Report on Metal Material Tests for Sri-Lanka-made Agricultural Edge Tools

AUGUST 1985

JAPAN INTERNATIONAL COOPERATION AGENCY

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Report on metal material tests for Sri-Lanka made agricutural edge tools

1. Purpose of tests and considerations on the historical and social background

The purpose of these tests is to promote effective manufacturing of agricultural edge tools in Sri-Lanka by making proposals for both production methods and technical improvement measures.

Normally agricultural edge tools are developed by local backsmiths to suit the local conditions and therefore they often come to have characteristic shapes and properties indigenous to the area. Techniques of these blacksmiths are results of numerous requests from farmers, and accumulated information concerning local conditions such as soil, geography, temperature and moisture. And it is for this reason that agricultural edge tools from different regions show infinitesimal differences in their shape, hardness and material.

In Sri-Lanka however, local agricultural implements gradually disappeared as British-made implements replaced them and became widely spread, under the British occupation. Local farmers were forced to use standard agricultural implements without much of a variety. Inefficient work lead to economical downfall of the agricultural sector and consequently blacksmithy itself lost its significance in the society to such an extent that blacksmithy as an occupation began to be seen as the lowest of class. If agricultural implements suited to each area are manufactured, it is surely expected that farmers and blacksmiths will make efforts to improve each other and take active part in the socio-economic field.

Recently, automation of agricultural implements have shown a rapid progress, but much of the spare parts supply in Sri Lanka is imported including consumable tools such as blades of rotary plow, which are rather expansive for farmers. Some of them are actually produced in Sri-Lanka, but the quality is not satisfactory since materials which are easy to work on tend to have low abrasion resistance and because of all this agricultural mechanization seems to have come to a standstill.

As almost all of the edge tools are made of low carbon iron, formed by hot forging, their durability is rather low. Therefore, efforts have been made to produce high quality import substitutes, using cheap middle carbon steel scrap such as springs or leaf springs of cars. However the quality of these products has not reached a satisfactory level, because of wrong selection of techniques in heat treatment, processing and finishing.

Fundamental tests on metal materials were carried out, by the request of division of development of mining and industries, Japan International Cooperation Agency (JICA), and their results are summarized in this report.

2. Items of test samples

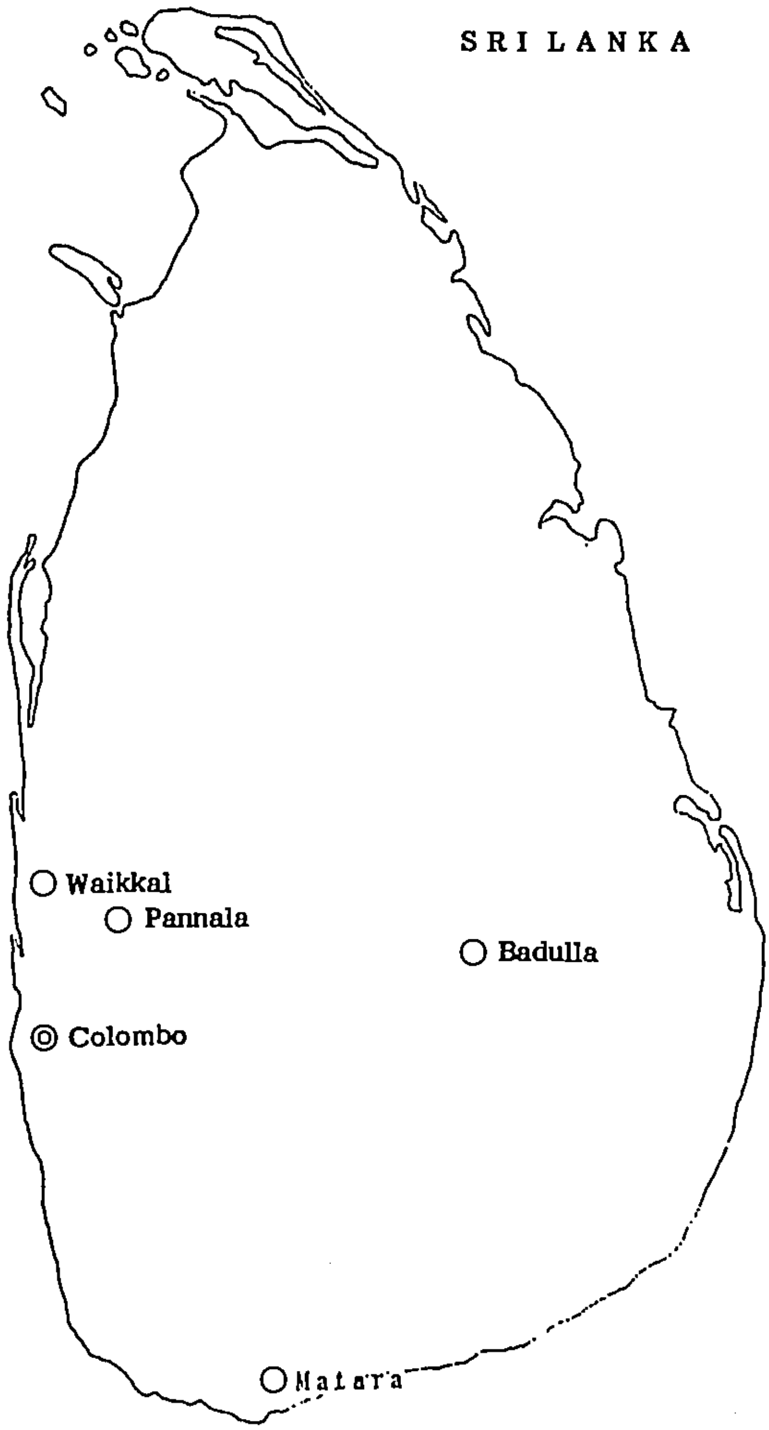
The test samples for this research, sickle, hoe, knife, hatchet etc. a total of 15 pieces, were collected by Mr. Miki, Appropriate Technology Research & Development Centre, in Sri-Lanka. Fig. 1 shows the details of the samples such as place collected and price and Fig. 2 shows places where tools were collected and used.

Fig. 1

Number	Name of tool	Place Collected	Price	Remarks
No. 1	Hoe	Hardware Authority (department)	¥325	As popular and widely used as British products
No. 2	Hoe for wet paddy field plowing	Street stall in Badulla	¥680	Very popular
No. 3	Worn hoe for wet paddy	Street stall in Badulla	¥50	In this area old hoe is reused by jointing new edge
No. 4	Bitchu hoe 3 Nails	Blacksmith in industry estate	¥742 including handle	Imitation of Japanese product
No. 5	Bitchu hoe with stick 4 Nails	Blacksmith in Alabatagama	¥790	Imitation of Japnese product
No. 6	Paddy harvet-ing sickle	Blacksmith in Matara	¥790	Mass produedt Saw teeth sickle
No. 7	Moving sickle	Blacksmith in Waikkal	¥278	Mass produced Saw teeth sickle
No. 8	Weeding sickle	Blacksmith in industry estate		Imitaion of Japanese product
No. 9	Moving sickle	Shopin Pannala	¥250	Popular type
No. 10	Moving sickle	Blacksmith in Alabatagama	¥326	Special type
No. 11	Cooking knife	Blacksmith in Waikkal	¥260	Family type
No. 12	Hacket	Blacksmith in Matara		
No. 13	Blade of rotary plow	Blacksmith in Pannala		Spare
No. 14	Raw material	Hardware authorityity (department)		Remainder of steel plate from which hoes have been cut out by large press machines
No. 15	Raw material	Blacksmith in Alabatagama		Broken spring steel

Items of test samples comprise 5 hoes, 5 sickles, 2 knives, one rotary plow and 3 row materials.

Fig. 2



3. Research items

(1) Assessment of manufacturing processes and their usage

Observation was made using a video film of manufacturing processes and farmers using the implements.

(2) Physical Appearance

Quality of finishing was determined through simple observation of the surface using, magnifying glass. Considerations were made on weight balance which is one of the important factors concerning work efficiency by estimating the strength from measured thickness of each section.

(3) Metal Tests

Test items as summarized below were conducted on blade edges, welded or forged parts.

(1) Chemical Composition

By applying X-ray analysis, proportions of constituting elements such as C, Si, Mn, P, S, Cr, Mo, V, W were determined.

(2) Metallurgical Structure

Through the observation of metallurgical structures of the raw materials as well as heat treated or welded parts, inferences concerning heat treatments and other manufacturing processes were made.

(3) Hardness Distribution

Through the measurement of surface hardness and section hardness using a rockwell hardness tests or micro-videos hardness tests, uniformity of raw materials conditions of heat treatments and strength properties were determined.

(4) Comparative test on abrasion resistance of the blade edges

Durability of sharpness was determined using a Honda type cutting quality test machine, and abrasion resistance inferred.

(5) Test of the strength of welded and forged joints

Test samples of welded and forged joints were prepared and the actual strength determined by the tension test.

4. Research Results

(1) Assessment of manufacturing processes and their usage

(1) Hoe

a. Hoe No. 1 seems to be sufficiently solid structurally, but too heavy for small jobs such as carrying soil and sand. High abrasion resistance can be expected as this is formed through forging pressure heat treatments. On the other hand, blades may be chipped if applied to gravelly.

b. For ridging sample No. 1 is more advantageous as it can carry more soil than sample No. 2. On the other hand the tool is rather thick and heavy making the work more laborious. It is better to make it lightes.

c. For sample No. 2, the handle is simply fitted into the round hole of the body forming a rivet structure and this is not a satisfactory dence to counteract stress from all directions. The handle would become loose if used for a long time. For hoes, a square hole and thick welded joints are more favorable.

d. For No. 3 the forged joint appears strong enough.

(2) Sickle

a. Degree of curvature for the blade of No. 6 is made large so that it is convenient for lifting up and harvesting rice plants which often grow irregularly because of direct seeding.

b. No. 7 is used for cutting grass by applying it just above the ground.

c. As No. 9 and No. 10 are used for cutting soft grass, the blade is not sharp.

Hardness must be increased if these are to be used for fine bushes but care must be taken to prevent the chipping of blades.

(3) Knives

a. No. 11 is an ordinary cooking knife. Its shape is similar to Japanese knives and it is used in more or less the same way. It is sometimes used without a chopping board, by simply pressing the objects against the blade.

b. The surface of concrete or brick is used for whetting the blade edge instead of whetstones.

c. No. 12 is used for hacking bushes from abore, and has a strong enough structure to withstand fairly rough use. It is used in the same way as the Japanese hatchet.

d. It is not sufficiently hard, as blade finishing was done using a file.

(4) Blade or rotary plow

a. This is fairly popular as it is cheap compared to Japanese products, but the durability needs to be improved.

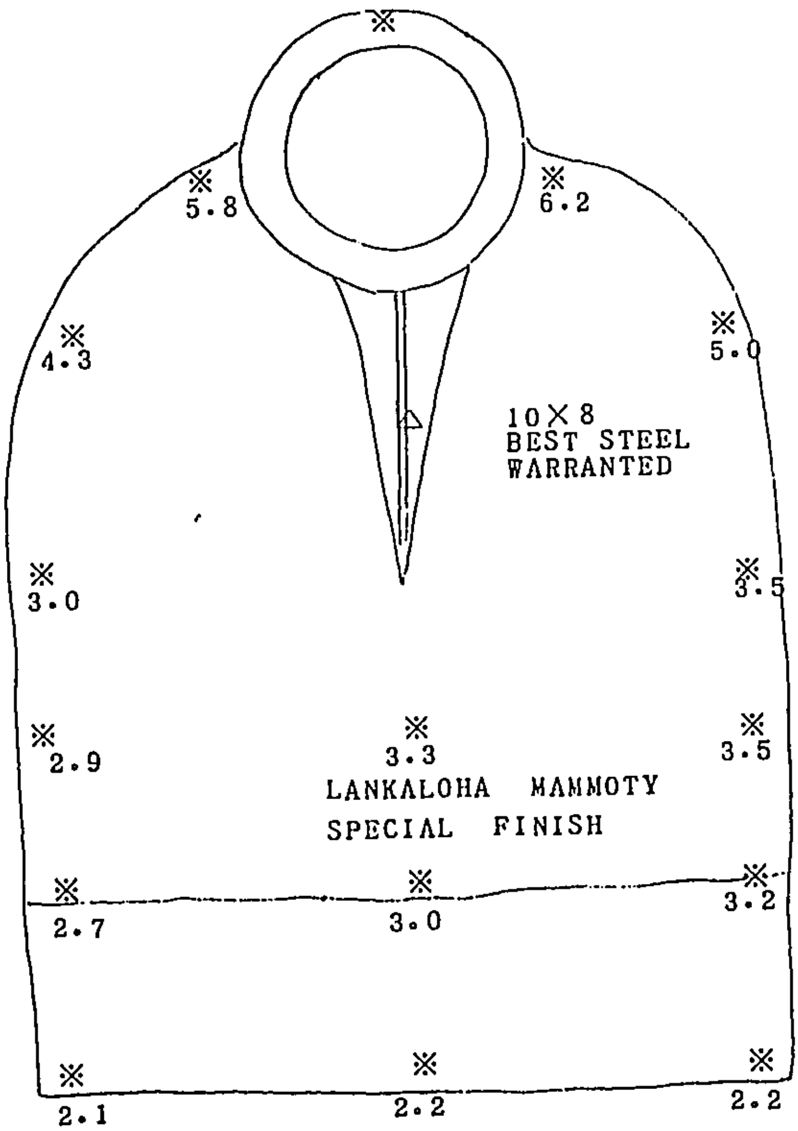
(2) Physical Appearance

A rough sketch, thickness, center of gravity, manufacturing methods, jointing and finishing of each tool are shown in Fig. 3 to Fig. 17 (scale 1 : 1/2). Figures with asterisks show thickness (mm), and marks indicate the centers of gravity. Other remarks are given underneath the diagrams.

Fig. 3

No. 1. Hoe

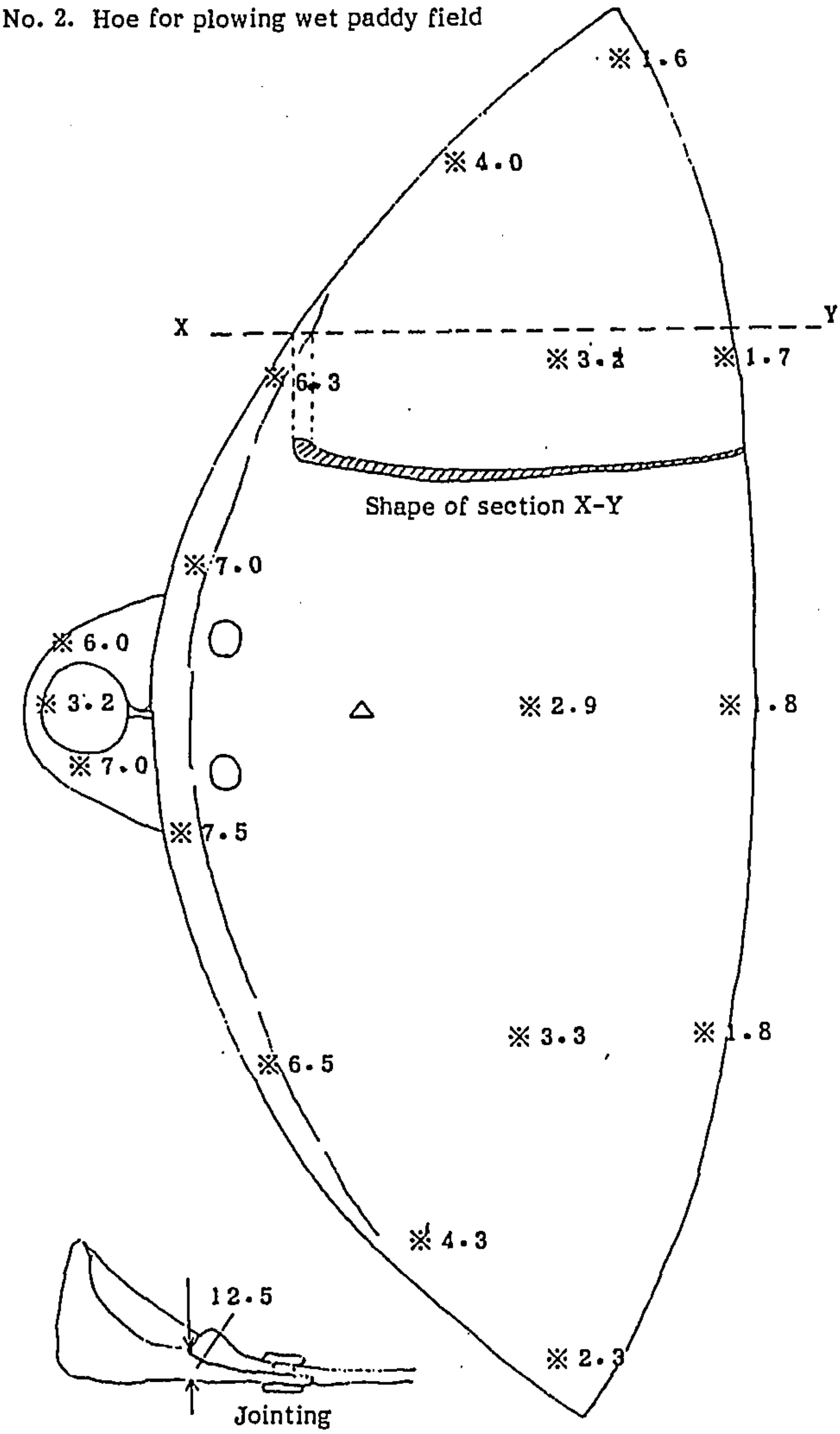
upper 6.0 lower 9.3 - 9.5



- o Fixing angle between blade and handle; 80°
- o Weight; 1800g, center of gravity 82mm away from the centre of handle
- o Inner curved surface
- o Paint finish

Fig. 4

No. 2. Hoe for plowing wet paddy field



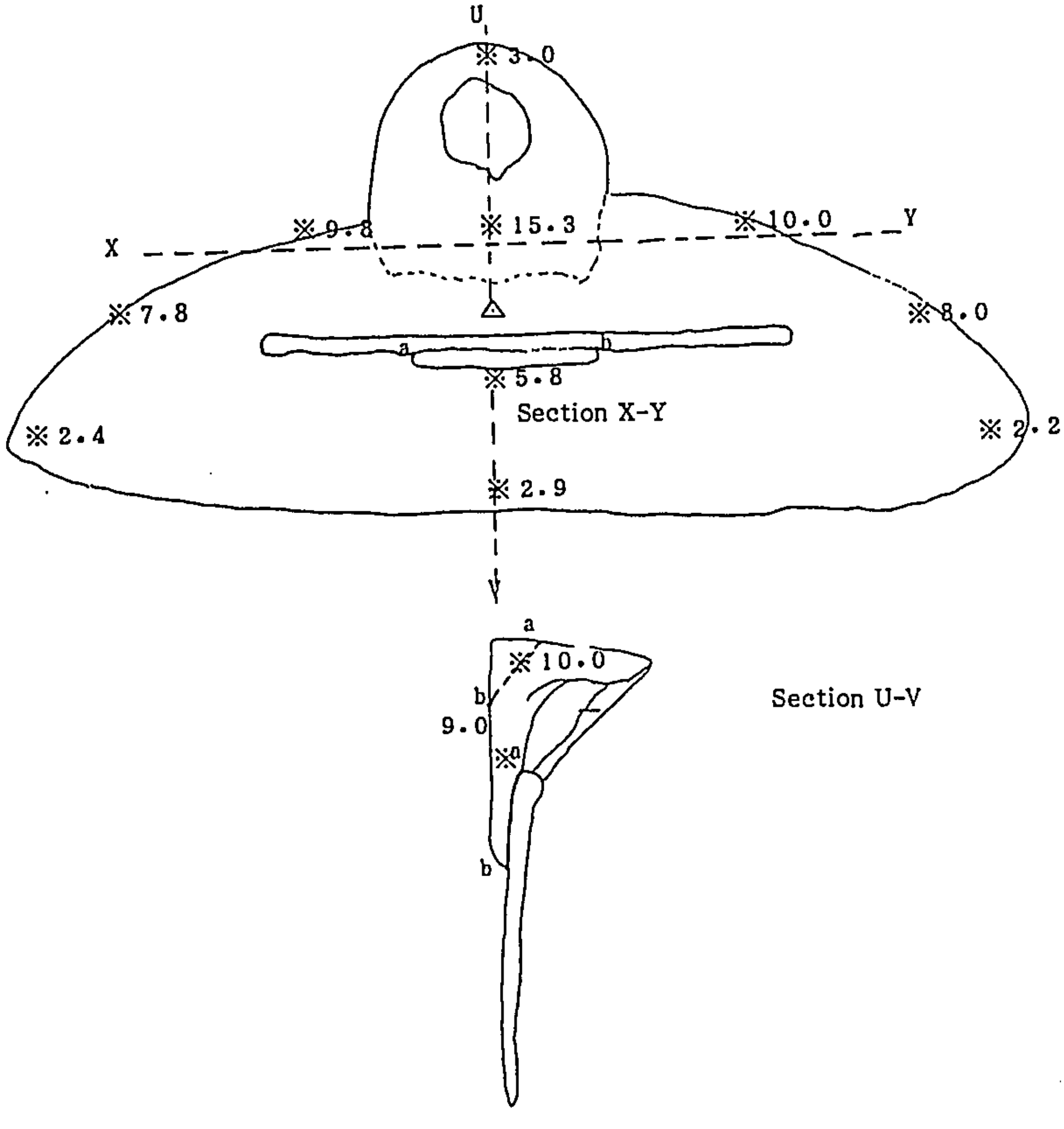
o Jointing angle between blade and handle; 78-81°

o Weight; 1600g, centre of gravity 84mm from the center of handle

o Forged black surface finish

Fig. 5

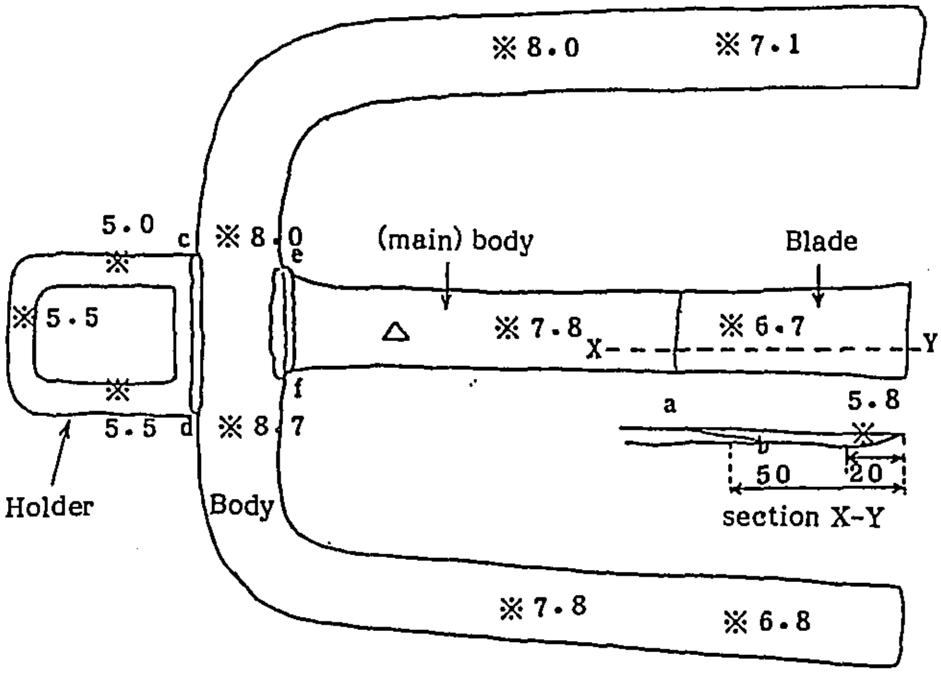
No. 3. Worn hoe for plowing wet paddy field



- o Jointing angle between handle and blade: 82°
- o Weight; 1000g, C of G 54mm from the center of handle
- o Blade and holder are jointed firmly by forging
- o Forged black surface finish

Fig. 6

No. 4. (Bitchu) hoe with 3 nails



- o Jointing angle between handle and blade: 87°
- o Weight; 880g, C of G 78mm from the center of gravity
- o Holder is jointed firmly with the body by welding.

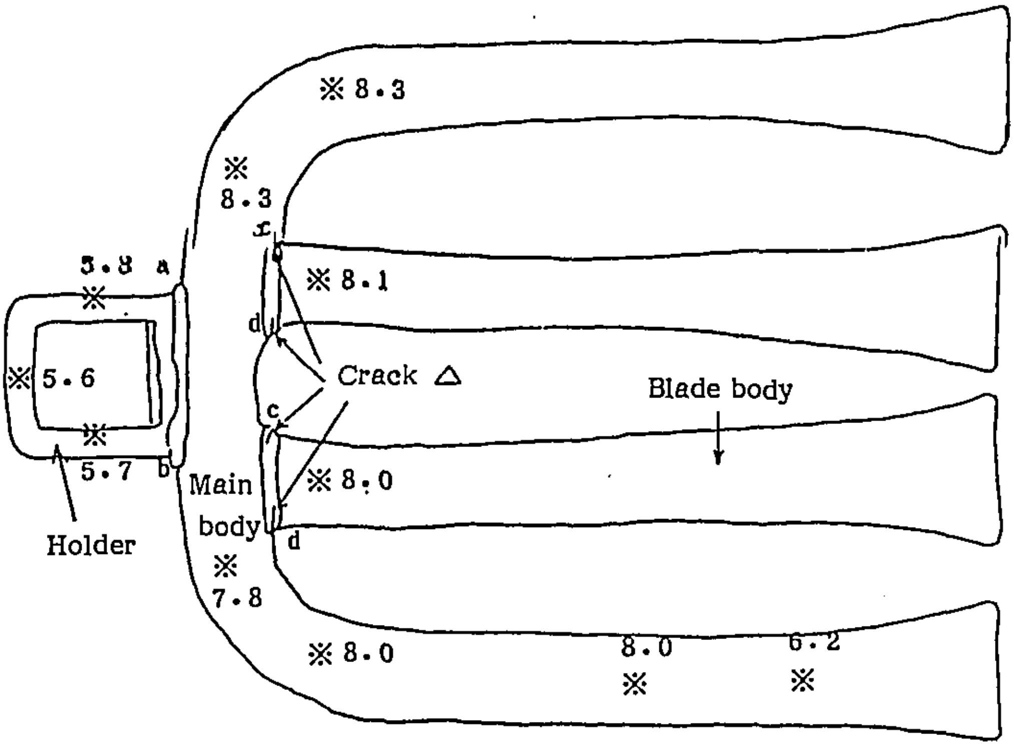
  c-d one laying from head and tail

  e-f two laying from head and tail
- o Body-blade joint by welding. In section X-Y, line a-b shows forging joint line. Forging joint surface appears good.
- o Forged black surface finish.

  c-d line and e-f line show grinder finishing.

Fig. 7

No. 5. 4-nail (Bitchu) hoe with trick



o Jointing angle between handle and blade; 88°

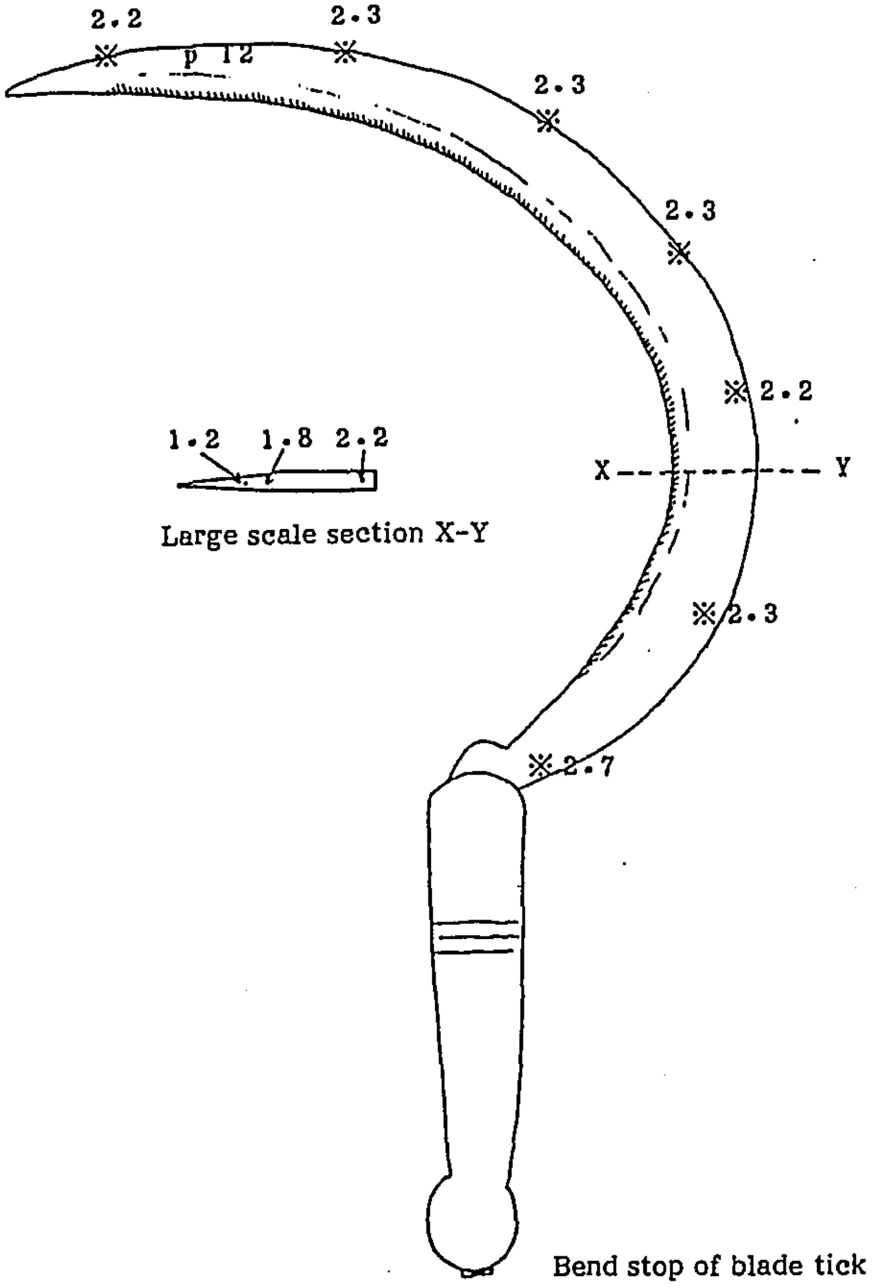
o Weight; 1300g, 96mm from the center of gravity to the center of handle

o Holder and main body, main body and nails are jointed by welding.
  Section a-b and c-d are 2 or 3 laying from both sides.
  There are cracks at the points C and D in the section c-d.
  Strength of section a-b is expected to be rather low because of insufficient melting during welding.

o Rust observed on the surface instead of forged black surface.

Fig. 8

No. 6. Paddy harvesting sickle

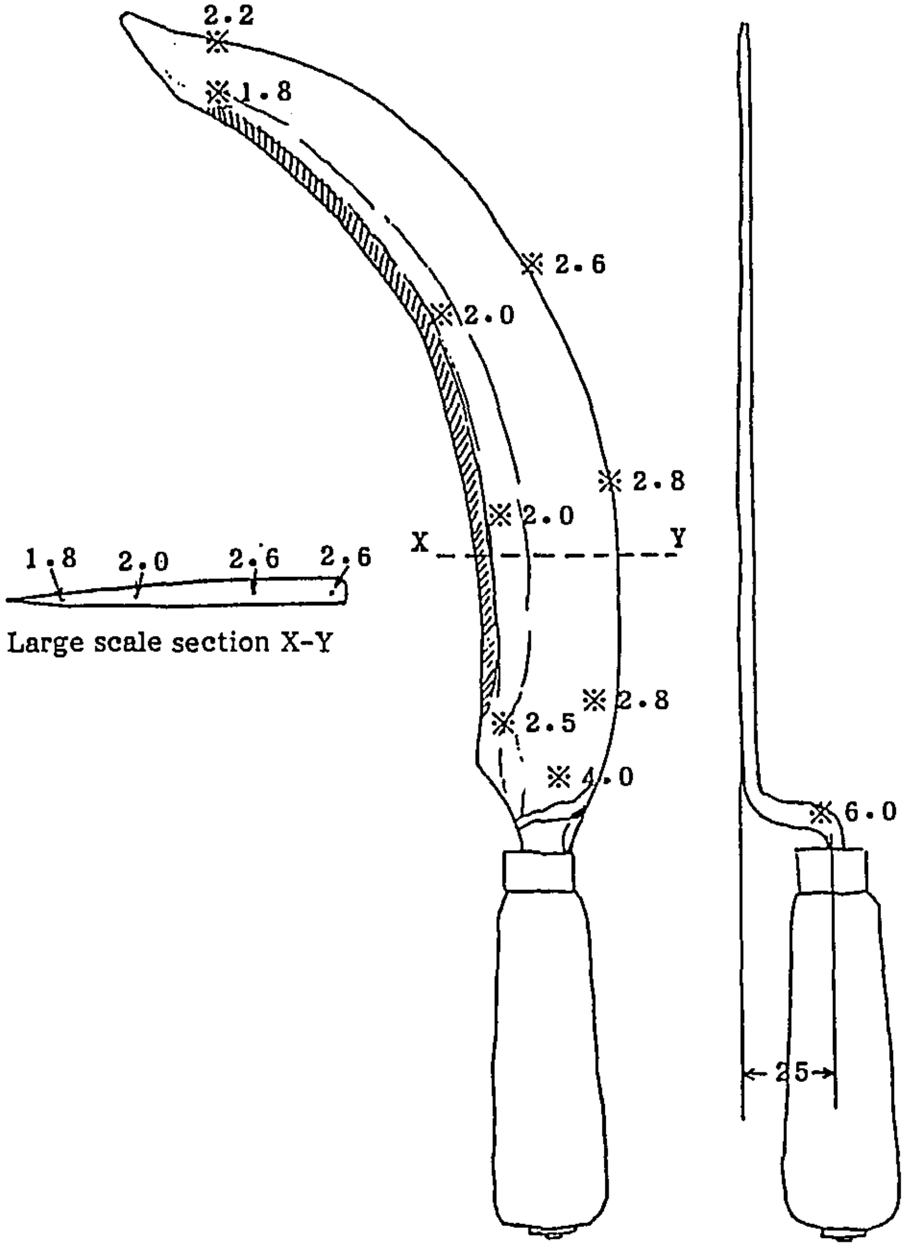


Large scale section X-Y

- o Product weight including the handle: 150g
- o A swan variation of size and curvature, but similar product throughout the country.
- o Hacksaw blade edge. Pitch of saw teeth, 13 per 10 mm, rather fine.
- o Saw teeth are formed by cold chisel, without sharpening. Saw teeth on the head surface are shallow and short, while on the tail surface they are deep and long.
- o Most likely, a product of forging and heat treatment.

Fig. 9

No. 7. Mowing sickle



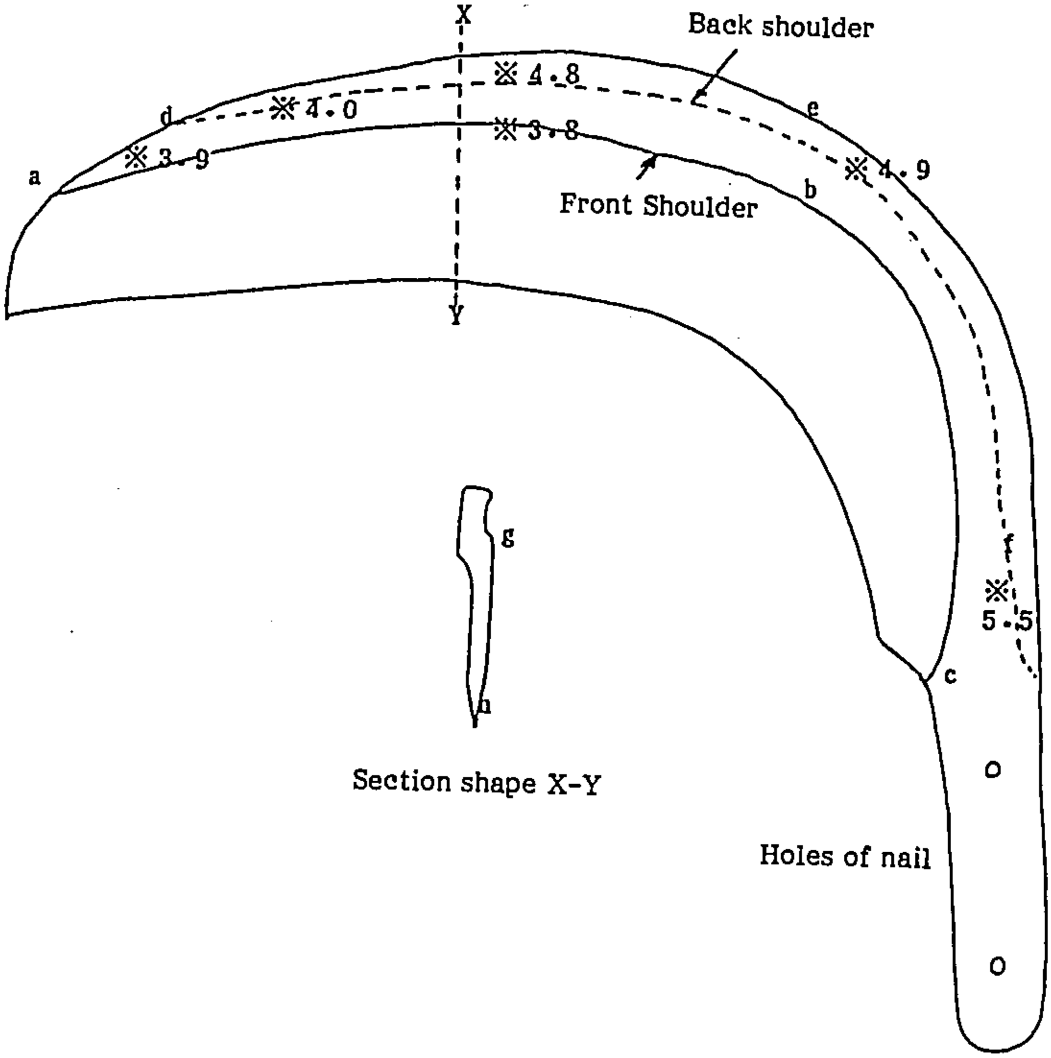
Large scale section X-Y

Bend end of steel handle

- o Product weight including the handle; 250g
- o Blade edge is formed into 7-3 double saw teeth. Pitch of saw teeth is fine, 5 per 100mm.
- o Saw teeth, without blade are deep on head surface nad shallow in the tail surface, so rather small saw teeth are formed during grinding.
- o Surface proves production through forging and heat treatments.

Fig. 10

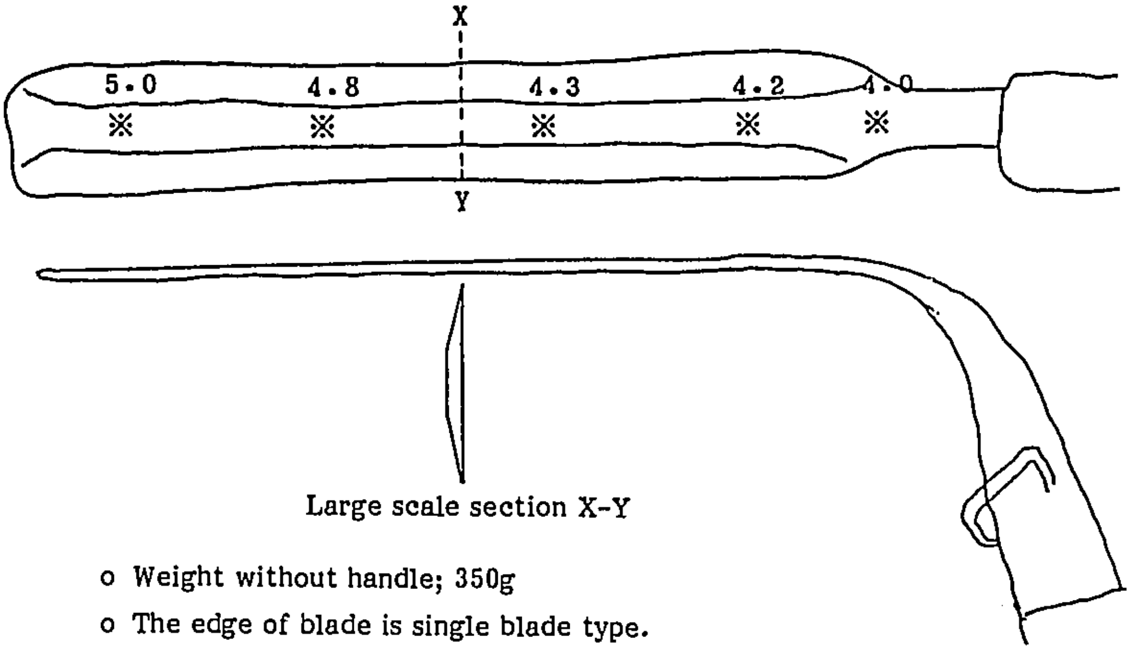
No. 8. Weeding sickle



- Weight without handle; 650g
- The edge of blade is single surface finishing, and blade (at the point 2-3mm from the tip of blade) is thick. 1.3-1.5mm thick is suitable.
- Front shoulder a-b-c and back shoulder d-e-f both are favorable.
- Finishing of curved surface g-h and curvature satisfactory.
- This was formed by forging, and then heat treated. Blade part probably finished by a file.

Fig. 11

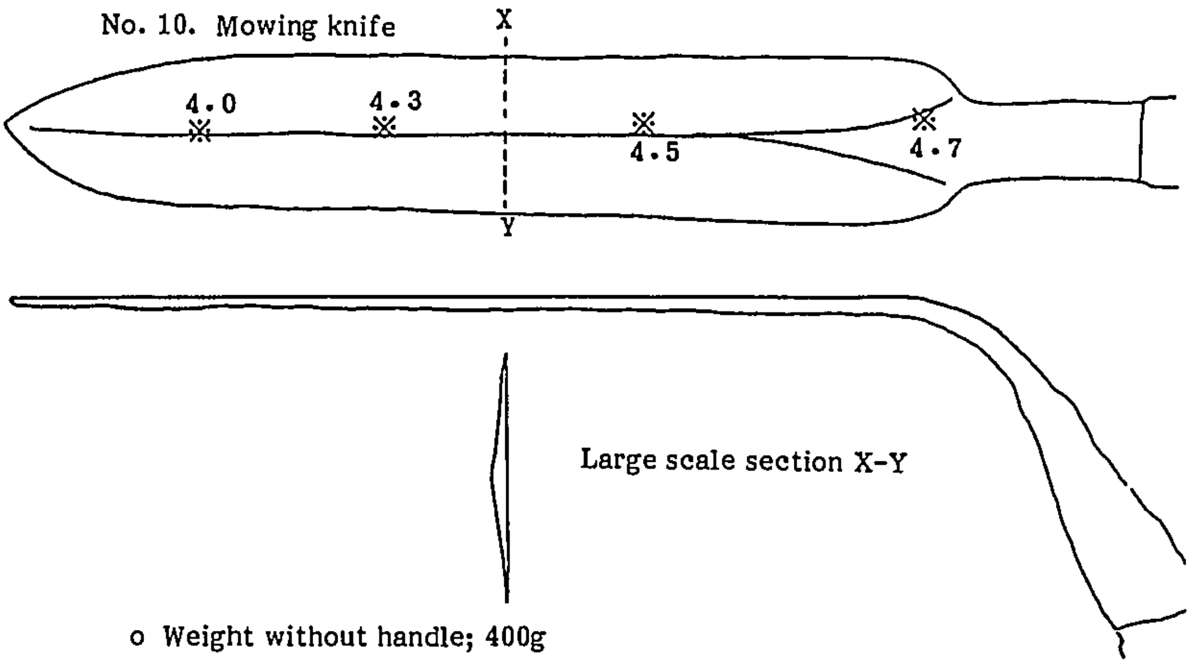
No. 9. Mowing knife



- o Weight without handle; 350g
- o The edge of blade is single blade type.
- o Jointing angle between handle and blade is 75 degrees. Body steel is flattened, then bent into the shape of ring. Handle length of 750mm.

Fig. 12

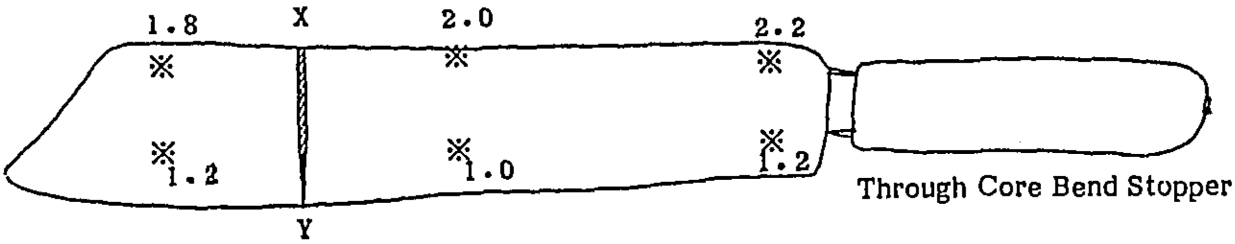
No. 10. Mowing knife



- o Weight without handle; 400g
- o The edge of blade is single blade type.
- o Jointing angle between handle and blade is 55 degrees. Body steel is flattened then bent into the shape of ring. Handle length of 1000mm.

Fig. 13

No. 10. Cooking knife

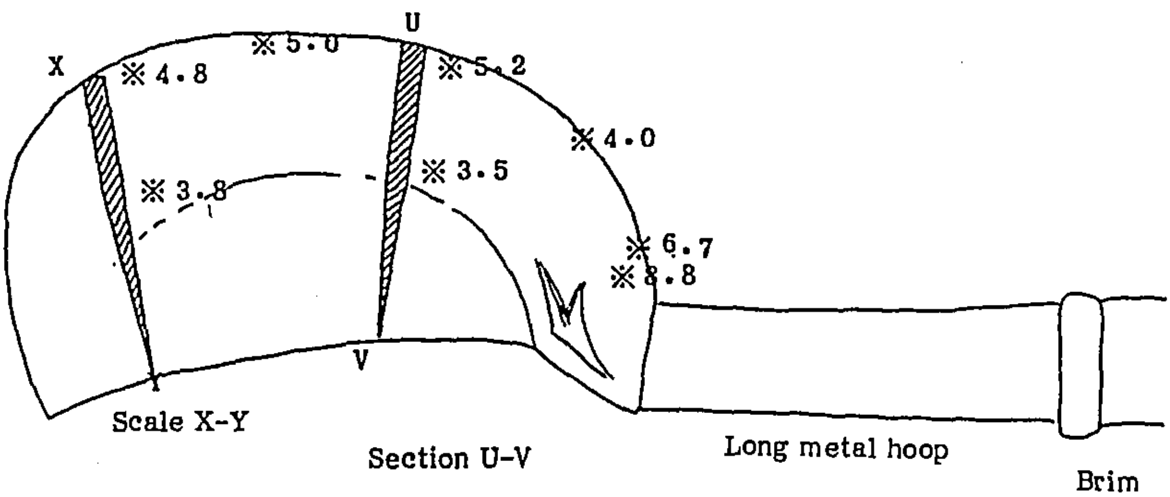


Large scale section X-Y

- o Weight with handle; 170g
- o The edge of blade is single blade type.
- o The finished surface not smooth and the thickness uneven, because of forging.

Fig. 14

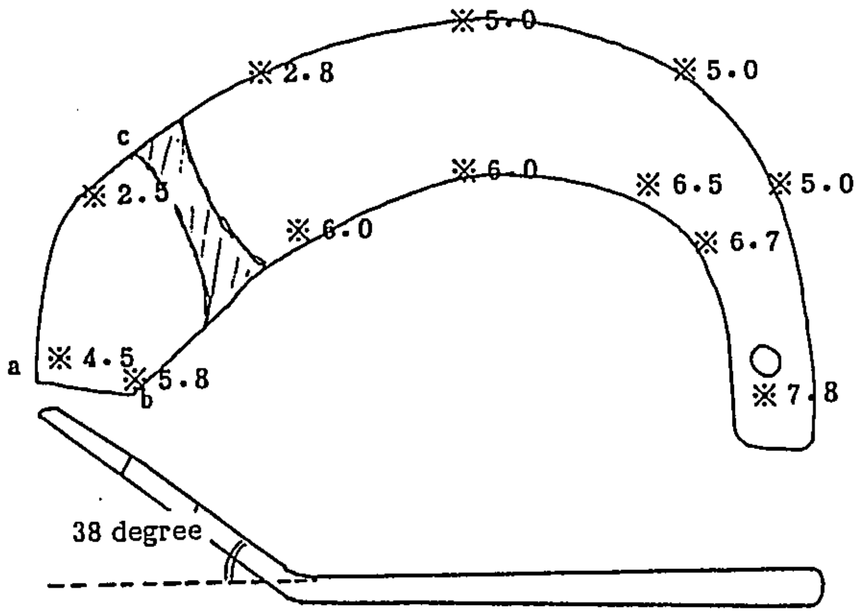
No. 12. Hatchet



- o Weith without handle; 900g
- o The edge of blade is double blade type.

Fig. 15

No. 13. Blade of rotary plow



- o Product weight; 410g
- o Forged black surface
- o Line a-b and a-c are sheared surface without finishing, so the edge of blade forms an obtuse angle.

Fig. 16

No. 14. Raw material

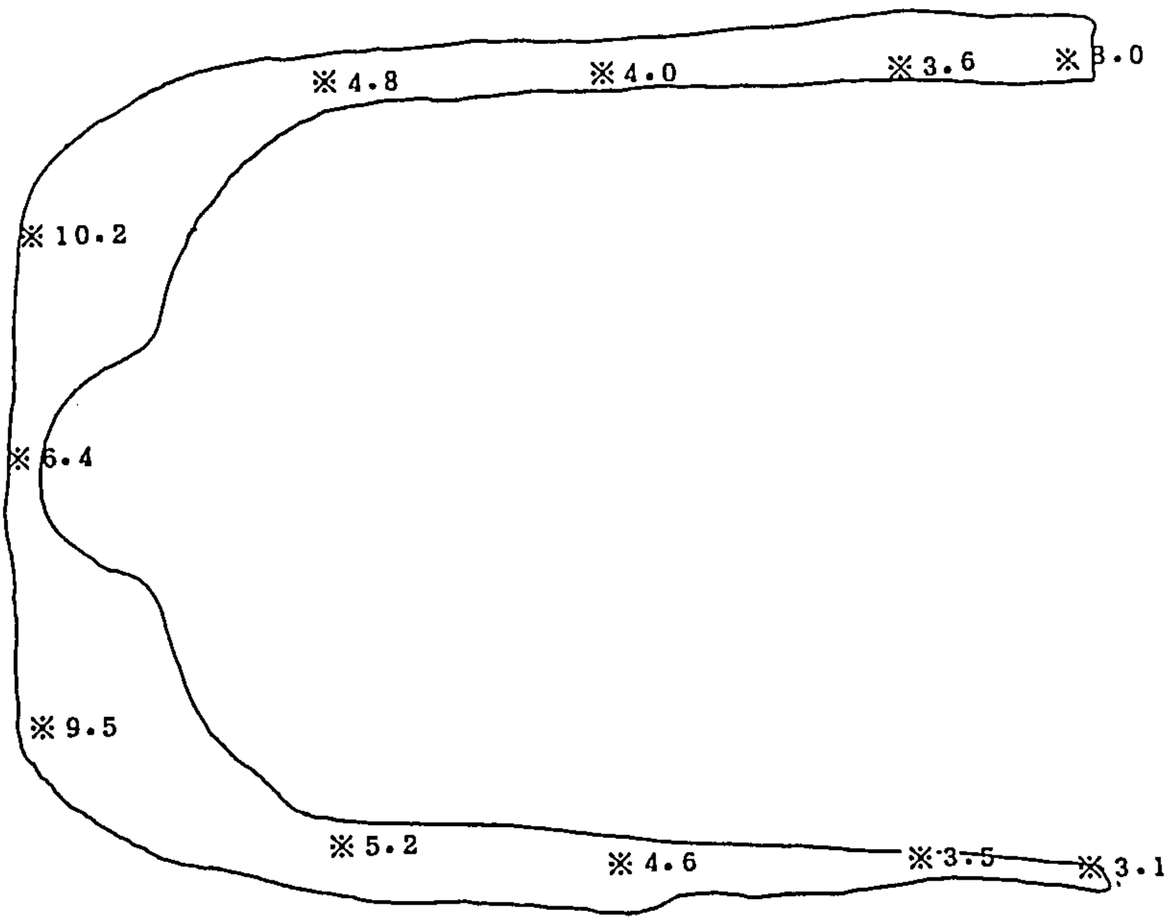
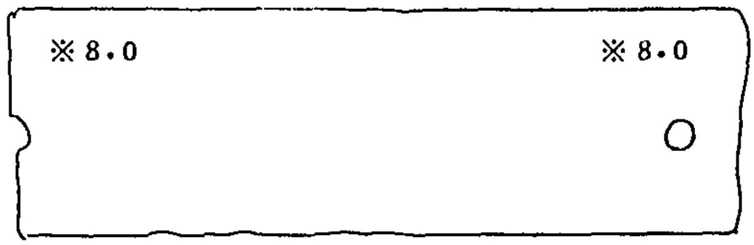


Fig. 17

No. 15. Raw material



(3) Research of matallic test

(1) Chemical composition (2) physical appearance and (3) hardness distribution are summarized below.

Fig. 18

No. 1. Hoe

(1) Chemical Composition (%)

C : 0.47, Si : 0.25, Mn : 0.61, P : 0.017, S : 0.01,

Cr : trace Mo : — V : — W : —

(2) Physical Appearance

Good metal structure probably obtained through quencing, tempering: middle carbon iron equivalent to JIS S45C.

(3) *Hardness Distribution*

The material shows uniform hardness within the area 90mm from the tip of blade.

The hardness is 47-49 in HRC scale.

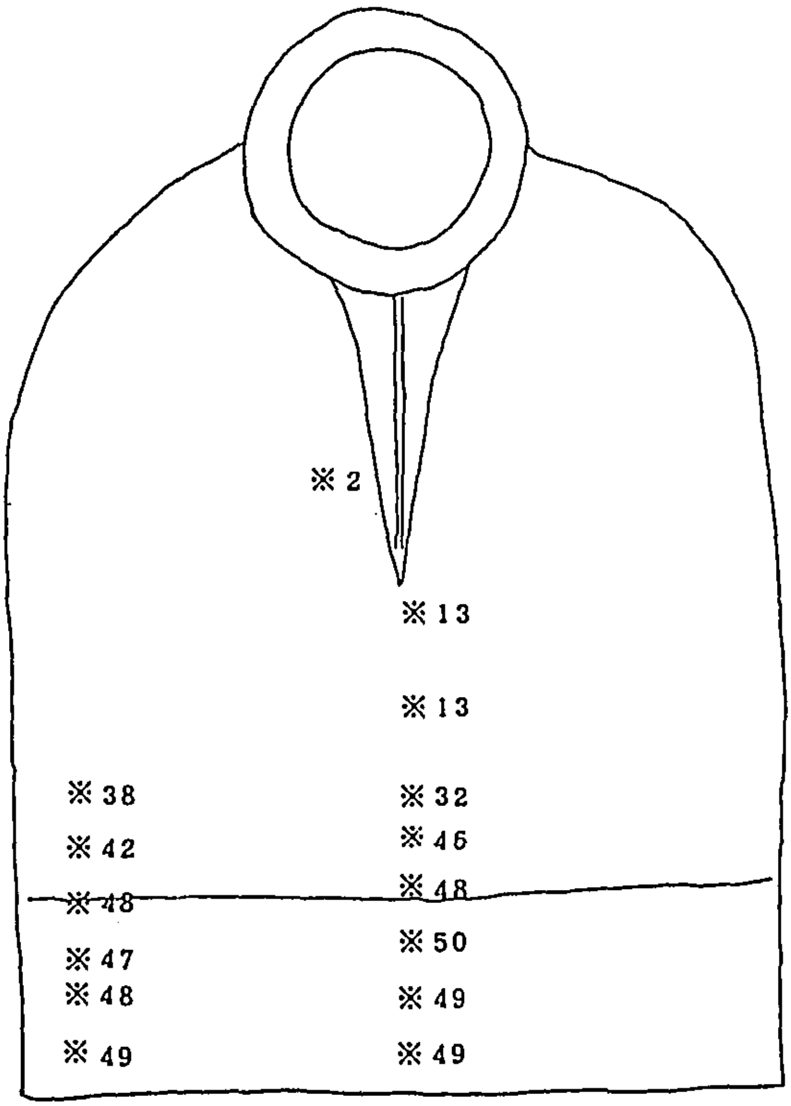


Fig. 19

No. 2. Hoe for wet paddy field plowing

(1) Chemical Composition (%)

C : 0.13, Si : —, Mn : 0.49, P : 0.020, S : 0.018,
Cr : —, Mo : —, V : —, W : —,

(2) Metallurgical Structure

This shows a standard feritecrystal structure of hot forged low carbon extreme mild steel, which is equivalent to JIS SS steel material.

(3) Hardness Distribution

HRB 72-80. Fairly soft.

Fig. 20

No. 3.

(1) Chemical Composition (%)

C : 0.14, Si : —, Mn : 0.49, P : 0.053, S : 0.033,
Cr : —, Mo : —, V : —, W : —,

(2) Metallurgical Structure, (3) Hardness Distribution,

This seems to be low quality rimmed steel, the same as No. 2.

Fig. 21

No. 4. 3 nails (bitchu) hoe

(1) Chemical Composition (%)

C : 0.62, Si : 0.20, Mn : 0.74, P : 0.018, S : 0.013,
Cr : —, Mo : —, V : —, W : —,

(2) Metallurgical Structure

Relatively fine pearlite sintered structure consisting of hoe body of soft iron forge welded to JIS 50kg class rail steel. No quenched or tempered structures observed.

(3) Hardness Distribution

Main material, soft iron HRB 80-72
Forge welded rail steel HRC 11-26

Fig. 22

No. 5. 4 nails (Bitchu) hoe with stick

(1) Chemical Composition (%)

C : 0.61, Si : 1.70, Mn : 0.71, P : 0.018, S : 0.015,
Cr : —, Mo : —, V : —, W : —,

(2) Metallurgical Structure

The main body of JIS SUP-6 spring steel was formed by forging and welding. No martensite structure characteristic of quenching and tempering was observed.

(3) Hardness Distribution

HRC 17-25

Fig. 23

No. 6. Paddy harvesting sickle

(1) Chemical Composition (%)

C : 0.47, Si : 0.11, Mn : 1.01, P : 0.044, S : 0.035,
Cr : —, Mo : —, V : —, W : —,

(2) Metallurgical Structure

This is made of steel quivalent to JIS Rail Steel which was quenched after formed by forging. Relatively good martesite structure. Tempered structure not fully developed.

(3) Hardness Distribution

Uniform hardness distribution, even at the top of blade.

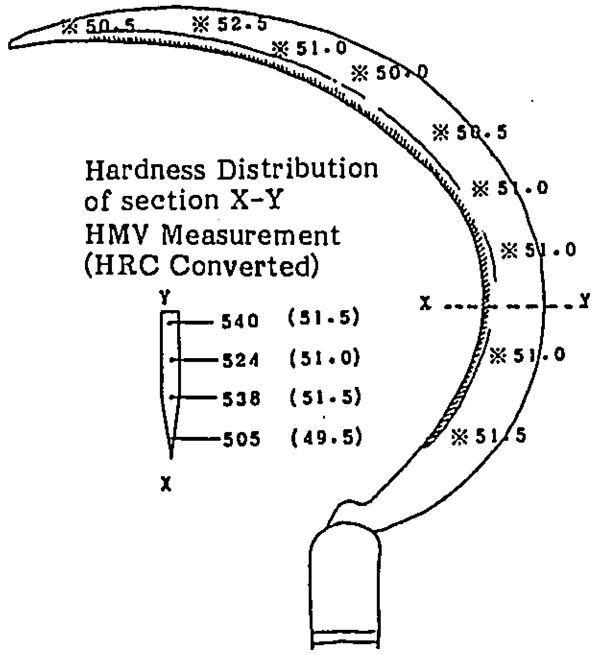


Fig. 24

No. 7. Mowing sickle

(1) Chemical Composition (%)

C : 0.48, Si : 0.12, Mn : 0.71, P : 0.019, S : 0.026,
Cr : —, Mo : —, V : —, W : —,

(2) Metallurgical Structure

This is made of steel equivalent to JIS Rail Steel quenched after formed by forging. A ferrite structure resulting from heating up to high temperatures and decarburization at high temperatures was observed. Quenched structure not uniform. It is necessary to keep it at a constant quenching temperature.

(3) Hardness Distribution.

Hardness not uniform, especially on the surface.

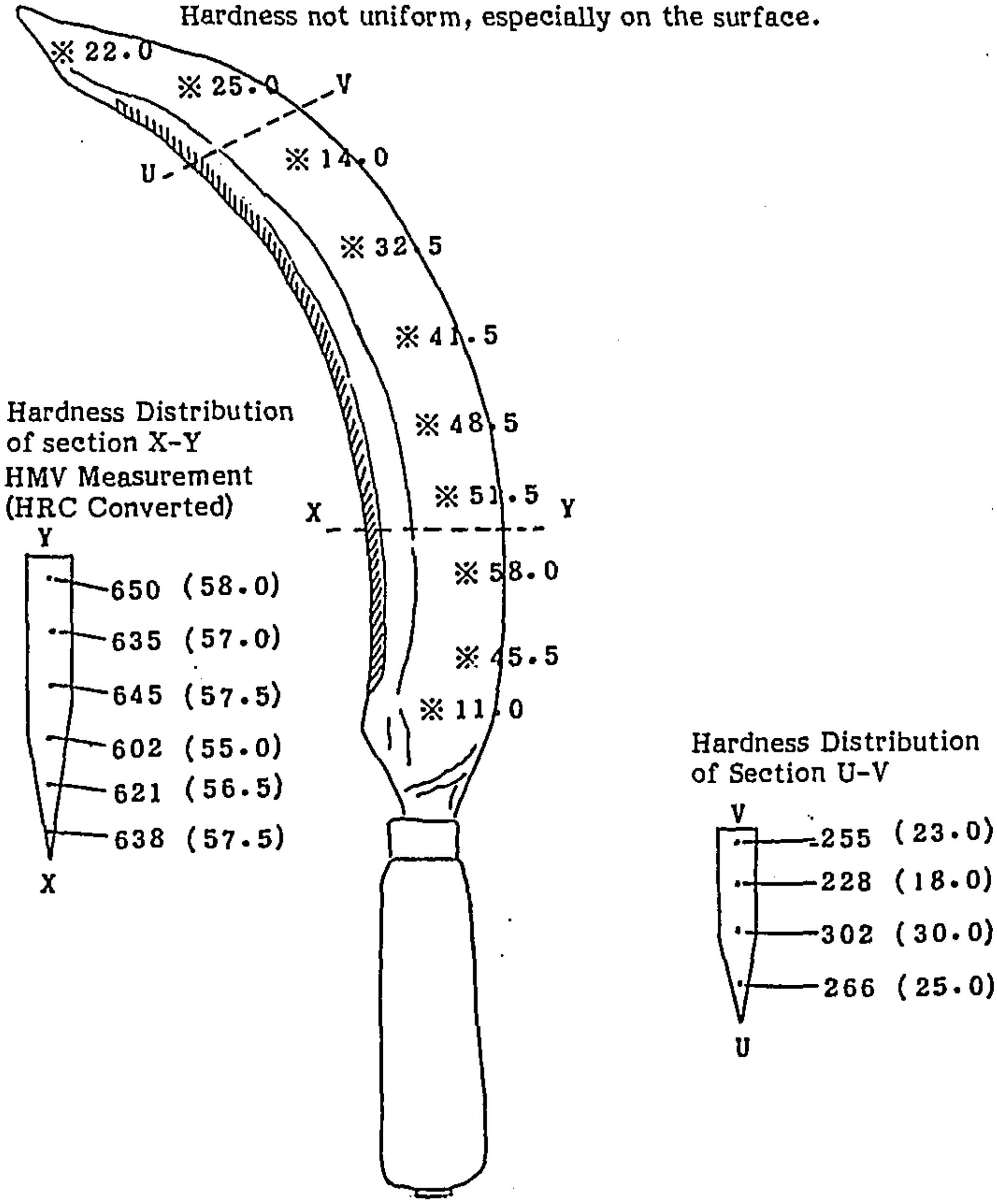


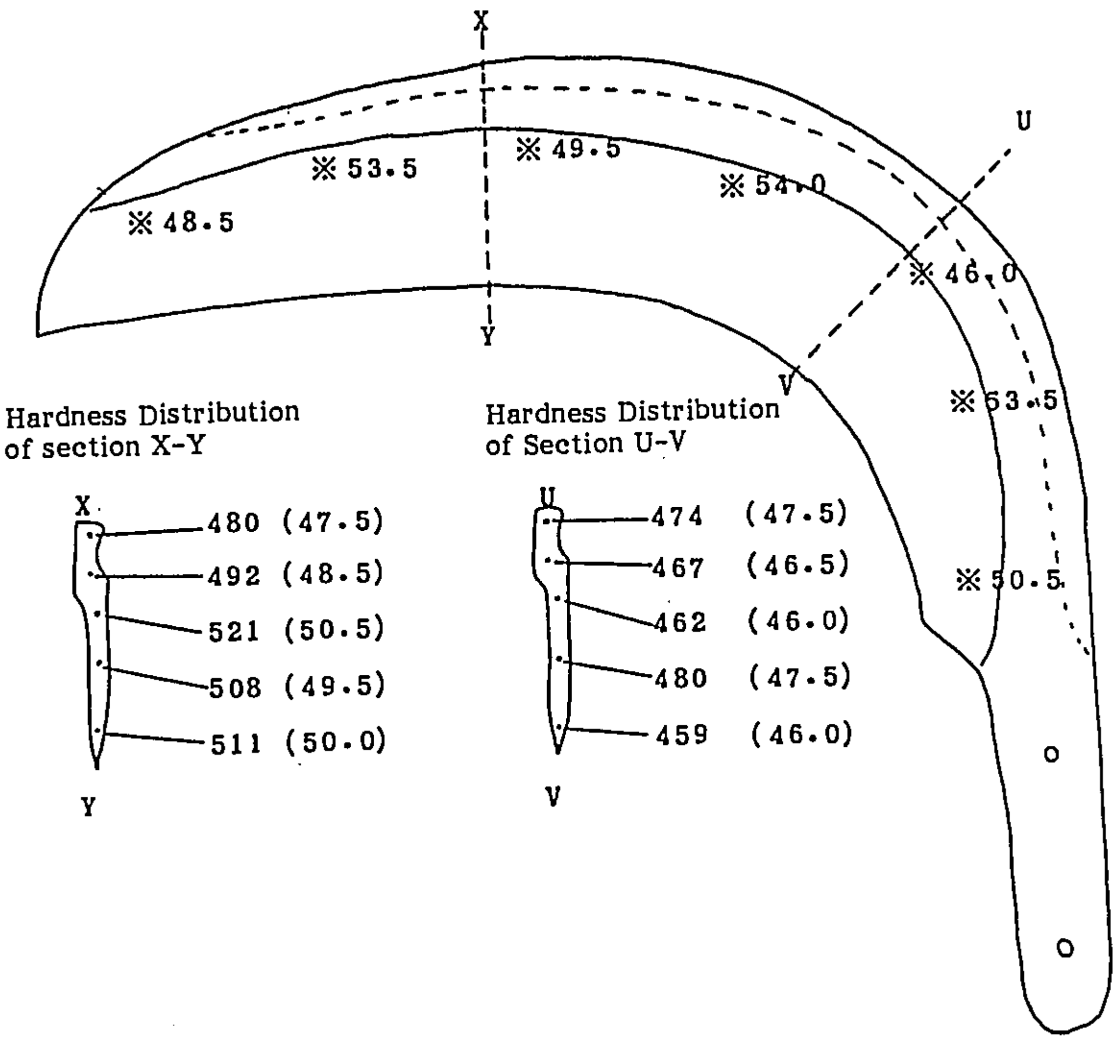
Fig. 25

No. 8. Weeding sickle

(1) Chemical Composition (%)

C : 0.54, Si : 1.71, Mn : 0.85, P : 0.015, S : 0.016,

Cr : —, Mo : —, V : —, W : —,



(2) Metallurgical Structure

This is made of steel equivalent to JIS SUP-6 Spring Steel formed by forging and quenching. A fairly good martensite structure was observed, but more uniform temperature distribution is required. Moreover, tempering is insufficient and must be improved.

(3) Hardness Distribution

There is a slight variation but satisfactory on the whole.

Fig. 26

No. 9. Mowing knife

(1) Chemical Composition (%)

C : 0.01, Si : —, Mn : 0.55, P : 0.053, S : 0.021,
Cr : —, Mo : —, V : —, W : —,

(2) Metallurgical Structure

This is made of extreme soft iron and formed through forging. A ferrite structure observed.

(3) Hardness Distribution

This was 75-84 in HRB scale, which was too soft to keep constant sharpness for long time. Low quality rimmed steel was used.

Fig. 27

No. 10. Mowing knife

(1) Chemical Composition (%)

C : 0.38, Si : 0.07, Mn : 0.59, P : 0.029, S : 0.028,
Cr : —, Mo : —, V : —, W : —,

(2) Metallurgical Structure

This is made of low carbon rail steel formed through forging, which had Ferrite and pearlite structures are observed and this shows that heat treatment is unsatisfactory as far as edge tools are concerned.

(3) Hardness Distribution

75 in HRB scale and 8 in HRC scale. Rather low abrasion resistance is expected.

Fig. 28

No. 11 Cooking knife

(1) Chemical Composition (%)

C : 0.30, Si : 0.10, Mn : 0.96, P : 0.034, S : 0.018,
Cr : —, Mo : —, V : —, W : —,

(2) Metallurgical Structure

This is made of iron equivalent to JIS Rail Steel formed through forging. It exhibits pearlite and air cooled martensite structures.

(3) Hardness Distribution

17-22 in HRC scale. Uniform distribution on the whole.

Fig. 29

No. 12. Hachet

(1) Chemical Composition (%)

C : 0.53, Si : 1.72, Mn : 0.73, P : 0.014, S : 0.007,
Cr : —, Mo : —, V : —, W : —,

(2) Metallurgical Structure

This is made of iron equivalent to JIS SUP-6 Spring Steel forged and quenched almost uniform low carbon Martensile Structure not uniform as quenching temperature was not kept constant.

(3) Hardness Distribution

17-32 in HRC scale. Uneven distribution is constant.

Fig. 30

No. 13. Blade of rotary plow

(1) Chemical Composition (%)

C : 0.55, Si : 1.70, Mn : 0.79, P : 0.024, S : 0.007,
Cr : —, Mo : —, V : —, W : —,

(2) Metallurgical Structure

Made of material equivalent to JIS SUP-6 spring steel. Formed by forging and then quenched. Relatively uniform martensite structure.

(3) Hardness Distribution

HRC 28-30. A uniform hardness distribution but the hardness itself should be raised.

Fig. 31

No. 14. Raw material

(1) Chemical Composition (%)

C : 0.37, Si : 0.08, Mn : 0.71, P : 0.046, S : 0.041,
Cr : —, Mo : —, V : —, W : —,

(2) Metallurgical Structure

A remaining piece of forged steel billet equivalent to JIS S-45C after the product had been blanked out. A standard pealite structure.

(3) Hardness Distribution

5 in HRC scale.

Fig. 32

No. 15. Raw material

(1) Chemical Composition (%)

C : 0.46, Si : 1.71, Mn : 0.83, P : 0.018, S : 0.008,
Cr : —, Mo : —, V : —, W : —,

(2) Metallurgical Structure

It is made of spring steel of car equivalent to JIS SUP-6, and shows a fairly quenched and tempered structure.

(3) Hardness Distribution

34-35 in HRC scale.

(4) Comparative test on abrasion resistance of the blade edges

In order to compare abrasion resistance of different blade edges, it is ideal to repeat the experiment applying the same abrasive object to each piece, however, it is difficult to obtain reproducible data by keeping all the conditions constant. Therefore, a comparative test was conducted as mentioned below to grasp the rough tendencies.

(a) A sample blade of the size 1.2 x 10.20mm is prepared by cutting and grinding.
The edge must have an open angle of 3 degrees and ground from both sides.

(b) A pure aluminum disk (50mm thick and 200mm diameter) is used, and its outer perimeter cut, to provide necessary abrasion.

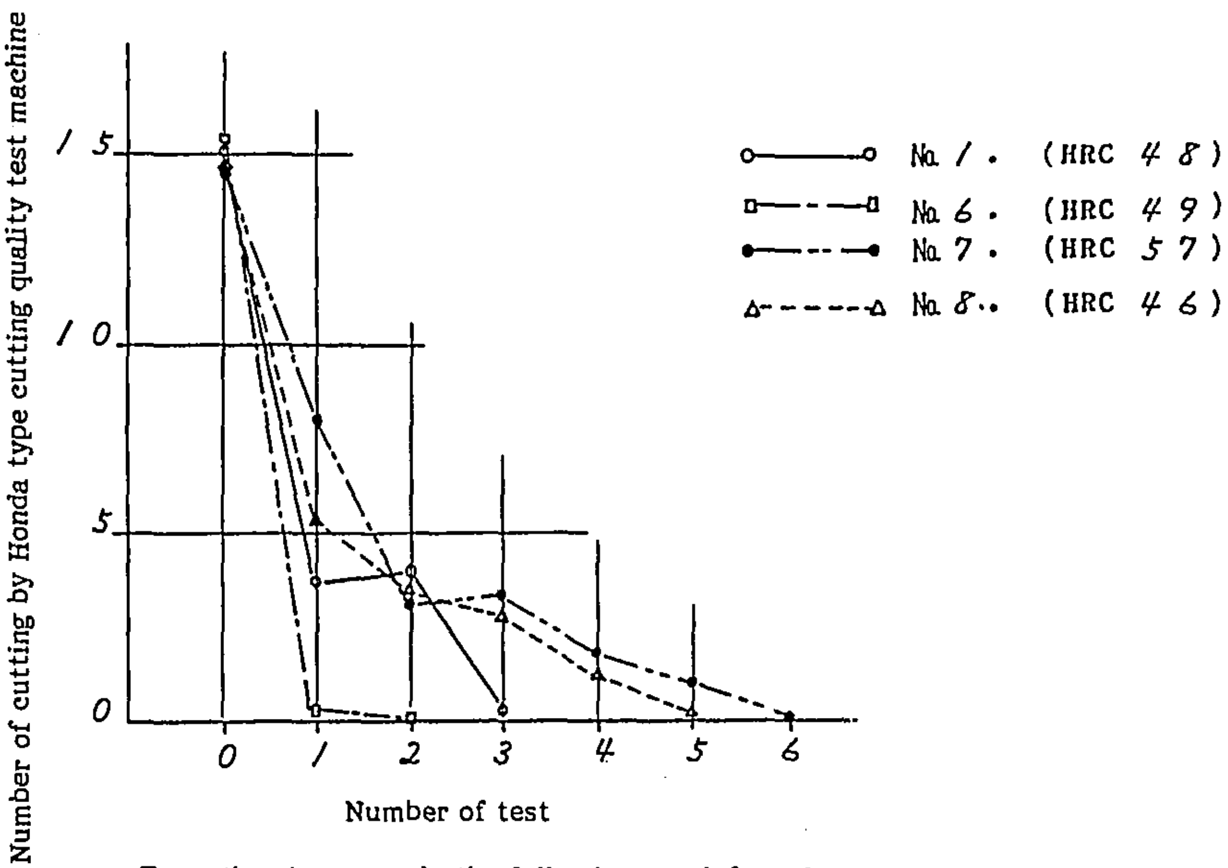
(c) Pressure is 5kg/cm^2, perimeter velocity of rotary disk is 6m/min.

(d) The sample blade is moved at a velocity 10mm/min so that the whole length (10mm) of the cutting edge way be used uniformly.

(e) Test period is 60 min/piece.

(f) After the abrasion test, durability of cutting quality is compared and judged using a Honda type cutting quality test machine. Results of test are shown in Fig. 33. It should be noted that only No.1, No. 6, No. 7 and No. 8 samples could be tested since the rest of the samples was not sufficiently hard for the test.

Fig. 33



From the above graph, the following was inferred.

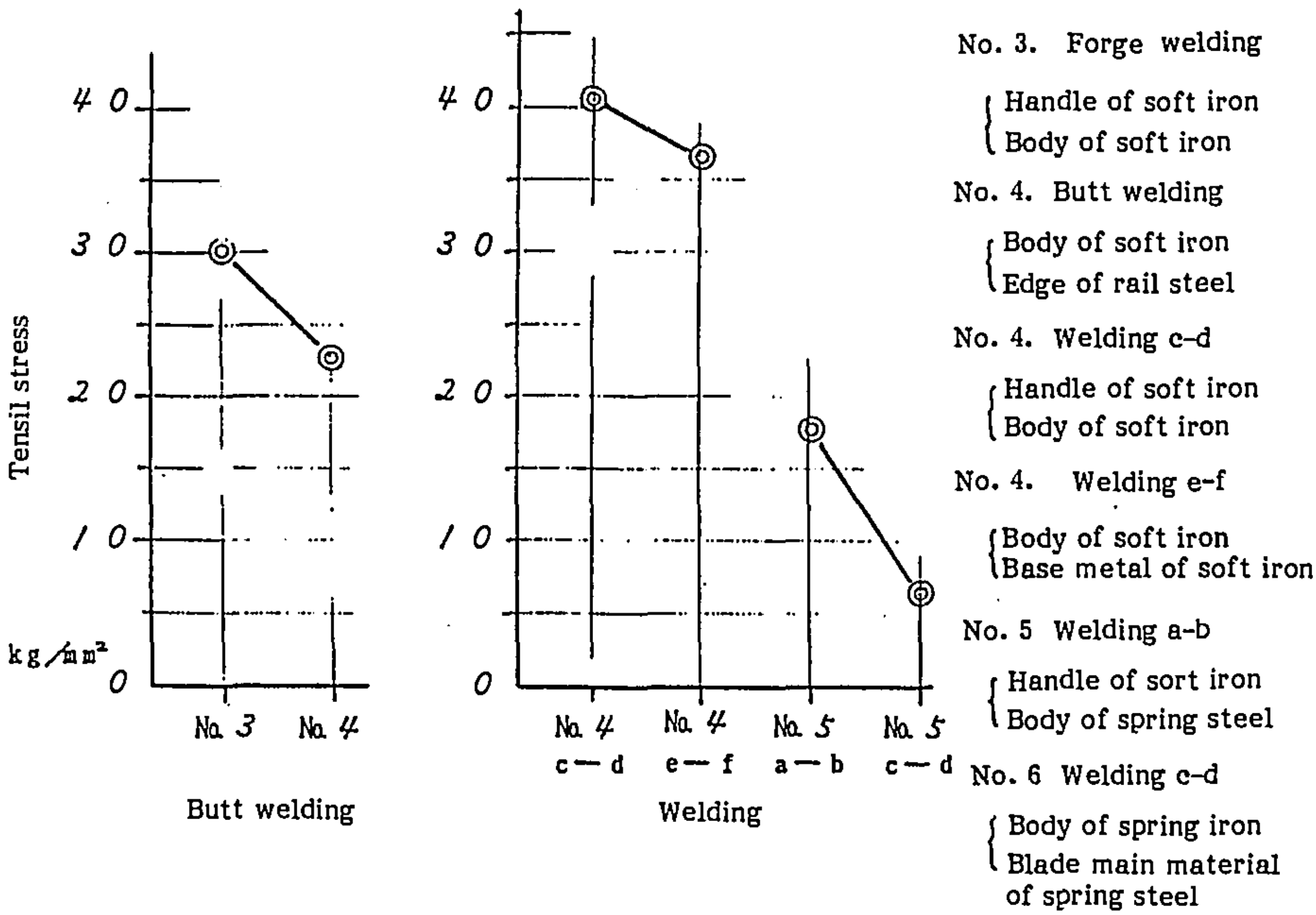
1. Test piece which shows the best cutting quality comes from the hardest part of products No. 7, made of quenched rail steel.

2. Out of No. 1, No. 6 and No. 8 samples showing more or less same hardness, spring steel with the highest carbon content (No. 8) shows the best cutting quality.

(5) Test on the strength of joints

One test piece was prepared from each of the forged or welded joints. For forged joints, test pieces were shaped such that they could be pulled in a direction perpendicular to the plain of joint surface, and for welded joints they were shaped such that two welded parts can be pulled in opposite directions. The resulting test pieces were different in size and so a comparison was made by making necessary adjustments using tensile cross section areas. Results are summarized in fig. 34.

Fig. 34



Using the above results, the following conclusions were drawn;

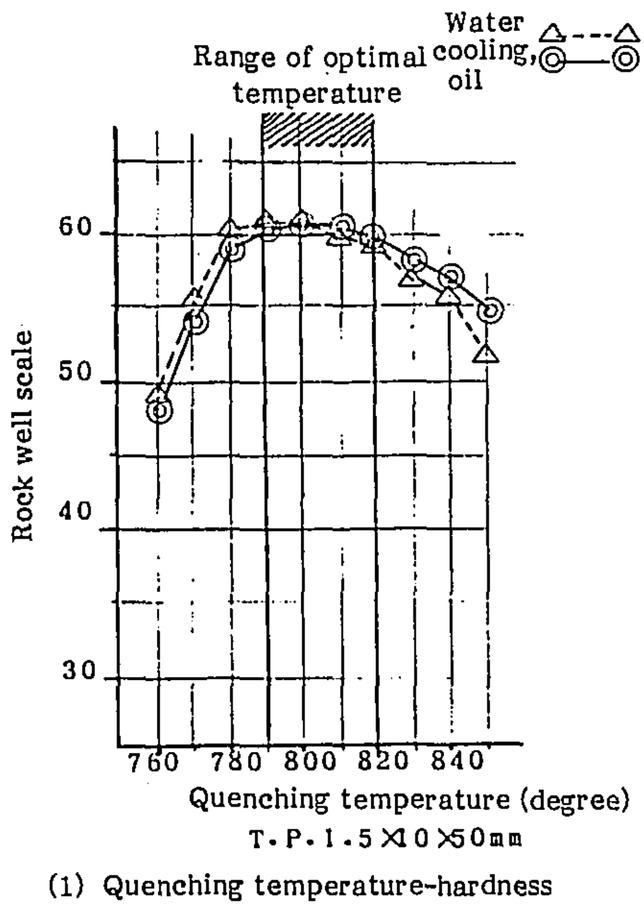
1. The strength of butt forge welded joints in No. 3 and No. 4 samples seems to be sufficient. Usually the strength around 35kg is considered sufficient. No. 4 gives a rather low figure and this is probably because of its forging pressure ratio being low. So tipped solid cutter needs high skilled technic.
2. The strength of No. 4 welding is as expected. Around 45kg is considered good. The small figures given for No. 5 may be because of occurrence of cracks. The improvement is required.

5. **Foundamental test on the heat treatment and the jointing with soft iron by butt welding for the research on the optimal conditions for the edge tools made of iron available in Sri-Lanka.**

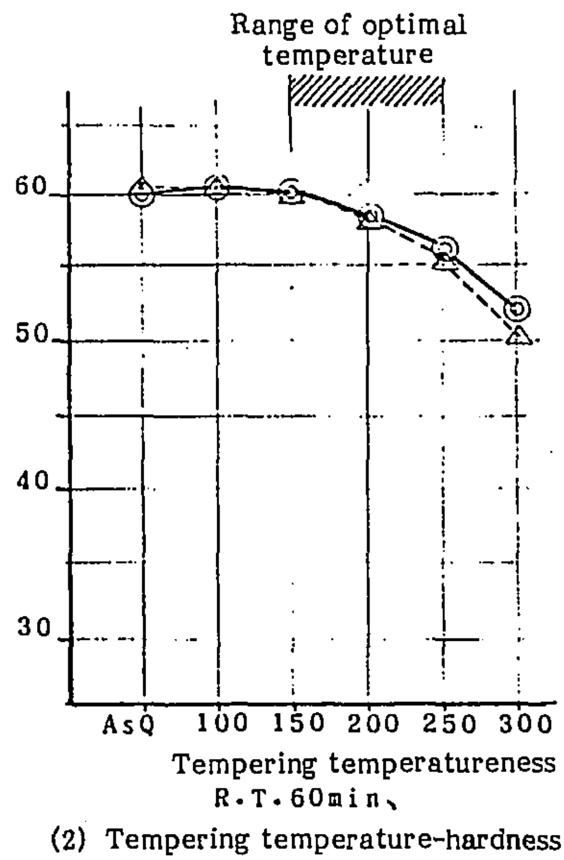
Among steels available in Sri-Lanka, it was recognaized that SUP-6, cantamining the most quantity of carbon is favorable by analysis of ingradients. Moreover, it was observed that conditions of heat treatment was inconstant, crystaline was getting larger by overheat and there were a lot of descarburization by the results of (2) observation by naked eyes and (3) measuring of distribution of hardness.

Therefore, this test was conducted on (1) Quenching temperature-strength curve by water cooling and oil cooling, (2) Tempering temperature-hardness curve by water cooling and oil cooling whcih were important mechanical characters. Moreover, (3) Test for prevention of growing of crystalline during heating, (4) Test on surface descarburization were conducted. The results are shown in fig. 35-37.

Considering ease of working in Sri-Lanka, test on (3) Relation between butt welding and temperature, butt welding ratio among important elements for forging with soft iron.

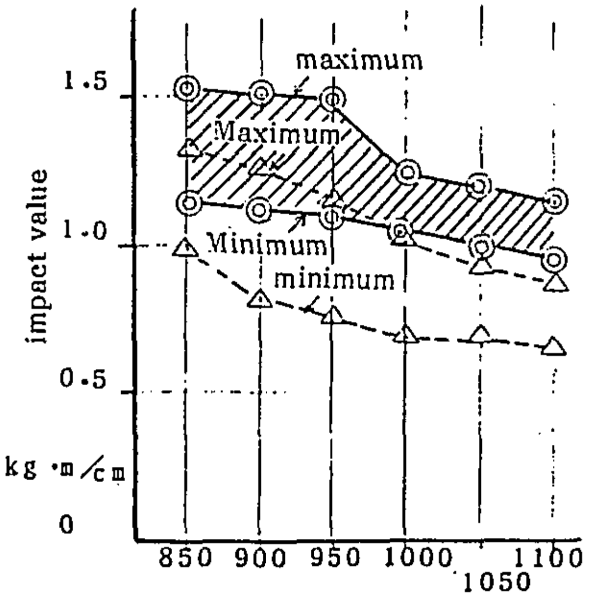


(1) Quenching temperature-hardness



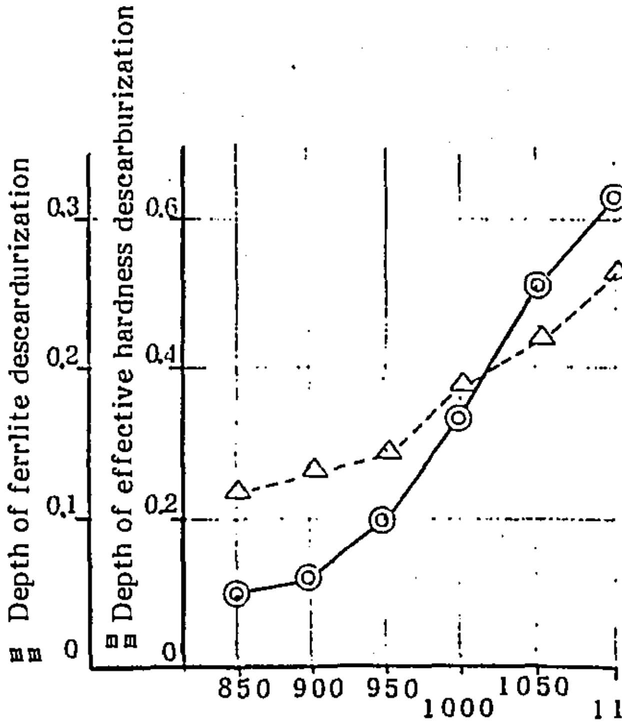
(2) Tempering temperature-hardness

Fig. 36



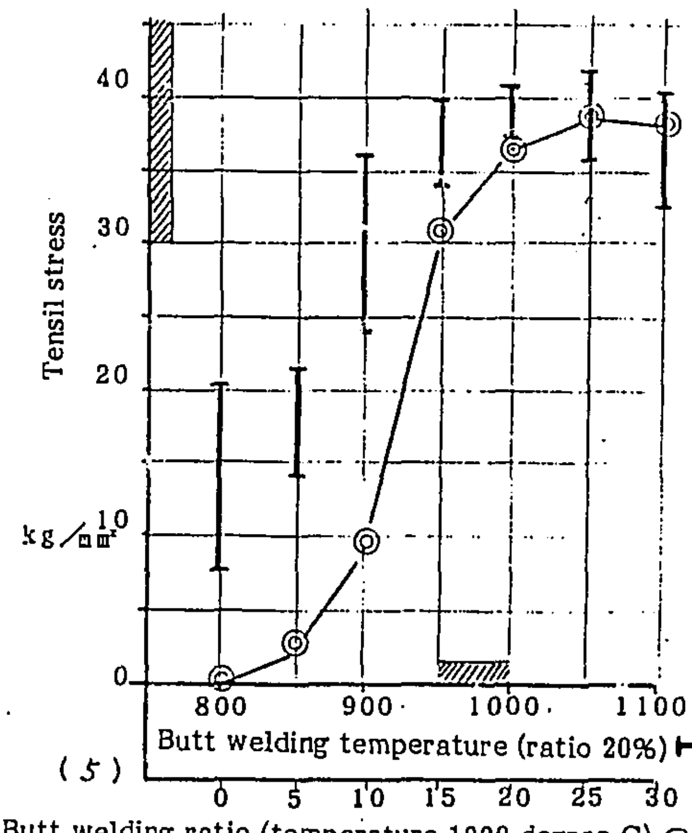
maximum forging temperature (duration 30 min)

(3) Normalized
No treatment



Forging temperature (duration 60 min)

(4) Ferrite depth
Effective hardness depth



Butt welding temperature (ratio 20%)

(5)

Butt welding ratio (temperature 1000 degree C)

(1) Quenching temperature-hardness curve

(1) Optimal temperature of quenching is 790-820 degree.

(2) For both water cooling and oil cooling, features are almost same. But cooling water, 10 degree cooler than cooling oil is preferable.

(2) Tempering temperature-hardness curve

(1) In case of utilization as edge tool, range of temperature 150-250 is preferable for tempering.

(2) Around HRC 55 is goal.

(3)

(1) Normalizing is preferably made after forging. Especially it is necessary for foging 1000-1100 degree.

(4)

(1) In case of hot forging causing ferrite, descarburization develops rapidly at temperature 1000 degree.

(5)

(1) If butt welding raito is 20% or more, sufficient strength is expected from temperature 900 degree.

(2) If butt welding temperature is 1000 degree, sufficient strength is expected at butt welding ratio 15%.

6. Proposal on technical improvement

(1) Problem of shape structure and utilization

a. It is vital for univeral and convinient tools that agricultural and industrial edge tools have vernacular and shape and structure. Research was made on the base of this point, no irrationality was observed.

b. For hoe, optimal weight must be considered. Heavier agricultural tool increases work load, while phisical fatigue gets larger. As weight balance gets out of the center of gravity, work load varies. It is necessary to eliminate excessive thickness as mucha as possible.

c. Hardness of edge must be optiomal hardness. So abrasion gets fewer and durability will be longer, and cutting resistance gets lower. As result, working efficiency will be improved. Optimal hardness mean degree of hardness whcih the material display full its performance. In case iron is hardened more by quenching, it is important not to make it brittle.

d. In order to improve such defect, tool must be manufactured so that forging part is united with part of high hardness by composition. Therefore, skilled butt welding and welding technic are necessary. Japannese (biccyu) hoe, however has advantages such as light, high plowing efficiency etc, it may be spreaded if this jointing technic is introuduced.

e. Round hole and square hole both are necessary. Handle can be fixed to round hole easily. For swuare, handle is fixed to body firmly.

(2) Problem of materials used

Materials used at present can be divided into 4 types as JIS equivalents.

- o SS41 (Extreme soft ordinary rolling steel)
- o Rail Steel (Middle carbon rail steel, 50kg grade light rail)
- o S45C (0.45% carbon content mechanical and structural steel)
- o SUP-6 (Middle carbon alloy spring steel type 6)

Standard of these steels are shown in Fig. 38. For edge tools, firstly quantity of carbon, influencing on hardness of blade must be considered. Secondly, quantity of nonmetal objects must be considered. As the edge of blade is worn, quantity of P and S must be a few as much as possible. Moreover, for spring steel, Si and Mn must be considered alloy element.

Fig. 3 shows ingradients of steel of agricultural tools most popularly used in Japan at present.

Fig. 39 shows comparison of expected performance of test samples.

Fig. 38 Table of standard of low materials

Row material	C		Si		Mn		P	S
S S 41	-		-		1.60	less	0.040	0.040
Rail	0.40	0.60	0.40	less	0.50	0.90	0.045	0.050
S 45 C	0.42	0.48	0.15	0.35	0.60	0.90	0.030	0.035
SUP-6	0.55	0.65	1.50	1.80	0.70	1.00	0.035	0.035
SK-3(white 2) Equivalent	1.10	1.12	0.10	0.20	0.20	0.30	0.025	0.004

Fig. 39 Shows comparison of expected performance of test samples

Low material	Hard-ness	Hot working	Descarburi-zation resistance	Abrasion resis-tance	Impact resis-tance	Quench-ing	Price
S S 41	F	A	A	F	A	-	A
Rail	C	B	B	D	C	C	B
S 45 C	C	B	B	C	C	C	B
SUP-6	B	C	C	C	D	B	B

f. If rail steel, S 45 C steel and spring steel available at prsent can be dealt with sufficiently, much more quality products will be manufactured. Therefore, improvement and development of manucaturing techinic are required. Moreover, if blacksmith obtains such manufacuring technic, it will be possible to ues high carbon steel with carbon 1.0% or more.

(3) Problem of manufacturing method (mainly welding and forging)

In case where high grade steel more than middle carbon steel is used as edge tools, it must be used by combination. One of the reasons is problem about ease of hot working.

Forging work is very diciculted especially for spring steel as shown in Fig. 39. If this is combined with soft iron, manufacturing become easier. Another reason of conversion is that quenching and tempering treatment can be done completely. On the other hand, in case where this is not by combination, deformation and crack occure if complete heat treatment is done.

The combination methods are as follows.

(1) Welding by hand rod
(2) Butt welding by hands
(3) Supplying by materials combined by roll but welding

Above mentioned 3 are simple methods. So, for (1) and (2), the following proposal was made.

g. For welding rod, soft iron rod usually can be used, for hot forging and heat treatment of sprig steel, high tension welding rod is favorable.

   In welding, different metals (for example spring steel and rail steel) the metals must be melted completely. Because if metals varying in melting point have different expension ratio. In welding same carbon content steels (for example spring steel and rail steel), preheating is must be done for certain shape of tool. Heat is given after welding so that rapid cooling causes occaurance of crack around welded metal. Moreover, spring steel is used for edge of blade, normalization is favorably done before heat forging.

h. Because plastic defomation is very a little, for butt welding by hands, butt welding temperature must be high. Especially burning of charcoal needs skill as atmoshere of inner furnance have to be kept reductive.

   Butt welding temperature 1000 degree and butt welding ration 15% are favorable.

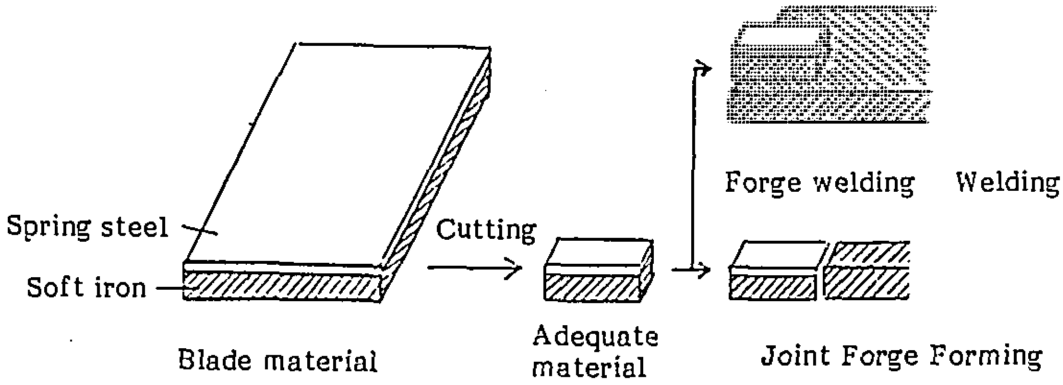
   The surface must be clean to obtain sufficient adhering strength. Butt welding agents (iron powder, boracic acid, boracic sand) are preferable used in case where atmosphere of inner furnance became exidable under certain fuel.

   Butt welding agent helps lower melting point by reacting with exidized scale occuring on the surface and function to take out corresponding to plastic deformation.

i. Butt welding can be applied everywhere, but work efficiency is extremely low. So particial adhering defect occures in whole 2 or 3 laying structure.

   Recently, edge tools, manufactured uniformly by roll are spreading widely. One of using methods is shwon in Fig. 38. Further planning and promotion are required.

Fig. 38



(4) Problem of heat treatment

j. 3 of 8 pieces of test sampls, can be quenched by heat treatment, are not treated by heat completely, which are sold in forging organization.

To give function to edge of blade, heat treatment must be done. Normalizing after forging is favorable. So good organization will be obtained as crystalline is grinded finely. Quenching is the most important work to determine quality of blade, so it is necessary to control exactly and understand the principle of correct quenching. 5 pieces of test sample were treated by heat, but almost all of their heat treatment are incomplete. For quenching around temperature 800 degree, temperature can be judged with error ± 10 if working environment is prepared well.

The following 3 elements, optimal quenching temperature, uniform distrubution of temperature, cooling speed of certain degree are essential. Completely heat-treated iron is softened by tempering acording to the purpose of tool. By such manner, strong and tough edge tools can be obtained. Ajustment of hardness must be done by both quenching and tempering. During butt welding and forging, heating time must be short considering that descarburazion is always occauring. Degree of descarburazation can be checked by sparking test.

k. What must be done to improve the quality of edge tools is to improve finishing technic by grinder. Even if problem of heat treatment was solved, it is impossible to obtain sharp blade only by convernsional method by file. For finishing, difference of the hardness between file and edge must be 10. It is meaningless to harden edge tools more than 55 in present situstion.

Therefore, training of finishing technic and using method of whetstone are vital. Heat treatment hardness rises and quality of blade varies depending on level of blade finishing.

(5) Problem of producting equipment

k. Productivity is very low because of manufacturing by hands at present. However, if electric power is avilable efficency will be improved.

Effective measures are preferably taken.

(1) Spread of fixed whestone and rotary whetstone by manpower (hands or legs)

(2) spread of belt hammer by manpower

(3) Spread of ekusen press by hands