

MULTI-GAUGE STRIP AND METHOD FOR LEVELING THE SAMEBACKGROUND OF THE INVENTION

1. Field of the Invention:

The present invention relates to a multi-gauge strip and a method for testing the same, said multi-gauge strip being one which varies stepwise in thickness in its widthwise direction. It is used to form electronic parts such as lead frames (for power transistors), terminals, connectors, relay contacts, etc. More particularly, the present invention relates to a multi-gauge strip and a method for leveling the same, said multi-gauge strip being one which has a small amount of strain and is suitable for use as electronic parts.

2. Description of the Related Art:

A multi-gauge strip is formed such that its cross section varies in thickness in its widthwise direction, with the cross section being uniformly continuous in the lengthwise direction. As shown in Figs. 1 and 2, it has one or two thick parts in its cross section.

There are several known methods for producing said multi-gauge strip. They include, for example, reciprocating rolling (Japanese Patent Laid-open No. 42150/1984), tandem rolling (Japanese Patent Laid-open Nos. 60010/1985 and 299701/1989), V-mill molding (Japanese Patent Laid-open No. 10849/1977), forging (Japanese Patent Laid-open No. 54462/1987), and cutting from a uniformly thick strip. Their choice depends on productivity and quality required. These methods, except for cutting, establish the, final multi-gauge cross section by plastic deformation.

A multi-gauge strip is worked for a power transistor in the following manner. First, it is punched into a prescribed form by stamping and divided into two parts in the widthwise direction. In the stamping process, the edge of thin part of the multi-gauge strip is slit from 0.5 to 2.0 mm by width. Then, it is given nickel plating and gold spot plating. It is cut in length (200-300 mm). It undergoes bonding, wire bonding, and resin molding for transistors to be mounted. The process is completed by solder plating and tie bar cutting.

Multi-gauge strips are usually produced by plastic deformation. The entire process consists of rough shaping from a flat strip,

annealing, and finish rolling. Therefore, the resulting multi-gauge strip varies in reduction in thickness and structure from thick parts to thin parts and hence it also varies in the distribution of residual stress from thick parts to thin parts. Residual stress due to rough shaping is removed almost completely by ensuing annealing. However, another stress occurs during finish rolling which brings about compression in thickness, expansion in width, and elongation in length.

Conventional multi-gauge strips produced in the above-mentioned method involve the following problems. Multi-gauge strips having inadequately distributed residual stress are subject to deformation (such as elongation, contraction, camber, cross bow, and twisting) during stamping and cutting for fabrication into electronic parts (such as lead frames and terminals). This deformation occurs as uneven stress is relieved and stress distribution changes. Excessive deformation that occurs during working causes the multi-gauge strip to clog the die, thereby reducing the punching speed or making the press working difficult. In addition, deformation in the multi-gauge strip decreases the dimensional precision of the stamped product.

Unevenly distributed residual stress aggravates the co-planality of leads and the precision of lead positions due to camber, cross bow, twist, etc. when the multi-gauge strip is fabricated into lead frames. These result in displaced wire bonding and uneven lead bond strength in the transistor mounting step. In addition, twisted leads and unevenly spaced leads present difficulties in mounting finished transistors on a printed circuit board. Thus, multi-gauge strips with unevenly distributed residual stress pose many problems as mentioned above.

OBJECT AND SUMMARY OF THE INVENTION

The present invention was completed in order to address the above-mentioned problems. Thus, it is an object of the present invention to provide a multi-gauge strip and a method for testing it. This object is achieved by producing a multi-gauge strip having only a small amount of strain, examining it for residual stress distribution under prescribed conditions, carrying out stamping without causing deformation, and subjecting it to adequate leveling for strain reduction.

The first aspect of the present invention is a multi-gauge strip with a cross section which has one or more thin parts and thick parts formed across its width by rolling, with said cross section

being uniformly continuous in the lengthwise direction, which is characterized in that the thin part has a hardness of H_1 and the thick part has a hardness of H_2 , with the ratio of H_1/H_2 being from 0.9 to 1.15.

The multi-gauge strip formed as mentioned above has a very small difference in residual stress between the thin part and thick part. (This residual stress occurs because the degree of working and the structure vary from the thin part to the thick part during rolling.) The multi-gauge strip permits one to judge whether or not internal stress is uniformly distributed in it. That is, the H_1/H_2 ratio indicates the distribution of residual stress.

The second aspect of the present invention is a multi-gauge strip defined in the first aspect, wherein the thick part is formed only at the center of the width and the thin parts are formed at both edges, and the cross section is uniform such that when the multi-gauge strip is cut in its lengthwise direction (1.2 to 5 times its width) at five positions, one at the center of the width, one each at the boundary between the thin part and the thick part, and one each at the edge of the thin part to be slit, the dimensional variation between the two points (symmetrical with respect to the center of the width) in the cut surface is smaller than 0.15 mm at the end where cutting starts.

The value specified above permits one to judge whether or not residual stress is adequately distributed. Residual stress tends to accumulate at a specific position in the case of multi-gauge strips which have one thick part and two thin parts on both sides thereof. Thus, one can judge whether or not the given multi-gauge strip is suitable for further fabrication.

The third aspect of the present invention is a multi-gauge strip defined in the first aspect, wherein two thick parts are formed symmetrically, with a thin part formed at the center of the width, and thin parts are formed at both edges outside the thick parts, and the cross section is uniform such that when the multi-gauge strip is cut in its lengthwise direction (1.2 to 5 times its width) at five positions, one at the center of the width, one each at the outer boundary between the thin part and the thick part, and one each at the edge of the thin part to be slit, the dimensional variation between the two points (symmetrical with respect to the center of the width) in the cut surface is smaller than 0.15 mm at the end where cutting starts.

The value specified above permits one to judge whether or not residual stress is adequately distributed. Residual stress tends to

accumulate at a specific position in the case of multi-gauge strips which have two thick parts formed symmetrically, with one thin part between them. Thus, one can judge whether or not the given multi-gauge strip is suitable for working.

The fourth aspect of the present invention is a multi-gauge strip defined in the first aspect, wherein the thick part is formed only at the center of the width and the thin parts are formed at both edges, and the cross section is uniform such that when the multi-gauge strip is cut in its lengthwise direction (1.2 to 5 times its width) at five positions, one at the center of the width, one each at the boundary between the thin part and the thick part, and one each at the edge of the thin part to be slit, the angle of inclination of the cut thin part is smaller than 4° to the base horizontal line at the end where cutting starts.

The value specified above permits one to judge whether or not residual stress is adequately distributed. Residual stress tends to accumulate at a specific position in the case of multi-gauge strips which have one thick part and two thin parts on both sides thereof. Thus, it is possible to minimize cross bow, twist, and camber in the production of multi-gauge strips.

The fifth aspect of the present invention is a multi-gauge strip defined in the first aspect, wherein two thick parts are formed symmetrically, with a thin part formed at the center of the width, and thin parts are formed at both edges outside the thick parts, and the cross section is uniform such that when the multi-gauge strip is cut in its lengthwise direction (1.2 to 5 times its width) at five positions, one at the center of the width, one each at the outer boundary between the thin part and the thick part, and one each at the edge of the thin part to be slit, the angle of inclination of the cut thin part is smaller than 4° to the base horizontal line at the end where cutting starts.

The value specified above permits one to judge whether or not residual stress is adequately distributed. Residual stress tends to accumulate at a specific position in the case of multi-gauge strips which have two thick parts formed symmetrically, with a thin part between them, and two thin parts on both sides thereof. Thus, it is possible to minimize cross bow, twist, and camber in the production of multi-gauge strips.

Also described herein is a multi-gauge strip with a cross section which has one or more thin parts and thick parts formed by rolling across its width, with said

cross section being uniformly continuous in the lengthwise direction, said multi-gauge strip being leveled after rolling by application of a tensile stress which brings about plastic deformation corresponding to 0.05-1% of the elongation in the longitudinal direction.

Leveling in this manner relieves multi-gauge strips from unevenly distributed residual stress. Thus it is possible to minimize the deformation of multi-gauge strips that occurs during working.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a perspective view showing the multi-gauge strip according to the present invention.

Figs. 2A and 2B are perspective views showing the important parts of the multi-gauge strip according to the present invention.

Fig. 3 is a perspective view showing another construction of the multi-gauge strip according to the present invention.

Figs. 4A and 4B are perspective views showing the important parts of another multi-gauge strip according to the present invention.

Figs. 5A and 5B are schematic diagrams showing the cross section of the multi-gauge strip according to the present invention, said cross section appearing after cutting.

Fig. 6A is a plan view of the multi-gauge strip of the present invention which has undergone stamping, and Fig. 6B is a perspective view showing the lead frame formed from the stamped multi-gauge strip.

Figs. 7A and 7B are perspective views showing another construction of the multi-gauge strip according to the present invention.

Fig. 8 is a schematic diagram showing the method of leveling the multi-gauge strip according to the present invention.

Fig. 9 is a schematic diagram showing the construction of the die used for leveling the multi-gauge strip according to the present invention.

Fig. 10 is a schematic diagram showing the change in cross section and hardness which occurs during rolling in the production of the multi-gauge strip.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The embodiments of the invention will be described with reference to the accompanying drawings.

(1) Material and shape of multi-gauge strip

The multi-gauge strip is so formed as to have one or more thick parts and thin parts in its widthwise direction, with its cross section being uniformly continuous in its longitudinal direction. Some typical structures of the multi-gauge strip are shown in Figs. 1 to 4. The multi-gauge strip 1 shown in Fig. 1 is composed of a thick part 3 at the center of its width W and thin parts 2 and 2 at both sides of the thick part 3. The thick part 3 is formed such that its walls have a specific angle (α) of inclination which is from 0° to 10° . The multi-gauge strip 11 shown in Fig. 3 is composed of two thick parts 13 and 13 and three thin parts 12. The two thick parts 13 and 13 are formed, with the thin part 12b interposed between them. Two thin parts 12a and 12a are formed outside the two thick parts 13 and 13. The thick parts 13 and 13 are formed such that their walls have a specific angle (β) of inclination which is from 0° to 10° .

The multi-gauge strip 1 or 11 is fabricated into electronic parts such as lead frames for power transistors (see Fig. 6), terminals, connectors, and relay contacts. The multi-gauge strip 1 or 11 for lead frames is made of pure copper, such as oxygen-free copper (C1020), tough pitch copper (C1100), and phosphor deoxidized copper (C1201), or copper alloy, such as Cu-0.1Fe-0.03P. The multi-gauge strip 1 or 11 for terminals is made of copper alloy (of higher strength), Fe-Ni alloy, Fe alloy, or Ni alloy. It is also made of any other alloys.

As shown in Figs. 1 and 3, the multi-gauge strip 1 or 11 differs from a flat strip having a uniform thickness. It is produced by rough shaping (rolling or forging), annealing, and finish rolling. The thick parts 3 and 13 and the thin parts 2 and 12 widely vary in hardness and grain size depending on the conditions (such as reduction in thickness and annealing temperature and time) of rough shaping and finish rolling.

Also, as shown in Figs. 1 and 3, the multi-gauge strip 1 or 11 has one or two thick parts 3 or 13 on one side thereof. These parts have the following dimensions.

Thickness T_1 of the thin part 2 or 12: 0.1 ~ 1.5 mm.

Thickness T_2 of the thick part 3 or 13: 3 ~ 20.2 mm.

Width W of the multi-gauge strip 1 or 11: 30 ~ 200 mm.

Width D_1 of the thick part 3 or 13: 5 ~ 150 mm (or the sum of the widths if the multi-gauge strip has two thick parts 13 and 13).

Incidentally, as shown in Fig. 7A, the multi-gauge strip 51 may be formed such that the thick part bulges both upward and downward. In addition, as shown in Fig. 7B, the multi-gauge strip 61 may have grooves 64 and 64 which run in the length wise direction on the reverse side near the boundary between the thick part 63 and the thin part 62. In other words, the present invention is directed any multi-gauge strip which is used for electronic parts. The multi-gauge strips 51 and 61 shown in Fig. 7A and 7B are examples having one thick part. The same idea is applied to those which has two thick parts. (not shown)

(2) Measurements of hardness

According to the present invention, the multi-gauge strip 1 or 11 is characterized in that the thin part 2 or 12 has a certain hardness and the thick part 3 or 13 has another certain hardness, with the ratio of the former to the latter being specified. Since the thick part 3 or 13 and the thin part 2 or 12 are formed from a flat strip (of uniform thickness), they differ in hardness depending on their reduction in thickness even though the raw material is the same. Hardness may be measured according to the hardness test method (Vickers, Rockwell, or Brinell) provided in JIS Z2244, JIS Z2465, and JIS Z2243. In the case of the multi-gauge strip 1 having one thick part 3, the hardness H1 of the thin part 2 is measured on the line S₁, and the hardness H2 of the thick part 3 is measured on the center line CL, shown in Fig. 1. The hardness is expressed in terms of an average of five measurements on each line.

In the case of the multi-gauge strip 11 having two thick parts 13 and 13, the hardness H1 of the thin part 12 is measured on the center line CL of the multi-gauge strip 11 and the hardness H2 of the thick parts 13 and 13 is measured on the center line S₁ of either of the thick parts, as shown in Fig. 3. The hardness is expressed in terms of an average of five measurements on each line. The ratio of H1/H2 should be in the range from 0.9 to 1.15, where H1 is the hardness of the thin part 2 or 12 and H2 is the hardness of the thick part 3 or 13.

The reason why the ratio of H1/H2 should be in the range from 0.9 to 1.15 is as follows. If the ratio is smaller than 0.9 or greater than 1.15, the multi-gauge strip 1 or 11 has such a large amount of uneven residual stress that it is subject to deformation (camber, cross bow, and twist) during stamping, (Fig. 6A), transistor mounting,

or terminal assembling. This greatly deteriorates productivity and yield. The ratio of $H1/H2$ should be 0.9-1.15, preferably 0.95-1.10, more preferably 0.98-1.05. The number of measurements may be smaller or larger than 5.

The multi-gauge strip is usually produced from a flat strip (or raw material) via an intermediate product. Fig. 10 shows the rolling steps used for the production of the multi-gauge strip of the present invention. The flat strip (raw material) should undergo rough rolling and finish rolling with an adequate reduction in thickness under adequate heat treatment conditions according to its alloy composition and the finished cross section (thickness of thick parts and thin parts) so that the resulting multi-gauge strip has satisfactory mechanical properties (hardness, tensile strength, proof stress, elongation, etc.) and good electrical conductivity.

- Flat strip (or raw material): A slab of copper or copper alloy is produced by continuous casting or semicontinuous casting. The slab is formed into a sheet by hot rolling, cold rolling, and heat treatment. The sheet is slit into flat strips of desired dimensions. The flat strip may be either as-rolled one or as-annealed one. The thus obtained flat strip has uniform hardness ($H0$) in both the lengthwise direction and the widthwise direction. The flat strip has a thickness of $T0$.

- Intermediate product: The flat strip undergoes rough rolling by a Pilger rolling mill or a rolling mill composed of a grooved roll and a flat roll, so that it has a thick part (with a thickness of $T12$) and a thin part (with a thickness of $T11$). Rough rolling is carried out such that the reduction in thickness is small in the thick part and large in the thin part. The thick part has a hardness of $H12$ and the thin part has a hardness of $H11$. Then, $H11$ is larger than $H12$ because the thin part has a larger value of reduction in thickness than the thick part.

The thus obtained intermediate product undergoes annealing for recovery of ductility. The thick part has a hardness of $H22$ and the thin part has a hardness of $H21$. Then, $H22 \geq H21$ because the thin part has a larger value of reduction in thickness than the thick part and it is softened more by annealing.

Finished multi-gauge strip: The annealed intermediate strip undergoes finish rolling with a rolling mill composed of a grooved roll and a flat roll. (The grooved roll has a concave part of desired depth at a prescribed position in the widthwise direction). The thick part has a thickness of $T32$ and the thin part has a thickness of $T31$.

The thick part has a hardness of H32 and the thin part has a hardness of H31. The values of hardness depends on the reduction in thickness.

According to the present invention, the ratio of H31/H32 should be from 0.9 to 1.15. To this end, it is necessary to select adequate rolling conditions for reduction in thickness and annealing.

(3) Cutting method and measurements of displacement

According to the present invention, the multi-gauge strip 1 or 11 should have a specific displacement after cutting. Cuts are made at specific positions shown in Figs. 1 to 4. A sample of length L_2 (200-500 mm) is taken from the multi-gauge strip 1 or 11 of standard length L . Cuts are made at five positions as shown in Figs. 2 and 4. The length L_1 of Cut is 1.2-5 times the width of the multi-gauge strip 1 or 11.

The amount and angle of displacement are measured at the end at which cutting starts. The five positions for cutting (in the case of the multi-gauge strip 1) are shown in Fig. 2. The first position e is at the center of the width W . The second and third positions b_1 and b_2 are at the boundary between the thin part 2 and the thick part 3. The fourth and fifth positions C_1 and C_2 should be 0.5 to 2.5 mm from both edges in thin part 2. These positions correspond to ones to be slit in the stamping process to produce lead frame. Cutting should be accomplished by electric discharge machining or chemical etching so as to prevent new strains from entering the multi-gauge strip 1.

The length (L_1 of cut should be 1.2-5 times the width W of the multi-gauge strip 1 or 11. (If the sample is cut over its entire length, it is impossible to measure the magnitude of displacement.) If the length of cut is smaller than 1.2 times the width W , displacement due to residual stress does not appear. If the length of cut is larger than 5 times the width W , displacement due to residual stress is affected by gravity.

Displacement is measured in the following manner. Assuming that the multi-gauge strip 1 has a width (W) of 65 mm, a sample having a length (L_2) of 200 mm is taken and cuts (about 150 mm long in the lengthwise direction) are made by electric spark machining at five positions (e , b_1 , b_2 , C_1 , C_2). Prior to cutting, marks are made at a_1 and a_2 (2 mm inside from the shoulders of the thick part 3) symmetrical with respect to the central cutting line e . The distance Δd between a_1 and a_2 is measured before and after cutting by using a projector (with a magnification of 30 to 100).

The multi-gauge strip 11 shown in Figs. 3 and 4 is tested in the same way as the multi-gauge strip 1. That is, they are the same in the sample length L_2 , the width W , the cut length, and the cutting method. Cuts are made at five positions. The first position e is at the center of the width W . The second and third positions b_1 and b_2 are at the boundary between the outer thin part 12 and the thick part 13. The fourth and fifth positions c_1 and c_2 are in the thin part 12 at both edges to be slit. Prior to cutting, marks are made at a_1 and a_2 (2 mm inside from the shoulders of the thick parts 13 and 13) symmetrical with respect to the central cutting line e . The distance Δd between a_1 and a_2 is measured before and after cutting by using a projector (with a magnification of 30 to 100).

The amount of displacement is obtained from the equation (1) below.

$$d - \Delta d \quad (1)$$

(where d is the length of distance before cutting, and Δd is the length of distance after cutting.)

According to the present invention, the value calculated from the equation (1) should be smaller than 0.15 mm.

The amount of displacement between two points a_1 and a_2 on the thick part of the multi-gauge strip is proportional to the magnitude of residual stress stored in the multi-gauge strip 1 or 11. If the amount of displacement is greater than 0.15 mm, then the following troubles occur in the multi-gauge strip 1 having one thick part 3 or in the multi-gauge strip 11 having two thick parts 13 and 13. The multi-gauge strip (as a blank 1A) does not permit smooth stamping for fabrication into a lead frame (1B), shown in Fig. 6A and 6B. During stamping, the main body 3A and terminals 2B clog the stamping die. Also, poor wire bonding and deformed terminals occur during transistor mounting and terminal assembling. Therefore, the amount of displacement should be smaller than 0.15 mm, preferably smaller than 0.1 mm, and more preferably smaller than 0.05 mm.

The angle of displacement is measured in the following manner. Fig. 5 is a schematic diagram showing the cross section of the multi-gauge strip 1 which has been cut. (The cross section is viewed in the direction of cut.) The symbol θ denotes the angle of inclination to the base horizontal line SL of the thin part 2. The angle of θ is determined by measuring the positions of P_1 and P_2 shown

in Fig. 5B. For measurement, a sample of the multi-gauge strip 1, in which cuts have been made, is placed on a movable table 5 and moved under the projector 7 (with a magnification of 30 to 100). In other words, the length A and the length B are calculated from the positions P_1 and P_2 and the angle of θ is obtained from the equation (2) below.

$$\theta = \tan^{-1}(B/A) \quad (2)$$

The same procedure as mentioned above is applied also to the multi-gauge strip 11 shown in Figs. 3 and 4. That is, the outer thin part 12a, which has been cut at the outer boundary b_2 between the thick part and the thin part, is examined under the projector, and the angle of θ is calculated from the equation (2) above.

According to the present invention, the angle of θ thus measured should be smaller than 4° . The reason for this is explained below. The angle of inclination to the base horizontal line SL of the thin part after cutting is proportional to the amount of residual stress stored in the multi-gauge strip 1. If the angle of θ is greater than 4° , then the following troubles occur in the multi-gauge strip 1 having one thick part 3 or in the multi-gauge strip 11 having two thick parts 13 and 13. The multi-gauge strip (as a blank 1A) does not permit smooth stamping for fabrication into a lead frame (1B), shown in Fig. 6A. During stamping, the main body 3A and terminals 2B clog the stamping die. Also, poor wire bonding and deformed terminals occur during transistor mounting and terminal assembling. Therefore, the angle of inclination should be smaller than 4° , preferably smaller than 3° , and more preferably smaller than 2° .

The direction of the angle of θ may be upward with respect to the base horizontal line SL. In this case, too, the angle of inclination should be smaller than 4° . Incidentally, the base horizontal line SL coincides with the lower surface of the multi-gauge strip 1 or 11.

(4) Method of leveling

Fig. 8 is a schematic diagram showing the tensile leveling machine for the multi-gauge strip 1 or 11. The multi-gauge strip 1 or 11, which has undergone finish rolling, slitting, and winding up, is passed through the leveling machine which carries out leveling by application of a tensile stress in the following manner.

As shown in Figs. 8 and 9A, the multi-gauge strip 1 is unwound from the pay-off reel 38 and wound up onto the tension reel 39. (The

first step) This state is maintained while the feeding of the multi-gauge strip 1 is suspended. (The second step) The gripping cylinders 34 and 36 are lowered so that the thick part 3 and the thin parts 2 and 2 of the multi-gauge strip 1 are gripped by the die 30. (The third step) The left die 30 is moved leftward by means of the stretching cylinder 35. (The fourth step) Since the right die 30 is fixed, the multi-gauge strip 1 receives a tensile force. The left die 30 is moved a prescribed distance (necessary for leveling), and then the stretching cylinder 35 is stopped. (The sixth step)

The stretching cylinder 35 is actuated again so that the die 30 is restored. (The seventh step) The left and right gripping cylinders 34 and 36 are raised to open the dies 30 and 30, so that the multi-gauge strip 1 is released. (The eighth step) The tension reel 39 is turned to wind up the leveled multi-gauge strip, which is as long as the distance between the left and right dies 30 and 30. (The ninth step) The third and subsequent steps are repeated. Incidentally, the distance between the two dies 30 and 30 is the length of the multi-gauge strip 1 to be leveled at one time. The upper and lower dies are indicated by 31 and 32.

The leveling machine shown in Fig. 8 has the left and right dies 30 and 30, which grip the thick part 3 and the thin parts 2 and 2 of the multi-gauge strip 1 at the same time, thereby applying a tensile force in the lengthwise direction, causing the multi-gauge strip 1 to undergo plastic deformation. The longer the distance between the left and right dies 30 and 30, the longer the multi-gauge strip that can be leveled at one time. This contributes to productivity and facilitates the control of the dies 30 and 30 for the same elongation. On the other hand, the gripping cylinders 34 and 36 and the stretching cylinder 35 need to have a large capacity and hence the leveling machine needs a large installation area. If the distance between the left and right dies 30 and 30 is small, the leveling machine is poor in productivity and cannot apply uniform plastic deformation to the multi-gauge strip. For this reason, the distance between the left and right dies 30 and 30 should be about 3 to 10 m.

The die 30 which comes into contact with the multi-gauge strip 1 may be formed from tool steel. It should have its contact surface covered with urethane coating so that it does not damage the multi-gauge strip 1. For the multi-gauge strip 11, the die 30a or 39b as shown in Fig. 9B or Fig. 9C, respectively, should be used which conforms to the shape of the multi-gauge strip 11 and fits to the thick parts 13 and 13 and the thin part 12.

The amount of plastic deformation (or elongation) to be added to the multi-gauge strip 1 or 11 should be 0.05-1%. The amount of elongation is controlled by the distance ΔL over which the die moves, and the distance ΔL is approximately represented by the equation (3) below.

$$\Delta L = \delta \times L_0 \quad (3)$$

(where L_0 is the distance between the left and right dies, and δ is the value (0.0005-0.001) of plastic deformation.)

The effect of leveling treatment can be confirmed by cutting a sample of the multi-gauge strip 1 or 11 at five positions (e , b_1 , b_2 , c_1 , c_2) explained above (in the paragraph (3) Cutting method and measurements of displacement). if desired leveling effect is not produced, as much stretching as before or more stretching than before may be repeated so long as the amount of plastic deformation is less than 1% (based on the length before leveling).

The application of tensile stress to the multi-gauge strip 1 or 11 should preferably be carried out after the final step (or slitting) of production; however, leveling may be followed by slitting. The leveled multi-gauge strip 1 or 11 may be slit before stamping.

With insufficient leveling (less than 0.05%), the multi-gauge strip will pose problems with stamping and lead-frame mounting (see Fig. 6) in the subsequent steps. With excessive leveling (more than 1%), the multi-gauge strip is poor in dimensional accuracy or has residual stress in the lengthwise direction, which adversely affects the subsequent steps. Therefore, the adequate amount of plastic deformation (or tensile leveling) should be 0.05-1%, preferably 0.1-0.6%, more preferably 0.2-0.5%. Tensile leveling may be repeated twice or more so long as the total amount of leveling is within the above-mentioned value.

The invention will be described in more detail with reference to the following examples, which are not intended to restrict the scope thereof.

Example 1

(Preparation of multi-gauge strip)

A slab of phosphor deoxidized copper (Cu-0.035P) was produced by semicontinuous casting. The slab was hot-rolled and cold-rolled into a

coiled sheet, 2.1-3.2 mm thick and 600 mm wide. The sheet was slit into a strip 70 mm wide.

This strip was made into a multi-gauge strip (shown in Fig. 1) specified below in the following manner.

Width W: 65 mm, width D, of central thick part: 34 mm, thickness T, of thin part: 0.4 mm, thickness T2 of thick part: 1.27 mm, angle α of slope of thick part: 10° (80°C to horizontal line). Production step: Rough shaping (by Pilger rolling), annealing (at $350\text{--}450^\circ\text{C}$ for 2 hours), finish rolling, and slitting.

The hardness of the thick and thin parts was controlled by changing the reduction in thickness in rough shaping, the annealing temperature, and the reduction in thickness in finish rolling. The thus obtained multi-gauge strip has hardness (Hv) as shown in Table 1.

(Preparation of samples)

Three multi-gauge strips (designated as Nos. 1 to 3 in Table 1) were prepared. Three pieces (about 300 mm long) were taken from each of the multi-gauge strips. Each piece had its ends (about 50 mm) cut by an electric spark machine (with a wire diameter of 0.5 mm). Thus there was obtained a 200-mm long sample. Two marks were made on the cut surface, each 2 mm inside from the shoulder of the thick part. The distance between the two marks was measured by using a projector provided with an X-Y moving table. Five marks were made on the cut surface (one at the center of the width, one each at the boundary between the thick part and the thin part, and one each 1 mm inside from the edges). Cuts (150 mm long) were made in the lengthwise direction at the five marks by using an electric spark machine (with a wire diameter of 0.5 mm).

(Press-punching test and measurement of strain)

Each of the coils (Nos. 1 to 3) was punched into lead frames by using a punching press. The punched product was halved in the widthwise direction. The halved frame was cut in a length of 200 mm. The resulting sample was examined for cross bow.

Each sample was examined for the distance of the marks and the inclination of the thin part by using a projector (with a magnification of 100), provided with an X-Y moving table. The distance of the marks is expressed in terms of an average of three measurements. The sample was examined for A and B (shown in Fig. 5) by

using a projector provided with an X-Y moving table. The angle (θ) of inclination of the thin part was calculated from A and B. It is expressed in terms of an average of six measurements (three each for right and left).

Table 1

	No.	Hardness H1 of thin part	Hardness H2 of thick part	H1/H2	Cross bow of lead frame	Variation in dimensions at shoulders of thick part	Inclination of thin part
Example 1	1	1.23	1.17	1.05	none	+0.03	0.7
	2	1.18	1.19	0.99	none	+0.05	0.8
	3	1.12	1.22	0.93	Very small	+0.09	1.2
Comparative Example	4	1.09	1.24	0.88	Large	+0.38	5.8

Note: In variation in dimensions at shoulders of thick part, the + sign indicates expansion and the - sign indicates contraction.

(Results)

Table 1 shows the results of measurements of the cross bow and strain of the halved lead frame. Samples Nos. 1 to 3 in Example 1 show very small or undetectable cross bow and very small strain (variation in dimensions between two points at the shoulders and inclination of the thin part). By contrast, Sample No. 4 in Comparative Example shows noticeable cross bow (as well as twist in the lead). It shows a large strain due to imbalance between the hardness of the thick part and the hardness of the thin part. (The result is a large variation in dimensions and a large angle of inclination.)

Example 2

(Leveling)

The multi-gauge strips Nos. 1 to 4 were passed through a tensile leveling machine specified below for a specific amount of leveling. The resulting samples are designated as Nos. 1-2, 2-2, 3-3, 2-3, and 4-2.

- Distance between dies: 6 m
- Width of die: 85 mm
- Length of die: 200 mm

(Preparation of samples and measurement of strain)

The same procedure as in Example 1 was repeated.

Table 2

	No.	Amount of tensile leveling M	Hardness H1 of thin part	Hardness H2 of thick part	H1/H2	Cross bow of lead frame	Variation in dimensions at shoulders of thick part	Inclination of thin part
Example 2	1-2	0.3	1.23	1.17	1.05	none	+0.01	0.4
	2-2	0.3	1.18	1.19	0.99	none	+0.02	0.6
	3-2	0.4	1.12	1.22	0.92	Very small	+0.06	0.8
Comparative Example	2-3		1.18	1.19	0.99	none	-0.16	0.9
	4-2		1.09	1.24	0.88	Large	+0.22	4.3

(Results)

Sample Nos. 1-2, 2-2, and 3-2 in Example 2 decreased in strain after cutting owing to the leveling treatment. By contrast, Sample No. 4-2 in Comparative Example has a larger value of strain than samples in Example 1 although the value of strain itself decreases after leveling. In addition, Sample No. 4-2 suffered cross bow after fabrication into lead frame. Sample No. 2-3 in Comparative Example showed a change (contraction) in dimensions between two points at shoulders and an increase in the angle of inclination of the thin part. This is because the amount of plastic deformation for tensile leveling was greater than 1%.

Example 3

(Preparation of multi-gauge strip)

A slab of phosphor deoxidized copper (Cu-0.035P) was produced by semicontinuous casting. The slab was hot-rolled and cold-rolled into a coiled sheet, 2.1-3.2 mm thick and 600 mm wide. The sheet was slit into a strip 110 mm wide.

This strip was made into a multi-gauge strip (shown in Fig. 3) specified below in the following manner.

Width W: 130 mm, width D₃ of central thin part: 36 mm, width D₁ of each of thick part: 34 mm, width D₂ of each of outer thin part: 15.5 mm.

A coiled sheet, 2.1-3.2 mm thick and 110 mm wide, was formed by rough shaping (by Pilger rolling), annealing at 350-450°C for 2 hours, finish rolling, and slitting. The multi-gauge strip varies in the hardness of the thick part and the hardness of the thin part depending on the reduction in thickness in rough shaping, the annealing temperature, and the reduction in thickness in finish rolling. Table 3 shows the hardness (Hv) of the multi-gauge strips (Nos. 5 to 8) thus obtained.

(Press-punching test)

Each of the coils (Nos. 5 to 8) was punched into lead frames by using a punching press. The punched product was divided into four parts in the widthwise direction. The divided frame was cut in a length of 200 mm. The resulting sample was examined for cross bow. (See Figs. 3 and 5.)

(Cutting of samples for strain measurement)

Four multi-gauge strips (designated as Nos. 5 to 8 in Table 3) were prepared. Three pieces (about 300 mm long) were taken from each of the multi-gauge strips. Each piece had its ends (about 50 mm) cut by an electric spark machine (with a wire diameter of 0.5 mm). Thus there was obtained a 200-mm long sample. Two marks were made on the cut surface, each outside the outer thick part. (See Fig. 3.) The distance between the two marks was measured by using a projector provided with an X-Y moving table. (See Fig. 5. Five marks were made on the cut surface (one at the center of the width, one each at the boundary between the outer thick part and the outer thin part, and one each 1 mm inside from the edges). Cuts (150 mm long) were made in the lengthwise direction at the five marks by using an electric spark machine (with a wire diameter of 0.5 mm). (Measurement of strain of the cut sample)

The same procedure as in Example 1 was repeated.

Table 3

	No.	Hardness H1 of thin part	Hardness H2 of thick part	H1/H2	Cross bow of lead frame	Variatio n in dimensio ns at shoulder s of thick part	Inclinat ion of thin part
Example 3	5	1.23	1.18	1.04	none	+0.03	0.6
	6	1.17	1.18	0.99	None	+0.06	0.9
	7	1.12	1.20	0.93	Very small	+0.08	1.5
Comparat ive Example	8	1.09	1.25	0.88	Large	+0.45	6.2

(Results)

Table 3 shows the results of measurements of the cross bow and strain of the quartered lead frame. Samples Nos. 5 to 7 in Example 3 show very small or undetectable cross bow and very small strain (variation in dimensions between two points at the outer shoulders and inclination of the thin part). By contrast, Sample No. 8 in Comparative Example shows noticeable cross bow due to imbalance between the hardness of the thick part and the hardness of the thin part. (The result is a large variation in dimensions and a large angle of inclination.)

Example 4

(Leveling)

The multi-gauge strips Nos. 5 to 8 were passed through a tensile leveling machine specified below for a specific amount of leveling. The resulting samples are designated as Nos. 5-2, 6-2, 7-2, 6-3-, and 8-2.

- Distance between dies: 6 m
- Width of die: 120 mm
- Length of die: 200 mm

(Preparation of samples and measurement of cross bow and strain)

The same procedure as in Example 1 was repeated to prepare samples and to measure cross bow and strain.

Table 4

	No.	Amount of tensile leveling (%)	Hardness H1 of thin part	Hardness H2 of thick part	H1/H2	Cross bow of lead frame	Variation in dimensions at shoulders of thick part	Inclination of thin part
Example 4	5-2	0.3	1.23	1.118	1.04	none	+0.02	0.5
	6-2	0.35	1.17	1.18	0.99	none	+0.04	0.6
	7-2	0.4	1.12	1.20	0.93	none	+0.06	0.9
Comparative Example	6-3	1.3	1.17	1.18	0.99	none	-0.11	0.9
	8-2	0.1	1.09	1.25	0.88	Large	+0.32	4.8

(Results)

Sample Nos. 5-2, 6-2, and 7-2 in Example 4 decreased in strain after cutting owing to the leveling treatment. By contrast, Sample No. 8-2 in Comparative Example has a larger value of strain than Sample Nos. 5 to 7 in Example 3 although the value of strain itself decreases after leveling. Sample No. 6-3 in Comparative Example showed a change (contraction) in dimensions between two points at shoulders and an increase in the angle of inclination of the thin part. This is because the amount of plastic deformation for tensile leveling was greater than 1%.

Example 5

(Preparation of multi-gauge strip)

A slab (150 mm thick, 500 mm wide, and 4000 mm long) of C19210 (CU-0.1Fe-0.03P) was produced by semicontinuous casting. The slab was hot-rolled into a hot coil, 15 mm thick. The hot coil was cold-rolled into a 2.6 mm thick sheet, which subsequently underwent heat treatment at 500°C for 2 hours. The heat-treated coil was cold-rolled into a 2.0 mm thick sheet. This sheet was slit to form a 50 mm wide flat strip for multi-gauge strips.

The flat strip was made into a multi-gauge strip by Pilger rolling and rolling with a grooved roll and a flat roll. The intermediate strip was continuously annealed at a rate of 13 m/s in an annealing furnace (at a temperature of 725°C and with a 20 m long heating zone). The annealed strip underwent finish rolling with a grooved roll and a flat roll. Thus there was obtained the desired multi-gauge strip specified below.

Thickness of thick part: 1.25 mm

Thickness of thin part: 0.40 mm

Width of thick part: 29 mm

Width of thin part: 28 mm

Overall width: 75 mm

Angle of side wall of thick part: 15°

The intermediate multi-gauge strip was rolled under different conditions so that the thin part varies in thickness. Annealing was carried out under different conditions so that the amount of softening varies. Finish rolling was carried out under different conditions so that the amount of work hardening varies and the hardness of the thin

part varies. Table 5 shows the thickness of the thick part and thin part of the intermediate multi-gauge strip and the finished multi-gauge strip.

Table 5

	No.	Intermediate multi-gauge strip		Finished multi-gauge strip	
		Thin part	Thick part	Thin part	Thick part
Example 5	9	0.48 mm	1.60 mm	0.40 mm	1.25 mm
Comparative	10	0.80 mm	1.60 mm	0.40 mm	1.25 mm
Example	11	0.43 mm	1.60 mm	0.40 mm	1.25 mm

(Measurement of hardness)

The multi-gauge strip prepared as mentioned above was examined for the hardness (Hv) of the thin part and the hardness of the thick part. The results are shown in Table 6. In this example, the thin part and the thick part have the same hardness.

Sample No. 10 in Comparative Example is characterized in that the hardness of the thin part is much greater than that of the thick part. This is because the reduction in thickness is small in the rolling of the intermediate multi-gauge strip, the amount of softening is small in annealing, and the reduction in thickness in finish rolling is large (which results in much work hardening).

Sample No. 11 in Comparative Example is characterized in that the hardness of the thin part is smaller than that of the thick part. This is because the reduction in thickness is large in the rolling of the intermediate multi-gauge strip, the amount of softening is large in annealing, and the reduction in thickness in finish rolling is small (which results in less work hardening).

Table 6

	No.	Hardness of thin part (H1)	Hardness of thick part (H2)	H1/H2
Example 5	9	120	120	1.0
Comparative Example	10	145	120	1.21
	11	104	120	0.87

(Results)

The multi-gauge strips in Examples and Comparative Examples were fabricated into lead frames by continuous stamping. The multi-gauge strips in Example 5 posed no problems with stamping and the resulting lead frames had no cross bow. By contrast, the multi-gauge strips in

Comparative Example clogged the stamping die, and the stamped lead frame (Sample No. 10) suffered cross bow and twist. This is attributable to great residual stress. The multi-gauge strip (Sample No. 11) caused no problems with stamping but the punched lead frames suffered slight cross bow.

According to the present invention, it is possible to produce multi-gauge strips having a small mount of residual stress (strain). Such multi-gauge strips contribute to productivity and yields in pressing, transistor mounting, and terminal assembling because they do not suffer deformation such as elongation, contraction, camber, cross bow, and twist.

The multi-gauge strip of the present invention is rolled such that the stress distribution varies from the thin part to the thick part. Therefore, the thin part has a hardness of H_1 and the thick part has a hardness of H_2 such that the ratio of H_1/H_2 is in the range of 0.9 to 1.5. This value suggests that the multi-gauge strip has adequately distributed residual stress, and this value also permits one to judge whether or not the residual stress is adequately distributed.

According to the present invention, the multi-gauge strip is evaluated by measuring the displacement between two points (which occurs when cuts are made in the sample as specified) and by measuring the angle of inclination of the thin part. The results of measurements permit one to judge whether or not the stress is distributed adequately at the position where residual stress tends to accumulate. This permits one to judge whether or not the given multi-gauge strip is suitable for further fabrication.

According to the present invention, the multi-gauge strip is given a tensile stress which brings about plastic deformation in the range of 0.05 to 1% in the lengthwise direction. The thus applied tensile stress levels the multi-gauge strip having residual stress and hence minimizes residual stress which has accumulated during manufacturing.

WHAT IS CLAIMED IS:

1. A multi-gauge strip with a cross section which has one or more thin parts and one or more thick parts formed across its width by rolling, with said cross section being uniformly continuous in the lengthwise direction, which is characterized in that the or each thin part has a hardness of H1 and the or each thick part has a hardness of H2, with the ratio of H1/H2 being in the range from 0.9 to 1.15,

wherein an inner thick part is formed at an inner portion of the width and an outer thin part is formed at each outer side of the inner thick part, and

wherein a central thin part is formed at the centre of the width and the inner thick part is two separate thick parts formed symmetrically on either side of the central thin part.

2. A multi-gauge strip defined in claim 1, wherein when the multi-gauge strip is cut at one of its ends and in its lengthwise direction for a distance of 1.2 to 5 times its width at five positions across the width of the strip, one at the center of the width, one at each boundary between the outer thin parts and the outer sides of the inner thick part, and one each at the outer edge of each outer thin part, a dimensional variation of the cut end of the strip is less than a predetermined amount.

3. A multi-gauge strip with a cross section which has one or more thin parts and one or more thick parts formed across its width by rolling, with said cross section being uniformly continuous in the lengthwise direction, which is characterized in that the or each thin part has a hardness of H1 and the or each thick part has a hardness of H2, with the ratio of H1/H2 being in the range from 0.9 to 1.15,

wherein an inner thick part is formed at an inner portion of the width and an outer thin part is formed at each outer side of the inner thick part, and

wherein when the multi-gauge strip is cut at one of its ends and in its lengthwise direction for a distance of 1.2 to 5 times

its width at five positions across the width of the strip, one at the center of the width, one at each boundary between the outer thin parts and the outer sides of the inner thick part, and one each at the outer edge of each outer thin part, a dimensional variation of the cut end of the strip is less than a predetermined amount.

4. A multi-gauge strip defined in claim 3, wherein the inner thick part is a unitary thick part formed at the centre of the width.

5. A multi-gauge strip defined in claim 2, 3 or 4, wherein the dimensional variation is a variation of the distance between two points which are symmetrical with respect to the center of the width and the predetermined amount is 0.15 mm.

6. A multi-gauge strip defined in claim 2, 3 or 4, wherein the dimensional variation is a variation of the angle of inclination of one of said outer thin parts to a base line of the inner thick part and the predetermined amount is 4°.

7. A method of testing for residual stress in a multi-gauge strip, the strip having a cross-section which has one or more thin parts and one or more thick parts across its width which are formed by rolling along the length of the strip, said cross section being uniformly continuous in the lengthwise direction with an inner thick part formed at an inner portion of the width and an outer thin part formed at each outer side of the inner thick part, the method including the steps of:

- (a) cutting the multi-gauge strip at one of its ends and in its lengthwise direction for a distance of 1.2 to 5 times its width at five positions across the width, one at the center of the width, one at each boundary between the outer thin parts and the outer sides of the inner thick part, and one each at the outer edge of each outer thin part, and
- (b) measuring a dimensional variation of the cut end of the strip, and

(c) determining whether the measured variation is less than a predetermined amount.

8. A method of testing as defined in claim 7, wherein the dimensional variation is a variation of the distance between two points which are symmetrical with respect to the center of the width and the predetermined amount is 0.15 mm.

9. A method of testing as defined in claim 7, wherein the dimensional variation is a variation of the angle of inclination of one of said outer thin parts to a base line of the inner thick part and the predetermined amount is 4°.