CHANGES IN MICROSTRUCTURE AND HARDNESS DURING PROPERZI PROCESS OF 6151 ALUMINUM ALLOY WIRE ROD FOR FORGING

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ABSTRACT Deformation behaviors during Properzi process[1] consisting of continuous casting and 6 steps of rollings in 6151 aluminum alloy for forging, were investigated by means of microscopy and hardness measurement. Original grain size in as cast bar decreases with increasing total area reduction and reaches to 15 ~ 20μm with homogeneous distribution through out the transverse section of rolled rods after the 6th rolling. Fine grains with the size of 2 ~ 10μm are formed within the original grains after each rolling. Remarkable softening occurs in all over the section after the 2nd rolling, total area reduction;56%, and work hardening proceeds gradually during the 3rd, 4th, 5th and 6th rolling. Above mentioned changes in microstructure and hardness during Properzi process results in good workability of 6151 aluminum alloy wire rod.

Keywords: *6151 Aluminum Alloy, Properzi Process, Continuous Casting and Rolling, Microstructure, Hardness, Fine Grain.*

1. INTRODUCTION

Aluminum alloys for forging are generally fabricated by extruding of cast billet. Recently, there has been the demand for more economical processing to produce workable aluminum alloy rods with diameter up to 30mm than the extrusion process. Properzi process consisting of continuous casting and rolling is suitable for long slender rods such as electric conductive cable. Recently, this process is used to produce aluminum alloys for forging from the economical viewpoint. There is, however, few report on the changes in microstructure and mechanical properties of the wire rod during the process of 6000 series aluminum alloy. We have been trying to produce aluminum alloy rods for forging by Properzi process. In the present work, the deformation behaviors during this process were investigated by means of microstructure observation and hardness measurement.

2. EXPERIMENTAL PROCEDURE

6151 aluminum alloy used is the typical alloy for forging and it's chemical composition is shown in Table1. The flow chart of Properzi process is shown in Fig.1. The transverse section size of cast bar is about 2600mm ^{2}. The rolling machine have 6 rolling stands. The 1st and 2nd stands in this rolling process are the 2-roll type, and other stands are the 3-roll type. The standerd size of the wire rod for forging is 25mm in diameter after passing the 6th rolling stand.

Table 1 Chemical composition of 6151 aluminum alloy (wt%)

element	Si	Fe	Cu	Mg	Cr	Ti	Mn	Al
A6151	1.11	0.12	0.03	0.74	0.16	0.04	0.01	bal.

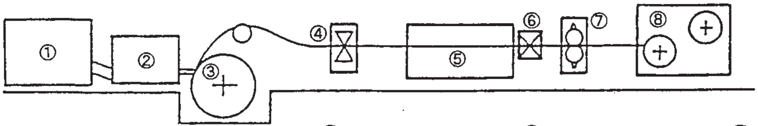

Fig.1 Flow chart of Properzi process. ① Melting furnace ② Holding furnace ③ Casting machine ④ Bar cutter ⑤ Rolling machine ⑥ Detecter ⑦ Rod shear ⑧ Tandem coiler

The casting and rolling conditions are shown in Table 2. Area reduction after each rolling shown in Table 3. Small specimens cut from the transverse section of the cast bar and each rolled rods were observed using optical microscope after mechanical polishing with water resistant papers (#100, 400, 800, 1200, 1500), followed by a polishing solution with 1.0μm Al_2O_3 powder and chemical etching by 2.0% HF-solution. Hardness of the small specimens were measured by micro-Vickers hardness machine under the condition of 200gf-30sec. The distribution of the hardness values over the transverse section was investigated within the area of 2mm square for each measuring spot.

Table 2 The casting and rolling conditions

casting temp.	685 °C	exit temp. of cast bar from the ring mold	385 °C
ring mold temp.	65 °C	entrance temp. of bar to the mill	360 °C
casting speed	5.2t/h	exit temp. of bar from the mill	260 °C

Table 3 Area reduction by each rolling stand

Stand №	1	2	3	4	5	6
Area Reduction (%)	36.1	31.0	22.0	18.7	12.6	18.9

3. RESULTS AND DISCUSSION

3.1 Microstructure

Fig.2 (a, b, c and d) shows microstructures obtained from the spot areas, a, b, c and d, respectively, in the transverse section of the cast bar shown in the right figure. There are coarse equiaxed grains around the central and belt side areas and fine equiaxed grains around the ring mold side area.

Microstructures, a, b, c and d coresponding to the spots a, b, c and d in the transversed section of the deformed rod after the 1st rolling, are shown in Fig.3. All grains are elongated in the lateral spread direction. Especially, grains around the d spot are most elongate.

Fig.4 shows Microstructures a, b, c and d corresponding to the indicated spots a, b, c and d, respectively, in the transverse section of the rolled rod after the 2nd rolling. Grains in the upper and lower area (a and c) are slightly elongated in the vertical direction. The shape of grains in the central area (b) and the sidewise area (d), is almost equiaxed.

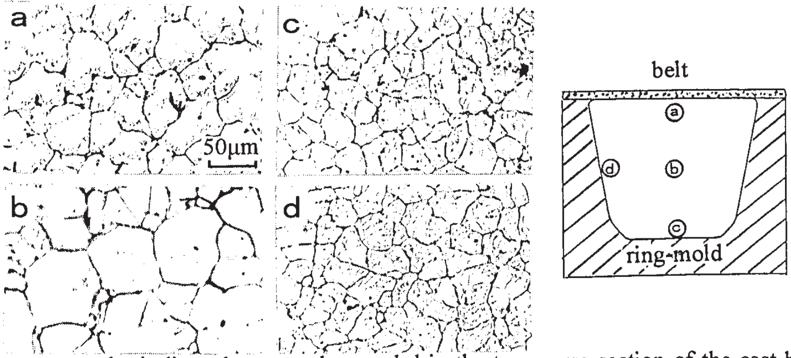

Fig.2 Microstructures at the indicated spots a, b, c and d in the transverse section of the cast bar.

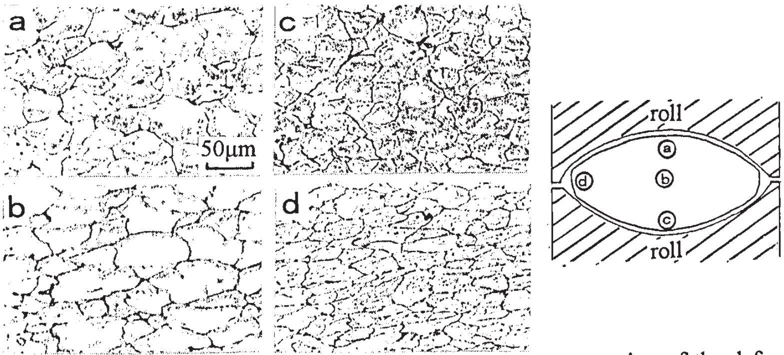

Fig.3 Microstructures at the indicated spots a, b, c and d in the transverse section of the deformed rod after the 1st rolling.

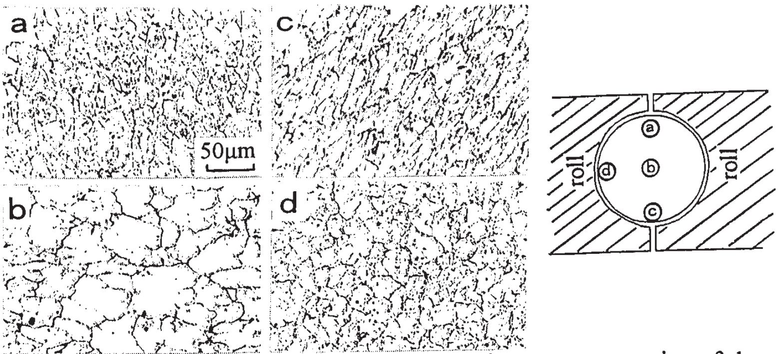

Fig.4 Microstructures at the indicated 4 spots a, b, c and d in the transverse section of the rolled rod after the 2nd rolling.

Microstructues a, b, c and d corresponding to the spots a, b, c and d, respectively, in the transverse section of the deformed rod after the 3rd rolling, are shown in Fig.5. Grain shape in the areas corresponding to the spots a, b and c is nearly eqiaxed and the grains corresponding to the spot d is elonged to the horizontal direction. During the 4th, 5th and 6th rolling the shapes of grains in each area are almost unchanged.

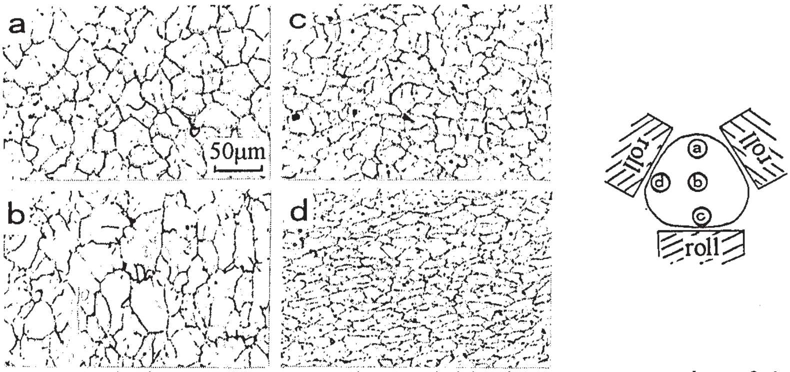

Fig.5 Microstructures at the indicated 4 spots a, b, c and d in the transverse section of the rolled rod after the 3rd rolling.

Changes of the mean grain size in the indicated area, a, b, c and d with total area reduction; about 36%, 56%, 67%, 71%, 74% and 79%, after the 1st, 2nd, 3rd, 4th, 5th and 6th rolling, are shown in Fig.6.

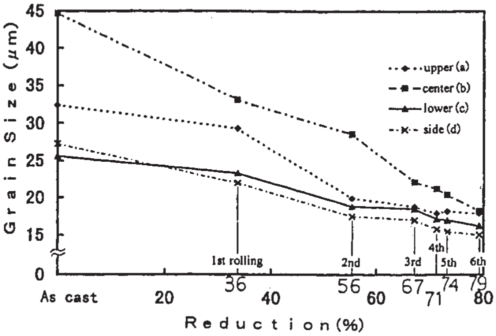

Fig.6 Changes of the mean grain size in the indicated areas, a, b, c and d with the total area reduction.

Initial grain size in the cast bar is large in order of the central, upper, side and lower area, and the difference of the grain size becomes smaller after the 6th rolling. The larger decrease of the grain size in the central area is due to the larger grain size in the cast bar.

Hardness in the central area is lowest in the early stages of the rolling, as seen in Fig.8, and grains in the central area deform preferentially in the rolling direction.

Fig.7 (a, b, c and d) show microstructures at high magnification of the central area in the transverse section of deformed rods after the 1st, 2nd, 3rd and 6th rolling, respectively. Many fine grains (2 ~ 10μm) are observed within the original grains. These fine grains seems to be formed by dynamical recrystallization mechanism[2]. The size of the new grains within the original grains is nearly the same after each rollings.

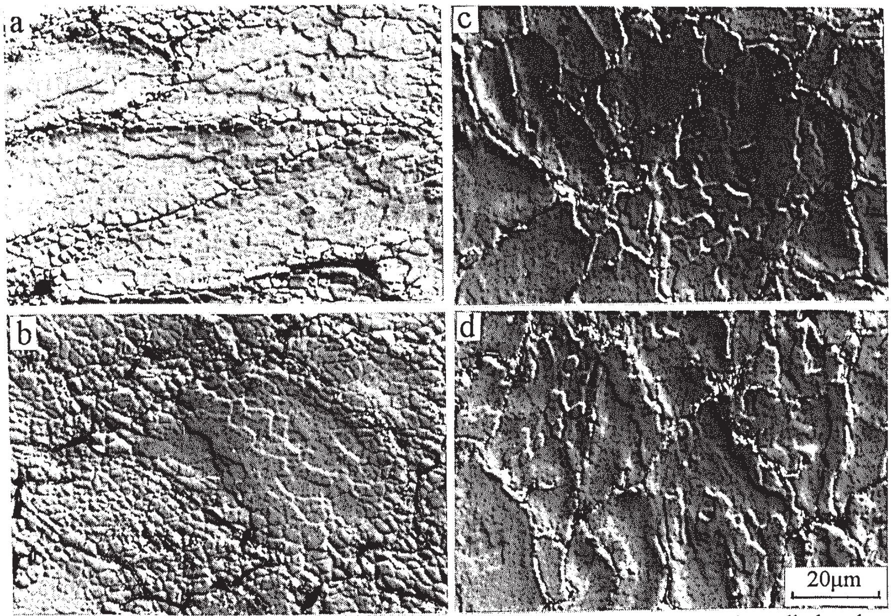

Fig.7 Fine grains observed in the central area of the transverse section of the rolled rods after the 1st (a), 2nd (b), 3rd (c) and 6th (d) rolling.

3.2 Hardness

Distribution of the hardness values in the transverse section of the cast bar and each rolled rod after 1st ~ 6th rolling are shown in fig.8. In the cast bar, there are softer areas around the

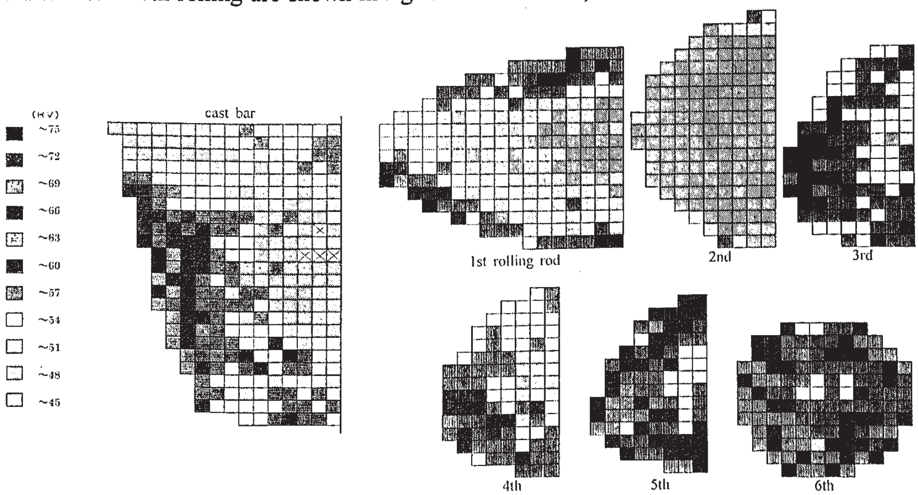

Fig.8 Distribution of hardness values in the tranverse section of the cast bar and deformed rods after 1st ~ 6th rolling, in half side except for the 6th.

center and belt side and the harder area is along the ring mold side. In the rod after the 1st rolling, hardness of the belt side area increases, and hardness in the central area and in the area along the ring mold is hardly unchanged in spite of large area reduction of 36.1%. This suggests that deformation in the belt side is especially large. In the rod after the 2nd rolling hardness decreases in all the cross section. This work softening seems to be due to dynamic recrystallization during the 2nd rolling, seen in Fig.7. After the 2nd rolling, total area reduction reaches to about 56%. After the 3rd rolling, hardness increases in the periphery of the section. During the 4th, 5th and 6th rolling, hardness increases gradually in all the section.

4. SUMMARY

(1) Original grain size in the transverse section of the cast bar decreases with increasing total area reduction, and large difference of the original grain size among the various area in the section becomes small after the 4th or 6th rolling.

(2) Fine grains with the size of 2 ~ 10μm are formed within the original grains after each rolling.

(3) During the 6 stages of rolling of the cast bar, distribution of hardness in the transverse section of the rod changes complexly. Remarkable softening occurs in all over the section after the 2nd rolling and work hardening proceeds gradually during the 3rd, 4th, 5th and 6th rolling.

(4) Changes in microstructure and hardness during Properzi process described above, result in good workability of 6151 aluminum alloy wire rod.

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