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TEXTURE AND STRUCTURE OF COLD-ROLLED AND TEMPER ANNEALED SHEET OF ALUMINIUM 1200

By

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ABSTRACT

Aluminium 1200 is the grade of aluminium used for hollowares. It is the good corrosion resistance and ductility of Aluminium 1200 that made it particularly suitable for hollowares. However, there is a need to control the texture of aluminium sheet to be cold rolled in order to obtain optimal condition favourable for metal drawing. This is the rationale for this work. The effect of annealing and cold rolling on texture and structure of Aluminium 1200 sheets has been established. Working on cold rolled reductions of 80%, 84%, 86%, 88%, and 92% and annealing temperature of 350°C, 400°C, and 480°C, for 1 hr and 3 hrs, Planar and normal anisotropy (that is, measure of crystallographic texture) were calculated from a known relationship.

Samples of 80% cold-rolled reduction and heated to temperature 35°C for three (3) hours showed the most favourable texture for metal drawing. Thus, crystallographic texture has been found to be determined by the average normal and planar anisotropy of Aluminium 1200 sheet metal which can be controlled by the annealing temperature and degree of previous cold-working. Texture with very low value of planar anisotropy (about zero) and high value of average anisotropy (about unity) has been found suitable for Aluminium 1200 metal sheet drawing. Although annealing is observed to enhance the preferred orientation for metal drawing, there is the need to control the grain growth associated with it, which can impair the mechanical properties of the sheet.

Key Words: Texture, Structure, Cold-roll,Temper-anneal, Aluminium 1200.

1.0 INTRODUCTION

Aluminium possesses a number of properties that make it an extremely useful engineering material. Its good corrosion resistance; ductility and low density make it particularly suitable for vats, thin foil for packaging and other vessels in the food and chemical industries. Aluminium 1200 is the grade of aluminium used for hollowware when cold-rolled aluminium or its alloys are recrystallised by annealing new grams form with orientation that differ from those present in the cold rolled condition.

Texture, another term for preferred orientation, describes the directional alignment of particular planes or crystal direction, which significantly affect properties. It is unusual for such orientation to be perfect. The term refers to a grouping about a mean value which is still significant until the angle between the extremes of direction exceeds about 30° (Tottle, 1984). Directionality is a three effects and its absence in the plane of the sheet does not assure that properties measured in a direction perpendicular or normal to the sheet are the same as the properties measured in the plane of the sheet. The normal directionality of a material is often more pronounced than its planar directionality, and while not usually observed in the press shop, is nevertheless important to the press performance of the material.

Preferred orientation in the plane of a sheet that are associated with textures may cause a problem known as 'earing'. This is manifest as irregular projections on the rim of the cup as against the case where there is a smooth rim surface (Wills and Blade, 1966). Research has shown that conditions that affect directionality in metal sheets are penultimate reduction, processing temperature, annealing cycle, cross rolling of industrial plates of metal and alloying elements (Hatherly and Hutchinsen, 1979).

In physical terms, the plastic strain is a measure of the capacity of a sheet to resist thinning. Since crystallographic texture is related to both the normal and planar anisotropy, it is possible to take advantage of the properties to improve drawing performance. The aim of this investigation can be summarised as follows:

- To investigate the effects of cold-rolling and annealing temperatures on texture and structure of aluminium 1200 sheet.
- To establish the preferred orientation favourable for deep metal drawing operations.
- To enhance the development of deep drawn aluminium products

3.0 MATERIALS AND METHODS

3.1 MATERIALS

Cold-rolled aluminium 1200 sheet were collected from Aliminium rolling mills, Sango Otta, Ogun State. The sheets were obtained in various cold-rolled reductions – 80%, 84%, 86%, 88% and 92%.

3.2 METHODS

The sample was tested for compositional analysis, using spectrometer. The sample to be analysed was cleaned thoroughly to remove the oil stains and then placed on a petrel table, inside the spectrometer. The result of the compositional analysis is shown in Table1.

3.2.1 Heat treatment

Heat treatment operations were carried out in the laboratory using muffle furnace. The samples were heat-treated to 150°C and then soaked for 1hr in the furnace. The above steps were repeated for temperatures of 250°C, 350°C, 400°C, and 480°C for soaking time of 1hr in the first instance and later for a soaking time of 3 hours.

The 80% cold-rolled sample was heated to 350°C and soaked for 1 hr. This was repeated for 480°C. Ranging from temperatures of 150° – 480°C. 84%, 86%, 88% and 92% cold works samples were then annealed for temperature range of 150° - 480oC, soaking time being 1hr. The results are contained in Figs 1 - 4

3.2.2 Deep Drawing (Erichson Modified Test)

The following steps were carried out for cupping or deep drawability of the aluminium sheets. The sample, heat treated at 150°C for 1 hour, was cut such that it could enter the sample window of the blanking head of the cupping machine.

Earing and percentage earring were calculated as follows:

$$H = \frac{h_1 + h_2 + h_3}{3}$$

Earing = H – L

$$\text{Percentage earing} = \frac{H - L}{H} \times 100\%$$

3.2.3 Tensile Test

The test piece was attached to the grips of the Monsanto tensometer. The tensometer was then filled with autographic recorder which gave a graphical display of load-extension behaviour of the material on the graph sheet attached to it. The result is shown in Fig 5.

3.2.4 Determination of Plastic Strain Ratio

The following steps were carried out to determine the plastic strain ratio. The sheet samples traced at 150°C for 1 hour, were cut into standard test pieces (100mm X 12mm). The burrs (uneven projections on the edge) were removed by grinding in order to have a smooth edge. For each sheet sample, the standard test piece was 45°. 90° to the rolled direction of the sheet. The test piece, cut at 0° to the rolled direction, was marked 25mm from its both ends (that is, the guage length, 50mm) with the aid of vernier caliper. The test piece was attached to the tensometer and tensile test was carried out. Appropriate blanking die and punch fixed on balking and two test pieces were blanked from each sample. Then drawing die was fixed on the drawing head of the cupping machine. The pressure knob of the machine was adjusted depending on the sample guage 1-5Kpa for 0.6-1.0mm sheet and above 10Kpa for 1.2-1.6mm sheet Lubricant was applied on both sides of the test piece and on punch head in order to reduce frictional effect.

One of the test pieces in the drawing die was produced and centered, using the centering device and the first drawn cup was produced. The above procedure was repeated for the second piece. Using a vernier caliper, the first draw height from one of the test pieces was measured. Earring and percentage earring were calculated. The results is shown in Figure.... The drawing head of the cupping machine was dismantled and the second draw punch and die were fixed. One of the samples already drawn using the above procedure and drawn again was positioned and drawn again. Using a vernier caliper, the second drawn height was measured according to the steps above. Earring and percentage earring was calculated for second drawn cup. The same steps were repeated for samples treated at 150°C for 3hrs, 250°C for 3 hours 350°C for 3hours, 400°C for 3 hours and 480°C for 3 hours. The final length and width of the test piece was measured at elongation of 15 percent to 20 percent and below the elongation where necking began. The above procedures were repeated for test pieces cut at 45° and 90° to the rolled direction of the sheet. The recorded results are shown in the Appendix. The plastic strain ratio, average anisotropy and planar anisotropy were calculated.

Plastic strain calculation

The plastic strain was calculated using the formula:

$$R = \frac{\ln W_o/W_f}{\ln 1_f W_f/l_o W_o}$$

Where 1_f, 1_o, $W_f W_o$ refer to the final length, initial length, final width and initial width respectively.

Average Anisotropy

Average Anisotropy is given as:

$$R = \tfrac{1}{4}(R_o + 2R_{45} + R_{90})$$

Where R_o, R_{45}, R_{90} referred to the plastic strain ratio at 0°, 45°, and 90° to the cold –rolled-direction of the sheet.

Planar Anisotropy

Similarly, planar anisotropy was calculated as

$$\Delta R = \tfrac{1}{2}(R_o + R_{90} - 2R_{45})$$

Determination of Ultimate Tensile Strength and Elongation

Steps taken for tensile strength determination were repeated until test piece got fractured. The maximum load on the load-extension curve was recorded. Then, ultimate tensile strength was calculated. The fractured test pieces were brought to close contact and the final length was measured. The percentage elongation was then calculated

$$\text{Ultimate Tensile Strength} = \frac{\text{Maximum Load}}{\text{Original cross-sectional area of test-piece}}$$

$$\text{Percentage elongation (\%)} = \frac{\text{Final gauge length} - \text{Initial gauge length}}{\text{Initial guage length}}$$

Hardness Test

Hardness (resistance to indentation and plastic deformation) was determined, using Webster hardness tester. The indenter was made to impinge the surface of the test piece. Hardness value was read on a scale.

4.0 RESULTS AND DISCUSSION

4.1 RESULTS

The results of spectrographic Analysis of aluminium 1200 sheets is shown in Table 1.

Tables 2 – 8 emanating from this investigation are contained in the Appendix. The corresponding figures on the results of heat treatment operations, deep drawing, tensile strength , ultimate tensile strength and elongation determination, and hardness tests are shown in Figs 1-6.

4.2 DISCUSSION OF RESULTS

A metal which has undergone a severe amount of deformation, as in rolling, will develop a preferred orientation or texture in which certain crystallographic planes t end to orient themselves in a preferred manner with respect to the direction of maximum (Kalpakjian1997).

Normal Anisotropy

Figure 1 and 2 show the relationship between average normal anisotropy and annealing temperatures. The following are observed.

Average normal anisotropy is nearly constant with increasing temperature up to about 250°C. This can be attributed to the ineffectiveness of the low temperature on the material causing no stress relief and no new grain formation yet. At temperature 250°C – 350°C, the average normal anisotropy increase with rise in temperature. This is because stress relief is occurring but grains are still aligned in preferred orientation. At temperatures 250°C – 350°C, the average normal anisotropy increases with rise in temperature. This is because stress relief is occurring but grains are still aligned in preferred orientation. At temperatures above 350°C, average normal anisotropy decreases with increasing temperature. This is as a result of re-crystallization causing anisotropy to decrease; and as material is further heated there is grain growth also causing further fall in anisotropy. Time of anneal was observed to increase anisotropy at low annealing temperatures but not increased in the annealing temperature ranges of 250-350°C while it shows the decline after 350°C. The increase in anisotropy at low temperatures with a longer soaking time can be attributed to some form of stress relief but grains still highly aligned in preferred orientations (direction of rolling).

Planar Anisotropy

Figure 3 shows the relationship between planar anisotropy (ΔR) and percentage earring. It shows that the height of the ears increases with increasing (Δ R). 86% cold rolled samples show direct relationship between the planar anisotropy and earring increases with decreasing planar anisotropy. Also, for 92% reduction, the earring is about 2.5% (still high). For samples 80% cold rolled, it can be observed that planar anisotropy decreases with decrease in percentage earring. At the point, ΔR = 0, the earing is 1% for 80% reduciton sample annealed for 3 hours. Thus, moderate cold-rolled reductions and partial annealing temperatures are beneficial.

Ears are objectionable because they have to be trimmed off, wasting materials. Planar anisotropy causes ears to form in drawn cups, producing a wavy edge (Galinowski, 1975). The number of ears produced may be four, six or eight. Apart from avoiding excessive deformation in the deep drawing process, earing can also be minimized by varying the shape of the blank (to oval or even square instead of circular) and by providing increased local clearance on the tools.

From Figures 3 and 4 planar anisotropy is nearly constant up to 86% cold-roll for all anneal temperatures after which it rises. As recrystallisation takes place, the tensile strength decreases while the ductility increases. This can be seen in Figure 5 and Figure 6. The tensile strength of the sheet is determined by the planar anisotropy, which defines the properties in the cold-roll direction. The higher the normal anisotropy, the lower the planar anisotropy. Tensile strength decreasing with increasing normal directionality. Increase in ductility and lower hardness introduced by annealing, is a result of formation of equiaxed grain structures as seen in Figure 6.

5.0 CONCLUSION

The crystallographic texture can be controlled by variation of the average normal and planar anisotropy of the Aluminium 1200 sheet material. This can be achieved by controlling the annealing temperature and degree of previous cold-work. Texture with very low value of planar anisotropy (about zero) and high value of average anisotropy (about unity) is suitable for metal sheet drawing.

Annealing enhances the preferred orientation for metal drawing but, there is a need to control the grain growth associated with it, which can impair the mechanical properties of the sheet.

The greatest improvement in drawability comes about by the control of crystallographic texture in the sheet that is to be drawn.

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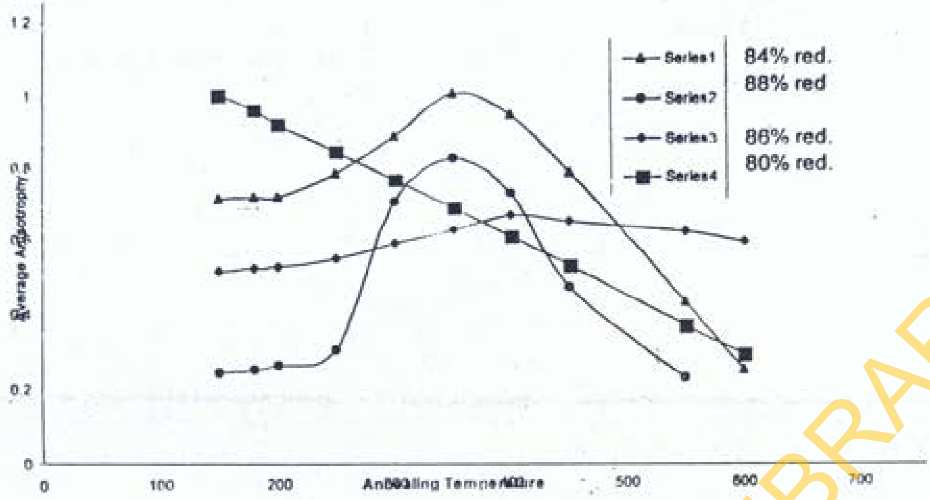

Figure 1: Average Normal anisotropy and Annealing Temperature for some Cold rolled Samples treated for one hour

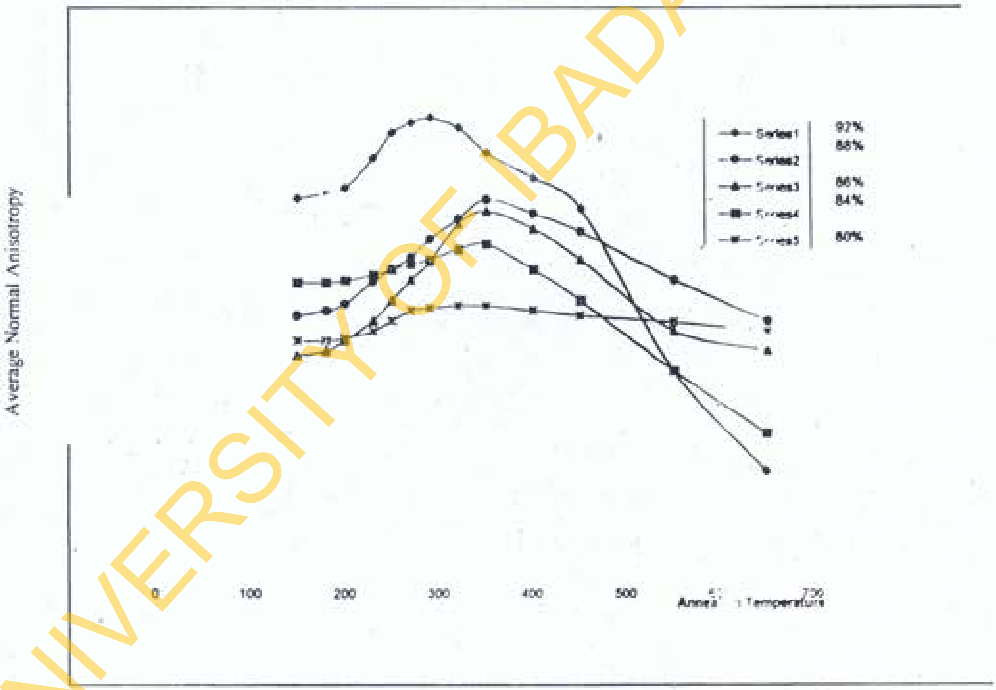

Figure 2: Relationship between Average Normal Anisotropy and Cold-rolled Reduction for some Samples

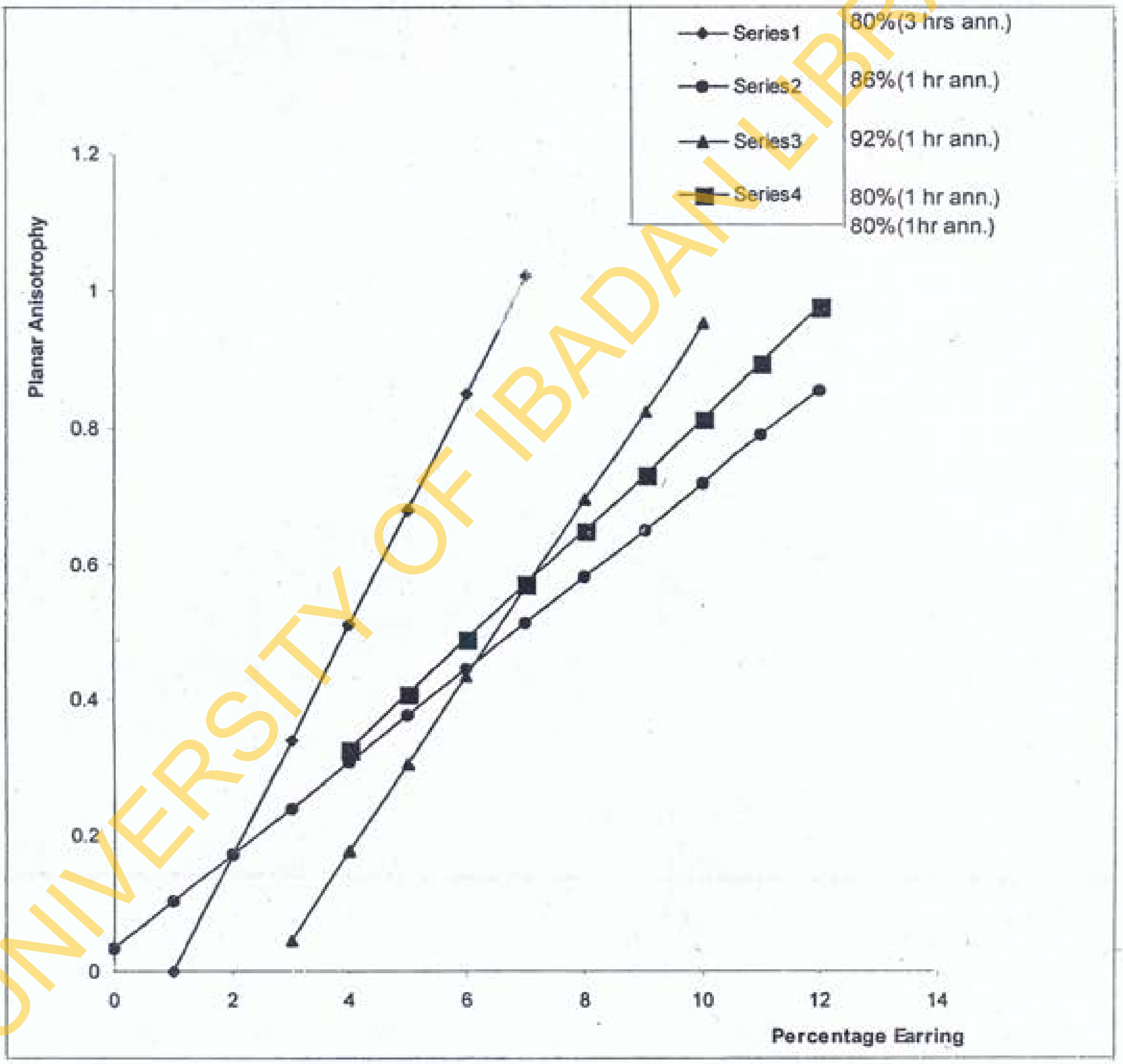

Figure 3: Planar Anisotropy and Percentage Earing for some Cold rolled Samples

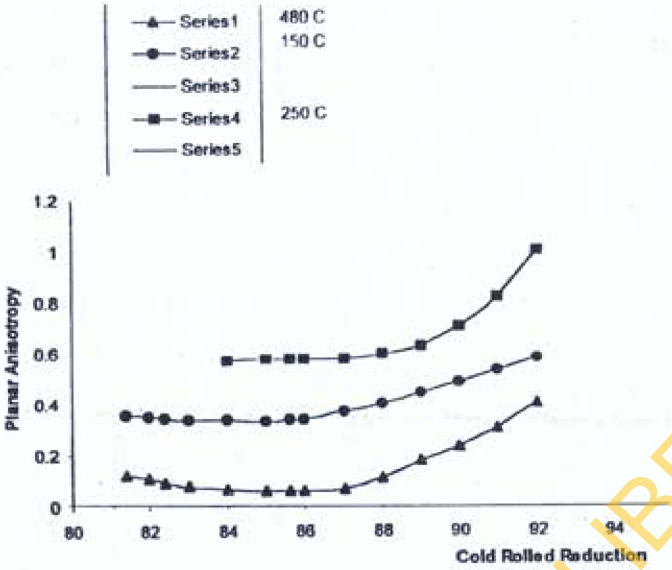

Figure 4: Planar Normal Anisotropy and Cold-rolled Reduction for some Samples

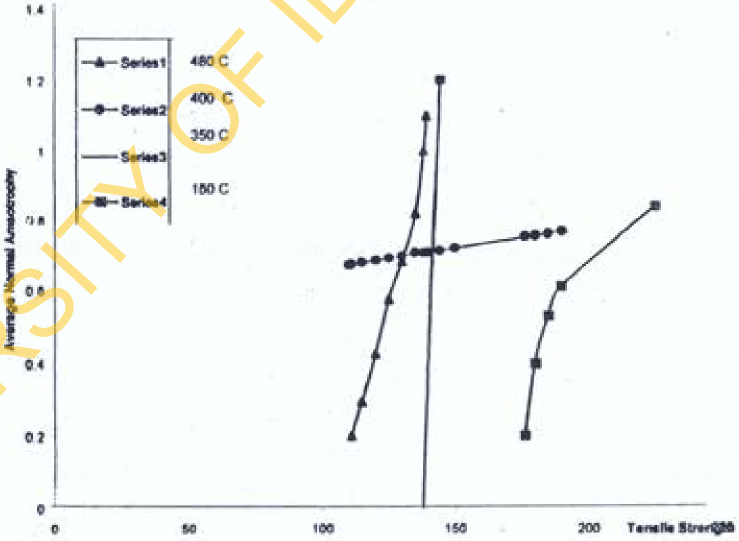

Figure 5: Average Normal Anisotropy with the Tensile Strength for some Samples

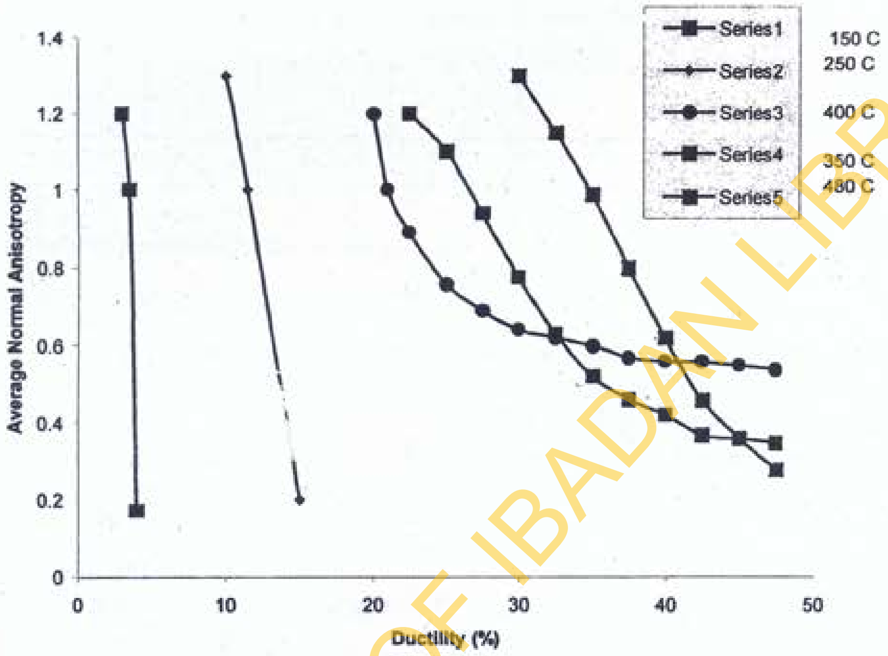

Figure 6: Average Normal Anisotropy with the ductility for some Samples

APPENDIX

Table 1: Spectrographic Analysis of Aluminium 1200 Sheet

Element	Mg	Si	Mn	Cu	Zn	Fe	Al
% composition	0.0004	0.21424	0.02487	0.04545	0.05111	0.49704	99.01

Table 2: Relationship between Average Normal Anisotropy and temperature for some Cold rolled Reduction Samples

Cold-rolled red.(%)	Temperature (°C)	Soaking time (Hrs)	Average normal anisotropy R
80	350	1	0.668
80	480	1	0.470
84	150	1	0.7157
84	350	1	1.013
84	400	1	0.63
86	150	1	0.532
86	350	1	0.591
86	400	1	0.671
86	480	1	0.7071
88	250	1	0.315
88	350	1	0.831
88	400	1	0.720
92	150	1	0.827
92	250	1	1.035
92	350	1	1.9021

Table 3: **Relationship between Average Normal Anisotropy and temperature for some Cold rolled Reduction Samples**

Cold-rolled red.(%)	Temperature (°C)	Soaking time (Hrs)	Average normal anisotropy R
80	350	3	0.5344
80	480	3	0.5054
84	150	3	0.560
84	350	3	0.652
84	400	3	0.532
86	150	3	0.431
86	350	3	0.729
86	400	3	0.634
86	480	3	0.566
88	250	3	0.622
88	350	3	0.730
88	400	3	0.698
92	150	3	0.730
92	250	3	0.900
92	350	3	0.805

Table 4: Variation of Planar Anisotropy with Earring Percentage for Some Cold Rolled Samples

Cold-rolled red (%)	Temperature (°C)	Soaking time (Hrs.)	Earing (%)	Planar anisotropy R
80	350	1	6.68	0.4964
80	480	1	2.4	0.1916
80	350	3	3.52	0.3924
80	480	3	1.21	0.0354
86	350	3	3.21	0.1804
86	400	3	2.52	0.1345
86	480	3	3.02	0.1224
92	250	3	8.21	0.7371
92	350	3	3.06	0.0432

Table 5: Planar Anisotropy with Cold rolled Reduction for some Samples

Temperature °C	Cold Rolled Reduction	Soaking Times	Planar Anosotropy
150	84	1	0.3686
150	86	1	0.342
150	92	1	0.5917
250	88	1	0.630
250	92	1	1.007
480	80	1	0.1916
480	86	1	0.0816

Table 6: Average Normal Anisotropy and Strength for given Heat Treatment Practice

Temperature (°C)	Cold-rolled red (%)	Soaking time (Hrs.)	Average normal anisotropy Ř	Tensile strength (N/mm^2)
150	84	1	0.7157	197.70
150	86	1	0.532	184.65
150	92	1	0.827	224.86
350	80	1	0.668	140.63
350	84	1	1.013	108.24
350	86	1	0.591	140.94
350	88	1	0.831	142.19
350	92	1	1.031	162.15
400	84	1	0.673	105.93
400	86	1	0.671	110.25
400	88	1	0.720	152.14
480	80	1	0.470	122.40
480	86	1	0.707	132.40

Table 7: Relationship between Average Normal Anisotropy and Ductility

Temperature (°C)	Cold-rolled red. (%)	Soaking time (Hrs.)	Average normal anisotropy R	Elongation (%)
150	84	1	0.7157	3.6
150	86	1	0.532	4
150	92	1	0.827	4
250	88	1	0.315	2.4
250	92	1	0.827	2.5
350	80	1	0.668	32
350	84	1	1.013	26.4
350	86	1	0.591	23.4
350	88	1	0.831	30
350	92	1	1.9021	24
400	84	1	0.673	28.8
400	86	1	0.671	28
400	88	1	0.720	26
480	80	1	0.668	32
480	86	1	0.707	39

Table 8: Average Normal Anisotropy with Hardness for some Samples

Temperature (°C)	Cold-rolled red (%)	Soaking time (Hrs)	Average normal anisotropy R	Hardness (Webster scale)
150	84	1	0.7157	5.5
150	86	1	0.532	4
150	92	1	0.827	3.5
250	88	1	0.315	2.4
250	92	1	1.035	2.5
350	80	1	0.668	0
350	84	1	1.013	0
350	86	1	0.591	0
350	88	1	0.831	0
350	92	1	1.9021	0
400	84	1	0.631	0
400	86	1	0.671	0
480	80	1	0.470	0
480	86	1	0.707	0