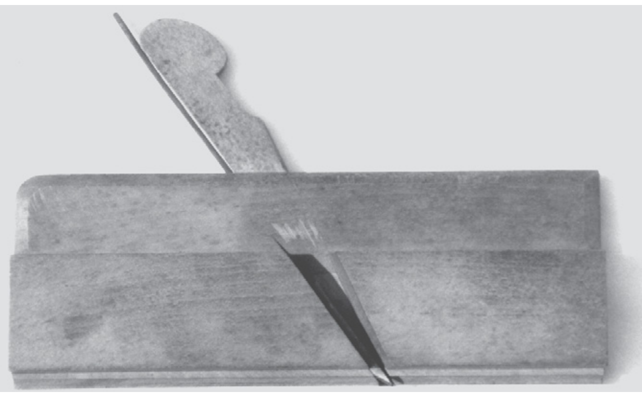

Figure 5: Modern moulding plane, length 236mm.

Figure 5 shows a modern moulding plane, with the shaped sole clearly visible. Roman planes used for manufacturing mouldings may have incorporated some or all of the above features. There is no evidence either way, but some sort of guide would seem to be a necessity. The guide need not be an integral part of the plane, and could easily be achieved by guiding the edge of the plane against a strip of wood clamped on to the work piece. If a shaped sole was used, this would have been difficult to manufacture in iron, and it is reasonable to assume that the body of moulding planes would have been constructed from wood only, and have not survived.

Plane blades or irons

Rather more plane blades or irons have survived than planes. This is not surprising, as the blades would have been made from iron, and it is quite possible that more than one blade may have been made per plane. Another consideration is that irons may have been mis-identified as chisel blades, especially if in a poor state of preservation.

Greber (1956) presents a table which lists some 59 'typical' blades which have been found without planes at Roman military posts and settlements in Gaul and Germany: many of these blades are now in the Saalburg Museum. (It is not clear from the translation of Greber's comment concerning his table 3, whether there are many more blades in the Saalburg collection, and that he has selected those he lists as representative, or whether his is a complete listing.) It is interesting, although maybe not surprising, that many of the plane blades were found at the Limes (border) forts of Saalburg, Feldberg and Zugmantell. The predominance of tools found at forts is probably because these settlements were liable to be abandoned at short notice by the occupants. Greber (1956) lists six moulding plane blades, all of which were found at either Saalburg or Zugmantell. These blades vary in length from 136-233mm, and in width from 16-28mm; there is no correlation between length and width. No information is presented as to the thickness of these blades.

In Britain, the two examples of Roman moulding plane blades are both from forts, one from Newstead (Curle 1911), and the other, the subject of this paper, from Vindolanda. Considering first that from Newstead and working from Curle's plate LIX, the moulding plane blade is 150mm long and tapers uniformly in width from 25mm at the cutting edge to 17mm at the other end where some 'mushrooming' is evident. Greber (1956) notes in his general comments about plane blades that 'many irons become narrower from the cutting edge to the top for some reason'. There is no predominance of tapering in certain blade types, and no obvious effect on the functionality of the blade caused by the taper. Greber also notes the mushrooming effect on the ends of the irons caused by 'pounding with a hammer.'

Metallographic examination

It was not possible to cut a section of the Vindolanda plane blade for examination, as this would have caused an unacceptable level of damage. However, much information may be obtained from an examination of part of the side of the blade near the cutting edge, which was prepared by polishing and etching in 2% nital solution. In addition to the visual examination, hardness measurements were made on a 3 x 1mm grid pattern on the blade edge using a Vickers micro-hardness testing machine with 100gf load.

Figure 6 shows a micrograph of a section of the plane blade. The cutting tip, although incomplete, is clearly visible on the left hand side. What may also be clearly seen is that the blade is a laminated structure of three pieces of material, which have been forge-welded together (Fig 7).

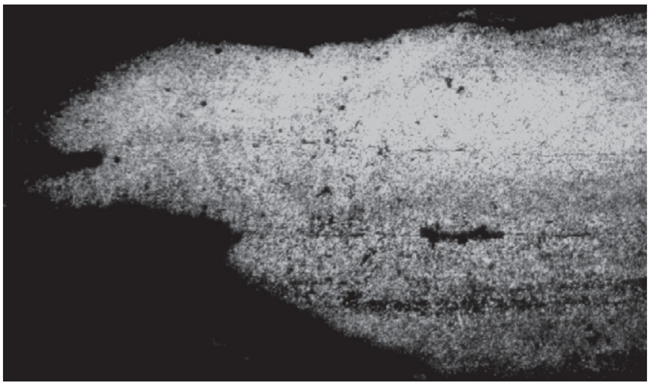

Figure 6: Micrograph of the tip of the plane blade showing the laminate construction (scale ~x 15)

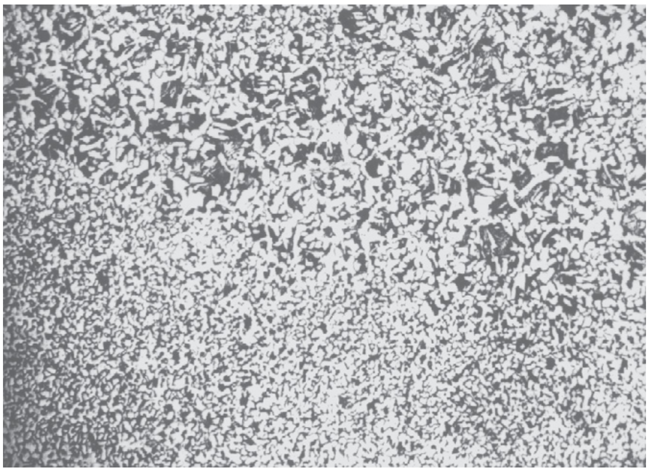

Figure 7: Micrograph showing the weld between two laminates in the blade—note the different grain sizes (scale ~x 60)

Slag inclusions are visible along the layer interfaces. Examination of these layers at higher magnification reveals the two outer layers to be of medium carbon steel (pearlite and ferrite) of about 0.4-0.5% carbon content, whilst the middle layer is a softer iron (ferrite) structure of about 0.1-0.2% C. These observations are reflected in the hardness measurements which are presented in Figure 8. For comparison, modern wrought iron has a typical hardness of 176 VPN.

Discussion

Great care had been taken by the Roman blacksmith in the construction of the moulding plane blade. The simplest method of manufacture would have been from a single piece of wrought iron. However, we can see an appreciation of the properties of the materials used,

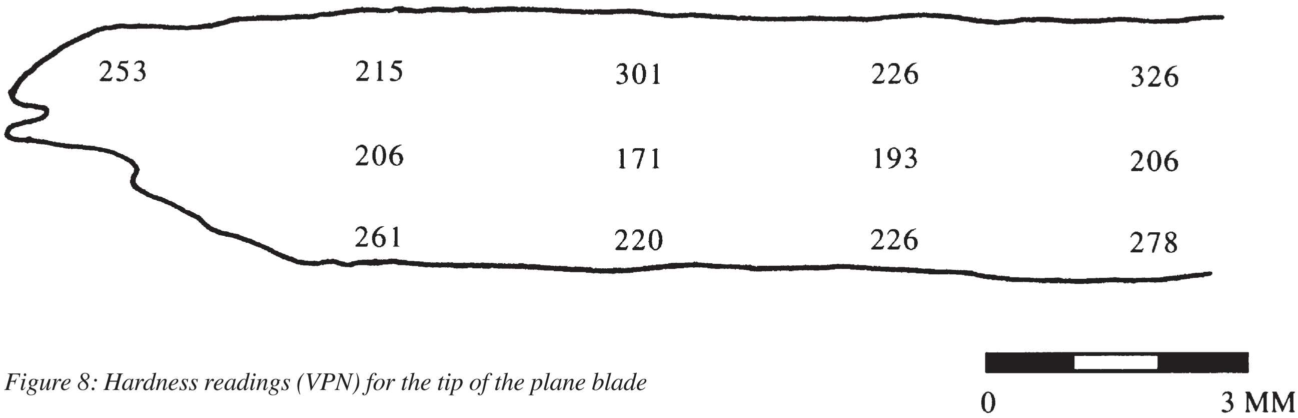

Figure 8: Hardness readings (VPN) for the tip of the plane blade

with the harder steel on the outside of the tool, in combination with a softer, more ductile, robust core of wrought iron. As a laminate structure, this blade would have lasted longer than one made just from iron, and would take a better edge.

It is likely that the blade would have been manufactured from a single piece of steel wrapped and welded around the iron core. This would have been relatively easy to manufacture, although more time-consuming than manufacture from a single wrought iron billet (Sim 1998). It would be possible to create a laminate structure by forging and folding a heterogeneous bloom, but in our example the microstructure is not consistent with this process, in that the grain size and carbon content of the layers differ (Fig 7).

The detail of the moulding shape would have been put on to the blade as a final step, using a file. The blade tip has been left in an unhardened state, which is however sufficiently hard to cut wooden mouldings. The lack of hardening may well have been deliberate, rather than due to a lack of knowledge of the process. A blade which is left unhardened will be much easier to repair or maintain in that it may be reshaped easily by file. A hardened edge would have to be annealed before repair and subsequently re-hardened (Sim 1998).

There is no other published data of which the authors are aware concerning the metallographic examination of plane blades. The closest comparison is of some wood-working chisels examined by Tylecote and Gilmour (1986, 69-71) as part of their research into the metallography of edged tools and weapons. In general, Tylecote and Gilmour found that the Romano-British chisels which they examined were manufactured from low carbon steel or wrought iron, with hardnesses varying from 124-250 VPN, depending on work hardening or carbon content, although one rather more sophisticated blade did contain tempered martensite with a hardness of 414 VPN. The standard range of hardnesses which Tylecote and Gilmour found is in line with but a little lower than those found in the moulding plane blade, which varied between 171-326 VPN. The chisels had also been made by welding layers of material together, so that steel was used at the cutting edge and supported by the more ductile softer wrought iron.

Conclusions

This metallographic examination of a Roman moulding plane blade found at Vindolanda has shown an appreciation on the part of the manufacturer of the properties of iron and steel. The blade consists of a iron core in a laminate structure with low carbon steel on the outside to provide a good cutting edge.

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