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COPPERGATE, YORK

IRONWORK REPORT No. 7

KNIVES 8414, 8685, 9702,

10090 and 10395

by

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IRONWORK REPORT NUMBER 7

KNIVES 8414, 8685, 9702, 10090 AND 10395

KNIFE 8414

Knife 8414 (Plate 1) has an overall surviving length of 135mm and a maximum width of 10mm and thickness of 4mm, it is Back Form type C. The tang end is gently bent through 180^{o}. The knife has a slim blade (width 6mm, thickness 3mm (maximum)). It has a slightly concave area at the back of the cutting edge, which may be due to wear. The knife had suffered heavy corrosion in parts, eg the tip, it was X-radiographed and two sections were removed by spark erosion in order to obtain a complete cross-section of the blade while keeping the knife complete. The interpretation of the X-radiographs and location of the sections are shown in Figure 1. The X-radiographs show the extent of the corrosion, particularly severe at the point and there is a distinct weld line running the length of the tang. It is probable that the cutting edge was also welded on. It is not clear whether these two weld lines ran together indicating that a strip of steel was welded to the whole length of the knife.

The two sections were mounted together and prepared in the usual manner. In the unetched condition the back showed a banded structure defined by fine lines of slag inclusions running vertically through the section. The cutting edge is slag free. Two possible weld lines were defined by void and slag inclusion lines, resulting from poor welding. When etched the

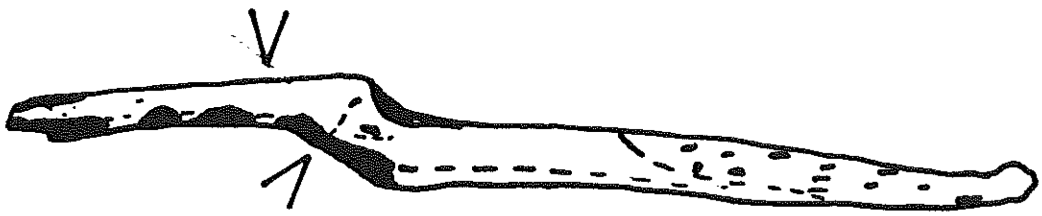

Fig 1

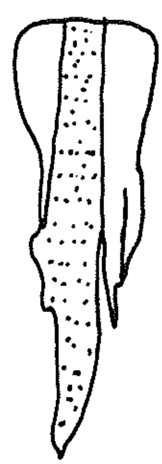

Fig 2

sections showed a central core of steel sandwiched by wrought iron (Figure 2). The wrought iron had not been folded over the top of the steel but welded to each side. The wrought iron was slagged, and had a fine precipitate within it, as yet unidentified. There was also a ghost structure indicating a high phosphorus content. The steel tip was pearlitic and ferritic, a hypo eutectoid steel (0.8% carbon). There was some evidence of decarburisation at the tip and in general the pearlite was coarse, in parts, especially at the back of the knife, the weld line between the wrought iron and the steel was not clear due to the diffusion of carbon into the wrought iron, where it occured as small carbide particles.

The hardness results are shown in Table 1, the wrought iron shows a high reading characteristic of phosphoric iron. The results for the steel core confirm the pearlitic/ferritic structure.

TABLE 1

VICKERS HARDNESS TESTS HV_5

Wrought Iron	119
Steel (Back)	152
Steel (Tip)	169

MICROHARDNESS TESTS mHV_{100}

Wrought Iron Sheath	170
Wrought Iron Sheath	145
Steel Core (Back)	201
Steel Core (Middle)	266
Steel Core (Tip)	227

The concave curvature of the blade was confirmed by the differential presence of the wrought iron sheath. It had clearly been worn away to a greater extent on one side than the other. Though the overall concave curve of the knife at the blade/tang interface can not be shown to be due to wear, since the cutting edge is a central steel strip and hence, if the blade was originally wider, it could have been resharpened many times, resulting in the thin blade and curved blade/tang interface.

METHOD OF MANUFACTURE

A central steel strip was sheathed on either side by strips of wrought iron. The pattern of corrosion was similar to that observed in knife 9045 which may indicate that the sheath has a piled structure. The knife has not been heat treated in any way, resulting in a less hard cutting edge which would not have been so efficient. The coarseness of the weld lines would indicate a poorer quality of knife.

KNIFE 8685

Knife 8685, is of Back Form type E1, it has an overall surviving length of 110mm, a maximum width of 11mm and thickness of 4mm (Plate II). The tang end is missing, the knife appeared to be well preserved except for an area two-thirds of the way along the back towards the tip, where it was apparent that a piece(s) of iron was missing. The knife was X-radiographed and two sections were removed by spark erosion, (Figure 3). The X-radiography showed the extent of the corrosion along the knife back, which had a sinusoidal wave pattern, this pattern continued along the length of the blade as a denser pattern. A cutting edge/back weld line was also present. The tang end had suffered heavy corrosion.

The two sections were mounted together and prepared in the usual manner. In the unetched condition the knife back had vertically oriented slag lines while in the edge section the fine slag particles were randomly

PLATE I

PLATE II

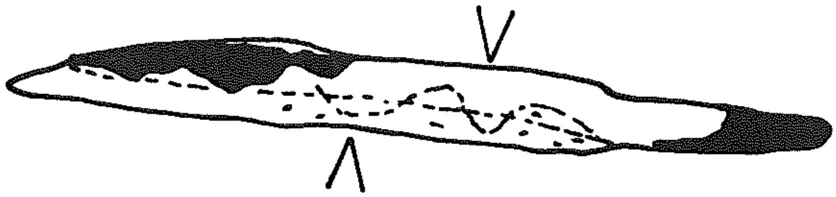

Fig 3

Fig 4

distributed. The top of the edge section was cut along a slag line running horizontally through the knife. When etched the two halves of the section showed completely different structures. The top section (ie the knife back) was a clean wrought iron. The cutting edge was a fine pearlite, high carbon (possibly 1%) with some retained austenite that had converted to Martensite (Figure 4). This structure resulting from a slow quench. The fact that the sections display different structures results from the location of the section. The top section (knife back) was located in one of the denser areas as shown in Figure 3, similarly the edge (lower section) was in one of the lighter areas. Both sections only reached the apparent weld line and did not cross it. Thus the slag inclusion at the top of the edge section must be the weld line.

Adhering to the specimen was a thin copper film which had derived from the spark erosion, further surface grinding could not be undertaken without losing the specimen.

The hardness results are shown in Table II and reflect the identified structures. The micro-hardness values for the wrought iron suggest a high phosphorus content, (the Vickers test was distorted). The results for the tip show an increase in hardness over Knife 8414 as indicated by the micro-structure.

TABLE II

VICKERS HARDNESS TEST	1kg
Wrought Iron	distorted
Steel Edge	244*

MICROHARDNESS TEST	mHV_{100}
Wrought Iron	157
Steel	460

METHOD OF MANUFCTURE

The knife back and tang were made from piled iron, and a high carbon steel cutting edge was butt welded to the back to form the cutting edge. The blade was subsequently heated to above 800^{o}C and slack quenched.

KNIFE 9702

Knife 9702 is of Back Form E3, 126mm long, blade width about 7mm wide and 3mm thick. The knife is well preserved, only the tang showing evidence of corrosion. The blade is slightly concave on one face. The knife was sectioned and examined as for 8414 and 8685 x-radiographed and two half-sections were removed using spark erosion (Figure 5). The radiograph shows little corrosion and the only feature is a possible weld line of the cutting edge/back join. In the unetched condition a single slag line was visible running virtually down to section but diverging before it reached the tip. There were also other dispersed slag inclusions. Etching (Figure 6) showed the knife to be made in a similar fashion to 8414, ie a steel core sandwiched between wrought iron. The wrought iron sheath showed some evidence of piling, there was also a fine precipitate in the ferrite. Carbon had diffused into the wrought iron during welding resulting in a network of carbides near the weld line. The steel itself was a fine grained tempered martensite quenched from between 723^{o} and

Fig 5

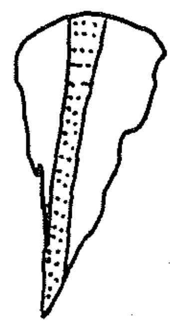

Fig 6

910°. (Eutectoid temperature and the ferrite transformation temperature) followed by tempering between 100-600°C. Within the steel small spherical white phases were present associated with the single phase slag inclusions. The hardness results are shown in Table III. The values for the wrought iron suggest a phosphorus content, and the blades for the steel are consistent throughout its length.

TABLE III

VICKERS HARDNESS	HV5
Wrought Iron Sheath	174
Steel Core (Back)	358
Steel Core (Tip)	407

MICROHARDNESS VALUES mHV_{100}	
Wrought Iron (Mean)	199
Steel Core (Back)	409
Steel Core (Tip)	476

One of the faces of the knife blade was slightly concave before running down to the cutting edge, while the other face is flat, the wrought-iron sheaths on either side of the steel core do differ in that one is much wider and extends slightly further down the steel core than the other. It would seem probable that the concave side (with the thicker sheath) is the original shape, and that the other side is flattened (and the sheath thinned) as a result of wear/sharpening.

METHOD OF MANUFACTURE

Knife 9702 was manufactured in a similar fashion to Knife 8414, a steel core sheathed on either side by wrought iron, which does not turn over the back.

PLATE III

PLATE IV

The core and sheaths would have been fire welded together at about $1000^{o}C$, and then quenched (to harden) followed by reheating at about $100-200^{o}C$ for as much as a few hours to temper the structure. The steel core enables the knife to be continually resharpened, as the core forms the cutting edge, thus it is probable that the present form of the knife was not the original shape, and that its present shape is due to wear.

KNIFE 10090

Knife 10090 (Plate IV) is of Back Form type A, 87mm long, maximum blade width 15mm, thickness 4mm. The tang is incomplete due to corrosion, which has also affected the tip. The Knife is 'decorated' with a single small groove 22mm long c.1mm wide, and less than 1mm deep on each face of the blade midway along its length.

The Knife was X-radiographed and two half sections were removed by spark erosion (Figure 7). The radiographs showed the heavily corroded tang end, and isolated areas of corrosion along the knife, especially at the cutting edge. The grooves were distinct and below which there is a weld line. The section was prepared in the usual manner, and in the unetched condition the weld line was defined by a line of predominantly single phase slag inclusions. There were some vertical slag lines in the back of the knife suggesting a piled structure. When etched (Figure 8) the knife displayed two distinct structures. Above the weld line (the Knife back) the overall structure is ferritic with a ghost phase present (phosphorus?) and some spheroidal carbides. There are also pile/weld lines defined by lines of slag inclusions and the ferrite etched yellow/brown. Many of the carbides and small slag inclusions are surrounded by a white/yellow film, this has not yet been identified. There is also a grey phase, unrelated to the carbides but nucleating on

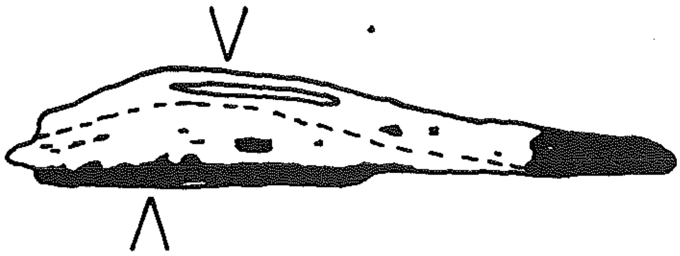

Fig 7

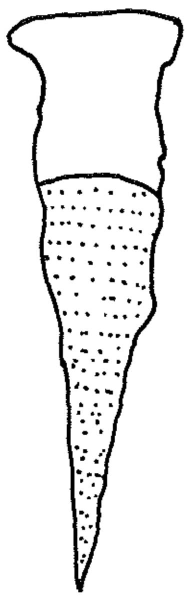

Fig 8

the slag inclusions.

The weld line is defined by slag inclusions and a 'white line' (high Arsenic? cf Knife 10556).

Below the weld line the structure grades from ferrite with fine pearlite through tansformation products (Bainite) to a Martensitic tip. Present in this metal are unidentified small spherioidal inclusions.

The grooves were clearly cut in using a chisel at a high temperature, since a number of pile lines are interrupted by the groove, some deformation of the lines occurs at the bottom of the groove.

The hardness values are shown in Table IV and reflect the variation in microstructures. The hardness of the ferrite suggests the presence of phosphorus which is also indicated by the ghost phase. The quenching to produce a hard martensitic cutting edge was clearly successful.

TABLE IV

VICKERS HARDNESS RESULTS	HV5
Ferritic Iron (Back)	1
Bainitic Area of Cutting Edge	201
Martensitic Cutting Edge	874

MICROHARDNES RESULTS	mHV_{100gm}
Ferritic Wrought Iron	213
Ferrite + Carbides	297
Bainite	397
Martensite	847

METHOD OF MANUFACTURE

The Knife back and tang were made from wrought iron, possibly piled, and the two grooves cut in. The steel edge was butt welded to the back and only the cutting edge quenched giving rise to the degradation in transformation products away from the edge towards the weld. This was clearly a very efficient tool. The wrought iron and steel must have been held at the welding temperature for a considerable time to enable the white line to develop. It is of interest to note the large width of the steel cutting edge compared with the knife back.

KNIFE 10395

Knife 10395 (Plate V) is of Back Form type E1. The knife is bent through 60^o at the blade/tang interface. The tang was very wide and hence complete, the knife was 90mm long, blade width 17mm and thickness 2mm.

The knife was X-radiographed and two half-sections removed by spark erosion (Figure 9). There was no evidence of structure in the radiographs and therefore appear to have been manufactured from one piece of wrought iron/steel. In the unetched condition the section showed vertically orientated slag lines probably indicative of piling. The tip contained very few slag inclusions. In the etched condition (Figure 10) the section showed an overall steel structure primarily consisting of ferrite and bainite, with the cutting edge being Martensite and Ferrite. A distinct 'yellow' weld line (cf Knife 10090) runs vertically through the section. There is also a 'white line' weld running vertically for part of the top section. The overall structure is that of a piled structure, the pile lines defined by slag inclusions and bainite grains. There are also unidentified phases,eg an area in the upper section containing triple points of a low melting point alloy, and there is a fine precipitate throughout much of the ferrite. The higher carbon tip is not welded on

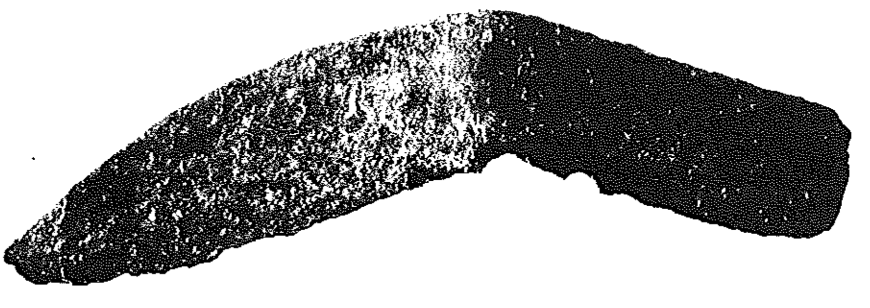

PLATE V

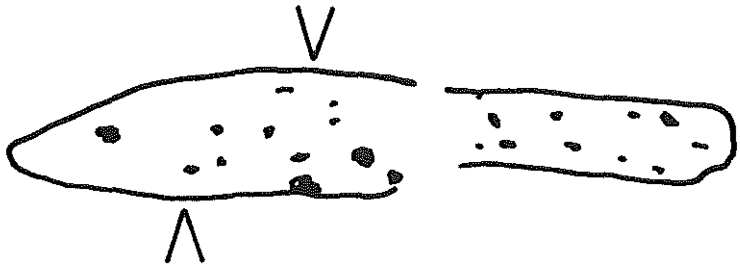

Fig 9

Fig 10

but has been carburised in-situ, since the central 'yellow weld' line runs through the carburised and un-carburised areas of the knife.

The hardness results shown in Table 5 show a more or less uniform hardness throughout the blade except for the cutting edge which is harder as expected from the microstructure.

TABLE V

VICKERS HARDNESS RESULTS	HV5	MICROHARDNESS RESULTS
Ferrite/Bainite Piling	186	176
Ferrite/Bainite Piling	113	159
Ferrite/Bainite Piling	134	127
Martensite Cutting Edge	487	420

METHOD OF MANUFACTURE

The knife was forged from one piece of piled iron, the cutting edge was then carburised and the whole knife quenched and tempered.