Ancient Monuments Lab Report No. 4610

METALLURGY RESEARCH (ARCHAEOMETALLURGY)

PRODUCTION ENGINEERING

ASTON UNIVERSITY

ASTON TRIANGLE BIRMINGHAM B47ET

COPPERGATE YORK METALLURGY REPORT NUMBER 11

THE ROD-SHAPED BLANKS

INTRODUCTION

A large number of iron strips and rods were recovered from the site. Similar items have been found on other sites, notably Helgo, Sweden (The Excavations at Helgo V:1, Workshop Part II Editors K. Lamm and A. Lundstrom 1978). They are interpreted as the primary rods and strips of iron and steel from which the blacksmith manufactured tools and artefacts. The physical description and classification of the Coppergate examples is discussed by Ottaway elsewhere. Fifteen examples were selected for analyses, one blank was totally sectioned to examine variations in structure along its length, most others had one end cut off and mounted. In some cases both ends were examined if one end had been worked, eg rolled or flattened. Detailed radiography of the rods was not undertaken due to their thinness.

BLANK 10860

Blank 10860 was a square sectioned blank approximately 70 milimeters long and 3 milimeters square. It was sectioned to produce alternating cross sections (numbers 1,3,5,6a,and 6b) and longitudinal sections (numbers 2,4,and 7). The rod had a banded or piled structure throughout its length that was apparent, in

the unetched condition from the slag inclusions. In the etched condition the microstructure was ferrite plus pearlite. The amount of pearlite varied between some of the bands, and others were defined by thin bands of larger grain size ferrite, carbon free, and probably higher in phosphorus There were typical white/yellow weld lines present.

Section 1 The slag lines indicated a rounded or rolled-up plate structure with a distinct circular weld line running through the rod. The slag lines followed the same pattern. The phase composition was as described above.

Section 2 The bands run lengthways along the longitudinal section, some of which turned through 180 degrees, indicating folding.

Section 3 As section 1

Section 4 As section 2

Section 5 The bands are no longer circular but parallel to the longitudinal direction.

Section 6a As section 5

Section 6b As section 5 but with some banding turning through 180 degrees as in piled structures.

Section 7 As section 4

The fundemental structure of the blank is a piled structure of alternating wrought iron and steel bands. For part of its length it has been subsequently worked to produce a 'ringed' rather than banded structure. The carbon content and quality of the metal remained constant throughout the rod's length. The hardness values are shown in Table I.

TABLE I BLANK 10860 Hardness Results

Section	Ferrite Band		Ferrite/Pearlite Band	
Number	HV 5	uHV	HV 5	uHV
1	143	142	168	168
2	201	142	168	194
3	140	172	210	194
4	133	168	193	195
5	148	150	165	195
6	162	156	189	186
7	165	160	185	192

BLANK 8364

A thin strip (84mm long, 8mm broad, 4mm thick) that had been flattened out to a plate at one end, which was the end sectioned. The unetched section showed a large number of single phase slag inclusions indicative of some banding. When etched the bands were alternate layers of small and large grained ferrite, and hence reflect phosphorus distributuion. There was no carbon present. The hardness values are shown in Table II.

Table II Blank 8364 Hardness Results

	HV 1	uHV
Large Grained Ferrite	201	203
Small " "	269	201

BLANK 8376

Blank 8376 was a rectangular section bar (67*9*7mm). The unetched section showed slag lines with a large number of single and multi phase slag inclusions. The etched specimen showed an overall ferritic structure with some small areas of pearlite. Hardness values were (HV_1), ferrite - 148; pearlite - 214.

BLANK 8424

Blank 8424 was wedged shaped with a square cross-section (60*16*9mm). The thin end of the wedge had been drawn out to cut the bar by extension and tearing. The thin end showed a fibrous 'ductile' fracture. The section was removed from the wedged shaped end. The unetched specimen showed a clean metal with a low number of single phase slag inclusions, but with some deep penetration of corrosion probably along weld lines. Etching showed a medium carbon steel with a pearlitic structure, but with some areas of martensite. The hardness values are shown in Table IV.

Table IV Blank 8424 Hardness Results

	HV_1	uHV
Ferrite, small grained	210	251
" large "	219	201
Pearlite plus ferrite	229	190
Pearlite	193	328
Martensite	772	

BLANK 8439

Blank 8439 is a flat bar with a rectangular cross-section (55*8*3mm). The unetched specimen showed a few orientated slag inclusions. Etching showed a ferritc structure with phosphorus ghost structures. Hardness values were HV 185, and uHv 183 and 203.

BLANK 8794

Blank 8794 is a square sectioned long bar (211*6*5mm). The polished specimen showed banded slag lines, when etched the banding was between small grained bands and large or grainless bands, the latter containing high phosphorus contents. The small grained bands are themselves banded, ie the band may contain three or four layers of small grains. They may also contain thin layers of probably high phosphorus iron. There is a higher number of slag inclusions and some small areas of pearlite in the small grained bands. Hardness values are shown in Table V.

Table V Blank 8794 Hardness Results

		HV 1	uHV
Ferrite	no grains	283	262
"	large grains		215
"	small "	148	146
"	" "		217

BLANK 8982

Blank 8982 is a deformed bar with an approximate rectangular cross-section (26*6*6mm). The section showed few inclusions and when etched a pearlitic structure with some ferrite present. There was no banding or segregation. The mean hardness value (HV) was 305.
1

BLANK 10658

Blank 10658 (52*13*12mm) was one of two examples of 'round bar' sectioned, although its section was rounded/sub-rectangular. In the unetched condition the specimen showed the presence of slag inclusions some orientated as a result of the rounding of the bar. When etched the structure showed a varying carbon distribution, an overall ferritic structure with areas of pearlite. Some areas of ferrite were large grained indicating a phosphorus/carbon segregation within the rod. The hardnesss values of the different areas are shown in Table VI.

Table VI Blank 10658 Hardness Results

	HV 1	uHV
Ferrite plus Pearlite	219	240
Ferrite grainless	263	339
Ferrite small grains	224	240

BLANK 10665

Blank 10665 is the second round bar (33*11mm diameter), having a circular cross-section. The section showed some effect of the rounding process on the inclusions. When etched the predominant structure was ferritic, but there were areas of

pearlite indicating some banding, probably the result of the rounding of the bar. Hardness values of the ferrite were 151 and 138 (HV_1).

BLANK 10975

Blank 10975 is a very long rectangular sectioned strip (187*9*6mm). When sectioned it contained a large number of inclusions. Etching showed the structure to be wholly ferritic with a high phosphorus content. Hardness values were (HV_1) 224 and (uHV) 195.

BLANK 11208

Blank 11208 was a very thin piece of wire (96*3*1.5mm) with a rectangular cross-section. It contained a high number of slag inclusions, and on etching was ferritic. Hardness values were (HV_1) 251 and (uHV) 237 and 285.

BLANK 11352

Blank 11352 was a rectangular sectioned strip (36*12*4mm) that had had one end thinned and flattened to produce an elongated rectangular section, both ends were sectioned. The unaltered end showed a variation or segregation of inclusions. When etched the predominant structure was small grained ferrite containing a large number of slag inclusions. There were three areas of pearlite (plus pearlite) that contained few slag inclusions. The second section showed the same structure elongated. The presence of the pearlite areas at each end would suggest that the structure resulted from the welding together of wrought iron and steel strips. The hardness values are shown in

Table VI.

Table VI Blank 11352 Hardness Results.

	HV 1	uHV
Pearlite plus Ferrite	283	240
Ferrite large grained	201	151
Ferrite " "		215

BLANK 11492

Blank 11492 (43*7*4mm) was of similar shape to 11352, having a worked and unworked end. Both ends had rectangular cross-sections with the long axis of one end at right angles to the other. It was not clear therefore which end was the worked end, and both were sectioned. Both showed evidence of banding in the form of slag lines in the unetched condition. When etched the broad end had bands, defined by varying carbon content, running longitudinally. All the bands had a pearlite plus ferrite structure. The second end had the same pattern, but compressed. The blank can therefore be considered a steel strip. The hardness values are shown in Table VII.

Table VII Blank 11492 Hardness Results

	Long Section		Compressed Section	
	HV 1	uHV	HV 1	uHV
Ferrite plus Pearlite	368	260		336
" "	276	336		243

BLANK 11550

Blank 11550 was a heavily corroded flat bar (93*12*5mm). The section contained few slag inclusions, when etched the structure was medium grained ferrite. The hardness values for the ferrite were 133 (HV) and 113 and 146 (uHV).
1

BLANK 11989

Blank 11989 was a thin square sectioned rod (66*5*4mm). The unetched specimen showed a clear weld line running through the centre of the rod. Etching showed the rod to comprise of a steel and wrought iron rod welded together. The steel half had a fine pearlite structure. The hardness values are shown in Table VII.

Table VII Blank 11989 Hardness Results

		HV 1	uHV
Ferrite Strip	Ferrite	257	227
Steel Strip	Martensite	686	920
	Bainite	401	498
	Ferrite plus Pearlite		297

SUMMARY

The rod shaped blanks analysed above can be divided into four groups on the basis of their metallurgical structure,(Table 13.). Firstly the wrought iron strips, secondly those with piled structures of wrought iron and steel, thirdly the welded strips in which strips of wrought iron and steel (or pilled structures) are welded together, and fourthly

the all steel strips. The rod shaped blanks therefore show the overall structures that have been encountered in the artefacts themselves.