On the Destruction of the Single Crystal of Aluminium by the Process of Rolling.

By

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ABSTRACT

The scattering of the orientations of the micro-crystals, caused by rolling slightly the single crystal-plate of aluminium, was investigated in the present research. It was found that the micro-crystals rotated, up to some extent, around the axis parallel to the surface of the specimen and perpendicular to the direction of the advance of the process of rolling, irrespective of the orientations of the crystallographic axes referring to the surface of the specimen and the direction of the advance of the rolling process. The maximum angle of rotation of the micro-crystals was seen to increase proportionally with the reduction in thickness of the plate by rolling.

It is already known that, when a metal composed of a single crystal is subjected to some regular cold working, the single crystal is disintegrated into micro-crystals arranged in some regular way. Recently Prof. Sh. Tanaka[1] of the Kyoto Imperial University examined the arrangement of the micro-crystals of aluminium in the specimens prepared by rolling the single-crystal-plates of aluminium. But his experiments was mainly concerned with the specimens rolled thoroughly, and no detailed investigation of the arrangement of the micro-crystals was undertaken for the specimens rolled weakly and slightly. With a thin piece of a slightly rolled single crystal of a metal, the Laue-photograph taken by illuminating the specimen with a narrow pencil of x-rays is a little different from the ordinary Laue-spots; the ordinary sharp and well-defined Laue-spots become somewhat diffused and elongated to some extent, in this case, in some directions, the exent of this elongation and its direction being different

1 These Memoirs, **10**, 303 (1927)

with the degree of rolling and its direction. Such elongation of the Laue-spots must of course be due to some regular scattering of the orientations of the micro-crystals formed by the destruction of a single crystal-specimen in the process of rolling. At the suggestion of Professor U. Yoshida, the writer has tried to find from the elongation of the Laue-spots above mentioned the manner of such regular scattering of the orientations of the micro-crystals of aluminium.

The single-crystal-specimen in the form of a plate was prepared by the stress-annealing-method from a commercial aluminium plate of 1·5 mm. thickness. An ordinary Laue-photograph was taken with this single-crystal-plate. Then this single-crystal-plate was rolled successively with small steps of reduction in thickness, and at each successive stage of rolling a Laue-photograph was taken. The roller used was of two steel cylinders of 15 cms. in diameter. As the single-crystal-plate was very liable to bend in an irregular manner by rolling, it was rolled by being held between two brass plates of 0·5 mms. thickness; and by this means the irregular bending of the specimen caused by the rolling was mostly avoided. As to the direction of rolling, special care was taken to roll always in the same direction for each specimen.

The orientation of the crystallographic axes of the undeformed initial single crystal of aluminium, in reference to the outside face of this single-crystal-plate, was determined by dealing with the Laue-spots for this single-crystal-plate by means of the spherical scale and the globe devised by Prof. U. Yoshida.[1] When the single-crystal-plate is rolled a little, each one of the ordinary sharp and well defined Laue-spots become elongated to some extent in some direction, the extent of this elongation and its direction being different for different spots. As was stated before, this elongation of the Laue-spots must be due to some regular scattering of the orientations of the micro-crystals of aluminium which is caused by rolling the single-crystal-plate of aluminium. If so, both ends of every elongated Laue-spot must correspond to two extremities of the scattered orientations of the micro-crystals; and the whole assemblage of the points representing the positions of both ends of every elongated Laue-spot on the photographic plate will be two sets of Laue-spots due to the micro-crystals at the two extreme orientations above mentioned. As an intermediate portion between the two ends of every elongated Laue-spot is caused by the micro-crystals at a certain intermediate orientation between the two extreme ones, the problem will be solved if we can determine

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these two extreme orientations from the elongated Laue-spots. Actually these two extreme orientations of the micro-crystals were found easily with the aid of the spherical scale and the globe before mentioned.

Thus, for the present purpose, it is very important to know as accurately as possible the positions of both ends of an elongated Laue-spot on a photographic plate. For this purpose the writer employed a Coolidge-x-ray-tube having a tungsten target. With the x-ray-tube having a target of another metal, such as molybdenum, the intensity of the characteristic radiation of that metal was much stronger than that of the continuous radiation, so that the appearance of the spectrum of the strong characteristic radiation on the continuous background in an elongated Laue-spot prevented sometimes a reliable determination of the positions of the end-points of the elongated Laue-spot. However with the tube having a tungsten target, the intensity of the impression of the elongated Laue-spots became rather uniform over the whole part of every spot, which was of course due to a rather uniform distribution of the intensities of the continuous x-rays for various wave-lengths. This fact enabled the writer, by the use of the tube with tungsten target, to determine definitely the positions of the end-points of the elongated Laue-spots.

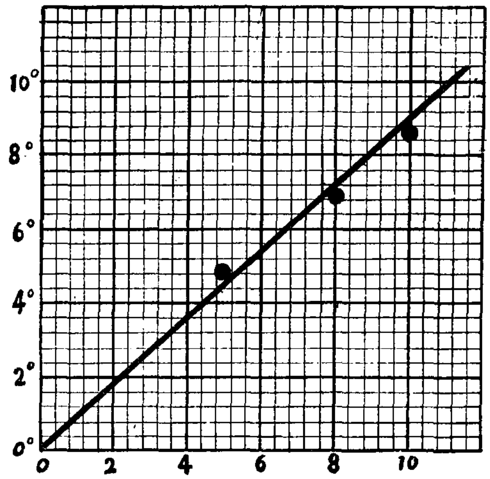
In taking the Laue-photograph, a narrow and circular beam of the x-rays was made to illuminate the aluminium plate in a direction perpendicular to its flat surface, and the photographic plate was placed behind the specimen at a certain distance. This distance between the specimen and the photographic plate was kept the same throughout the present experiment, so that the continuous change of the Laue-photographs with the lapse of the stages of rolling could be easily traced by overlapping the photographs.

The Laue-photographs taken are reproduced in Figs. 1, 2, 3, 4 and 5, Plate I. Fig. 1 is an ordinary Laue-spots taken with a single-crystal-plate of aluminium, and the remaining four figures are taken with the same specimen at its four successive stages of rolling. The reductions in thickness of the plate by the rolling were 2, 5, 8 and 10 percent of the original thickness respectively, corresponding to Figs. 2, 3, 4 and 5, Plate I. In all the photographs in Plates I, the horizontal direction passing through the centre of the direct image is parallel to the flat surface of the specimen, and is perpendicular to the direction of the advance of the rolling process on the surface of the specimen.

From the figures in Plate I we know that the elongation of each Laue-spot increase with the increase of the reduction in thickness of the plate by rolling, and that for different spots in the same figure this elongation is much smaller with the spot which subtends a smaller angle at the centre of the direct image with the horizontal direction passing through the centre of the direct image on the surface of the figure. This fact seems to suggest that the scattering of the orientations of the micro-crystals caused by the process of rolling is such that the micro-crystals rotate, up to some extent, around the axis parallel to the surface of the specimen and perpendicular to the direction of the advance of the process of rolling. This suggestion was confirmed to be so by the aid of the spherical scale and the globe, and the maximum angle of rotation of the micro-crystals around the said axis was measured on the spherical scale. The relation between this maximum angle of rotation of the micro-crystals and the reduction in thickness of the plate by rolling is shown in *Fig.* 1, and the proportionality between these two quantities is observed to hold nearly so far as the present experiment is concerned.

The writer has repeated the same experiment with seven single-crystal-plates of aluminium of different orientations of the crystallographic axes, and found that the scattering of the orientations of the micro-crystals by the process of rolling was the same as that stated above irrespective of the orientation of the crystallographic axes referring to the surface of the plate and the direction of the progress of the rolling process.

Fig. 1.



Reduction in thickness of the plate in percent.

It will be very interesting to see whether or not the scattering of the orientation of the micro-crystals proceeds in the manner above stated, when the degree of rolling is very much more increased; and the experiments in this direction are now going on.

In conclusion, the writer wishes to express his deepest thanks to Professor U. Yoshida of the Kyoto Imperial University, under whose guidance the present research was completed.

Plate I.

Fig. 1.

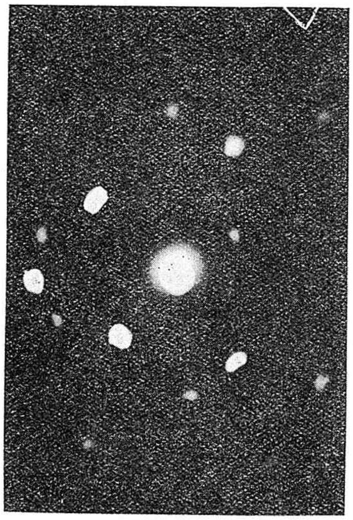


Fig. 2.

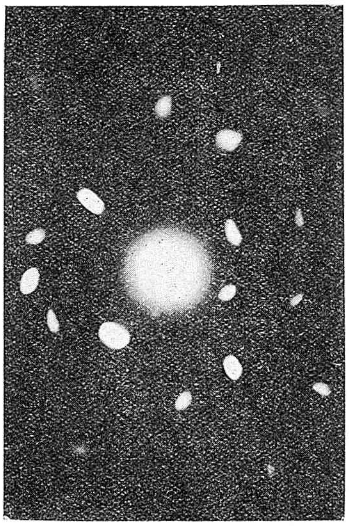


Fig. 3.

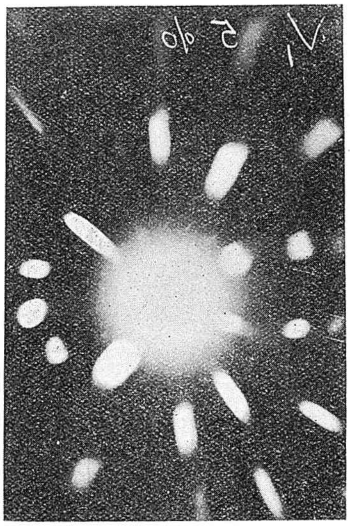


Fig. 4.

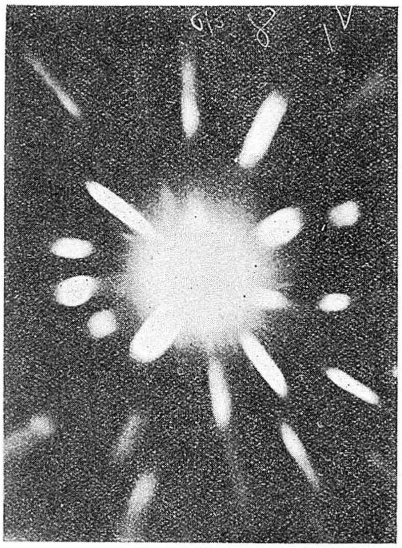


Fig. 5.