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技術論文

A Study on the Directionality of Aluminium Sheets (1st Report). On the Detection of Directionality by Means of Knoop Indentator.[†]

Takuichi MORINAGA* and Shigeo ZAIMA**

(*Tokyo Institute of Technology, **Faculty of Engineering, Yamanashi University)

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Synopsis

We explain in this paper a new method of detecting the directionality by means of the differences of the major diagonal length L of the Knoop depression corresponding to the angle θ against the direction of working. In the experimental condition, that is, under the loading of 25~1000g, the fact that the directionality grows more distinct as the load P increases, that is L is shortest in 0°-direction, longest in 90°-direction and its change is linear in proportion to θ , may be utilized for detecting the texture. As the minor diagonal length l of the depression is affected by the piling-up on both the sides of the depression, we can detect the texture by means of the ratio (L/l), and it is consistent with the detection usually achieved by measuring the tensile strength or the elongation.

I. Introduction

When we use a cold-rolled sheet or plate, the question is whether it has a directionality or not, and there are a great many excellent studies in this connection in the past. Quite recently, an experiment was performed with aluminium sheets to eliminate the influence of the directionality by adding certain elements⁽¹⁾. The detection of directionality is usually achieved by measuring the tensile strength and the elongation in tension tests, or by using X-ray, but these methods are complicated in operation and industrially inefficient. So, instead of specially preparing a test piece, we propose in this paper the simple method of detecting the directionality which is distinctly determined by means of the difference of the major diagonal length of the Knoop depression according to the direction of working.

II. Knoop Indentator

The principal dimensions of the Knoop indentator which was used are as follows; in Fig. 1 the vertically opposite angles $\alpha=172^\circ10'$ and $\beta=129^\circ40'$, the ratio of the major to the minor diagonal length of the rhombic depression (L/l)=6.85, the depth of the depression is nearly equal to 1/29 of the major diagonal length L and to 1/4 of the minor

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(1) T. Morinaga, T. Takahashi, S. Muromachi and S. Hori, J. of Japan Inst. of Metals, 18 (1954), 607.

Fig. 1 Knoop Indentator.

diagonal length l .

The standard dimensions of the Knoop depression $\alpha=172^\circ30'$, $\beta=130^\circ$, $(L/l)=7.11$, and the depth of the depression is nearly equal to $1/30$ of the major diagonal length⁽²⁾. It is considered to be a useful measuring test by the reason that this major diagonal length L is not influenced by the piling-up, the elasticity and so on. And this indentator used may safely be said to be closely similar to the standard indentator.

III. Specimens and the Experimental Procedure

We used for specimens sheets of 2S (thickness $t=4$ mm), 17S ($t=3$ mm) and Al-Cu (4%) alloys ($t=2$ mm), all rolled; their chemical components are shown in Table 1.

The depression produced by the loads of eleven grades within the range of 25~1000 g, was measured in the unit of μ .

Table 1 Chemical composition of specimens.

	Cu %	Mg %	Mn %	Si %	Fe %	Ni %	Al %
2 S	0.57	0.13	0.09		0.28	nil.	bal.
17. S	3.29	0.38	0.70		0.37	nil.	bal.
Al-Cu alloy	6.58	tr.	0	0.10	0.08	nil.	bal.

IV. Experimental Results

The relation between the angle of direction against the rolled direction θ and the major diagonal length L is shown in Fig. 2.

Fig. 2 Relations between θ and L , (a) in case of 2S, (b) in case of 17S, and (c) in case of Al-Cu alloy.

where h is a constant varying with the material, the reduction and so on. So, as far as we know, the directionality is barely detected in the case when P is small but is more distinctly detected when P is as large as possible.

Fig. 4 shows the relation between P and L of the same metal and direction which is known from Fig. 2, and in each case, the formula

$$L = P^k \dots \dots \dots (2)$$

is similarly qualitatively formulated, where k is a constant varying with the material, the reduction and so on. Thereupon, if we assume P properly (in fact P is more than 500 g as shown in Fig. 4), we obtain a stable measured value of L .

The fact that L is shortest in 0° -direction, longest in 90° -direction and its change is linear, that is, L changes in proportion to θ may be regarded as the expression of directionality. The tangent m of each line in the figure increases with the load P , and this relation may be shown as the lines in a logarithmic diagram as shown in Fig. 3. Thence qualitatively follows the formula

$$m = P^h \dots \dots \dots (1)$$

By measuring L , we may detect the directionality.

Fig. 3 Relation between m and P .

V. Discussion

Having learnt that L varies according to the direction, we will discuss in further details.

The relation between L and l in depressing each metal is shown in Fig. 5, and the ratio (L/l) is expressed as a nearly straight line in 0° - and 90° -directions, but is different from the former case in 45° -direction. The number printed beside each line in Fig. 5 is the tangent value m . From this we can see that the ratio (L/l) is nearly equal in the same metal in spite of the length of depression, for example, $5.6 \sim 5.9$ in the case of 2S and $6.0 \sim 6.1$ in 17S, but is always smaller than the ratio (L/l) = 6.85 calculated by the used

(a)

(b)

(c)

Fig. 5 Relation between L and l , (a) in case of 2S, (b) in case of 17S and (c) in case of Al-Cu alloy.

Fig. 4 Relation between P and L .

indentator.

Now we have studied the surface of depression by means of the Ogoshi Surface Roughness Tester, and can suggest some reasons for the difference in tangent.

For example, in Fig. 6, (a) is the surface of depression in the minor diagonal direction at 500 g and 1000 g loaded in 90° -

Fig. 6 Surface flatness of Knoop depression, magnified 1000 times in vertical direction and 50 times in horizontal.

direction in 17S, (b) is that of 2S under similar conditions, and (c) is the surface of depression in the major diagonal⁽³⁾. Here, the piling-up appears on both sides of the depression in l -direction, but in L -direction it is slight or nonexistent and this is the reason why L is applied to the measurement of hardness. While in Fig. 6 the depression is 1000 times magnified in the vertical direction and 50 times in the horizontal, equal magnification in both directions makes Fig. 7, and (a) and (b) correspond to (a) and (b) in Fig. 6, when depressed with 1000 g loading. There is a piling-up nearly 2μ in height on each side of the depression. When we measure the length l from overhead with a microscope, we are apt to measure the distance

(3) As the contact needle of Surface Roughness Tester slides with difficulty along the edge line in L -direction, we are, strictly speaking, not quite sure whether the needle has slid on the edge in the case of Fig. 6, but the general aspect may be grasped.

between the tops of the piling-up. The result is $64\ \mu$ as shown in Fig. 7 but in actual survey it is $66.2\ \mu$, and if we read the length l correctly in original surface plane, we obtain l of $60\ \mu$ and (L/l) of 6.55 taking $L=394.6\ \mu$ by actual measurement, and we know that this ratio is more approximate to the original value, 6.85 , than the value of Fig. 5.

Fig. 7 Illustration of Knoop depression correspond to Fig. 6 (a) and (b).

exact surface. Likewise, in the case (b) of $2S$, l is $84\ \mu$ in the figure of the original surface plane, and L is $582.6\ \mu$ by measurement, we therefore obtain, by eliminating the influence of piling-up, the ratio $(L/l)=6.95$ which is more approximate to the real value, 6.85 , than the value, 5.6 , of Fig. 5. There is a piling-up about $4\sim 5\ \mu$ in height, and $L=104.4\ \mu$ as measured nearly corresponds with $102\ \mu$ in the figure measured between the tops of the piling-up. In consequence, the reason that the ratio (L/l) varies as in Fig. 5 is largely due to the effect of the piling-up caused by the plasticity, the elastic recovery and other factors.

As there is the piling-up of nearly $1\sim 1.5$ times the length in the minor diagonal direction on both sides of the Knoop depression, it is to be desired not to measure the hardness in this deformed zone⁽⁴⁾.

In the above, (L/l) is looked upon as nearly equal in the cases of 0° -direction and 90° -direction, but, it examined more minutely, a different result may come out as shown in Fig. 8.

Thus, the ratio is highest in 45° -direction, because the effect of the piling-up caused by the plasticity, the elastic recovery and other factors is smallest in this direction, and there is a slight difference between the values of 0° - and 90° -direction as shown in Fig. 8. In the detection of directionality by means of L , the value L changes linearly as shown in Fig. 2, but the result of the detection by means of the ratio (L/l) is consistent with the fact⁽¹⁾ that there is more directionality in 45° -direction in the case of $2S$.

Fig. 8 Relation between θ and (L/l) .

VI. Vickers Depression

We studied the Vickers depression with the same method, and a part of the data is as follows: in the case of $17S$, Fig. 9 shows the relation between the diagonal length L_1 , L_2 , and the direction θ according to the load P . So, it may be said that there is a slight directionality in 45° -direction, but it is not so distinct as in the case of the Knoop depression. The difference is 1% or so and according to the circumstances it happens to be inverse in its direction as shown above. The Vickers depression has a higher piling-up, influenced largely by the plasticity, the elastic recovery, the grain size and other factors, than the Knoop depression, and it may be said that it is difficult to measure exactly the depression caused, specially by a small load.

VII. Conclusion

- (4) It is in agreement with the opinion that the mutual distance of the Brinell depression must be more than 4 times of the diameter of the depression, e.g. cf. A Handbook of Mech. Engn., compiled by Japan Soc. of Mech. Engn., (1951) pp. (6)-36.

The results are summarized as follows:

Fig. 9 Relation between L in 17 S.

(1) We may easily detect the directionality in rolled sheets of aluminium and its alloys with the Knoop indenter.

(2) In the experimental condition (25~1000 g loading), the directionality appears more distinct by as the load P increases and we can obtain the directionality by measuring the length L because the formulas (1) and (2) are formulated qualitatively.

(3) We can also find the directionality by means of the ratio (L/l) affected by the piling-up of the edges of the depression, and it is consistent with the result achieved by the usual method of detection by measurement of the tensile strength or the elongation.

(4) The method by means of the Vickers depression can detect a slight directionality but it is not so distinct as when the Knoop depression is used.

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