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Winter et al.

[11] **3,866,451**

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[54] **METHOD FOR PRODUCING MULTIPLE GAUGE STRIP**

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[51] **Int. Cl.** **B21b 1/10**

[58] **Field of Search** 72/199, 365, 366

[56] **References Cited**

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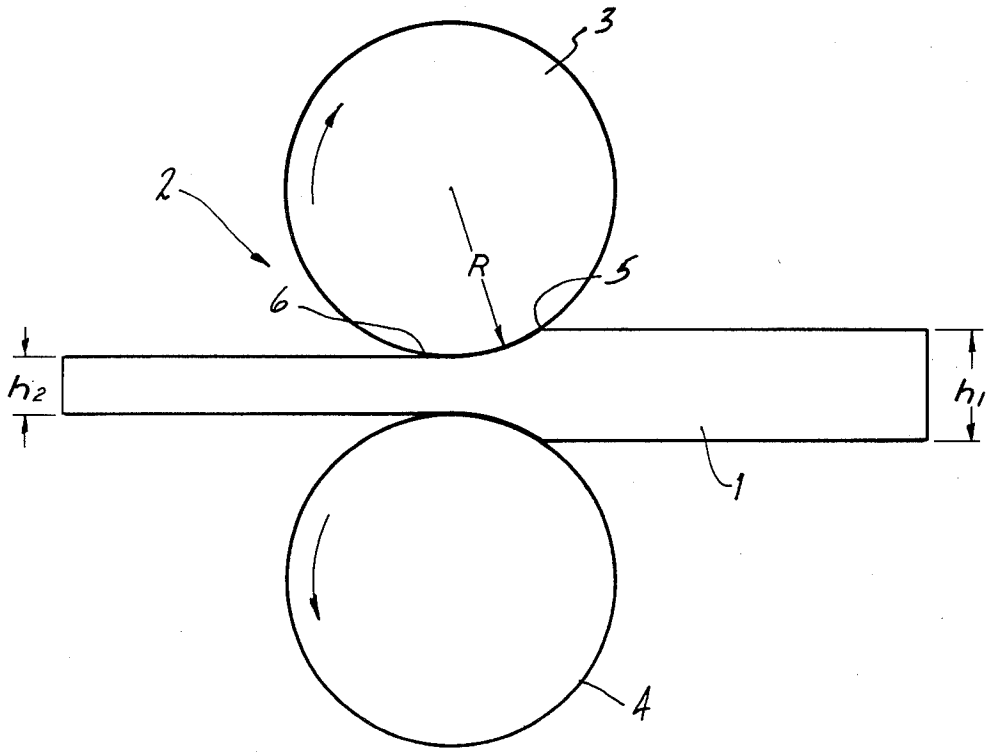
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[57] **ABSTRACT**

A method for the preparation of multiple gauge metal strip possessing improved dimensional precision is disclosed which comprises passing the strip through a grooved roll assembly whereby strip reduction is confined to the area of contact with the grooves. The roll assembly of this invention employs a grooved upper roll whose dimensions are defined by the ratio of the length of the arc of contact of the upper roll with the strip to the width of the groove. The method of this invention is advantageously employed as a single pass operation.

19 Claims, 3 Drawing Figures



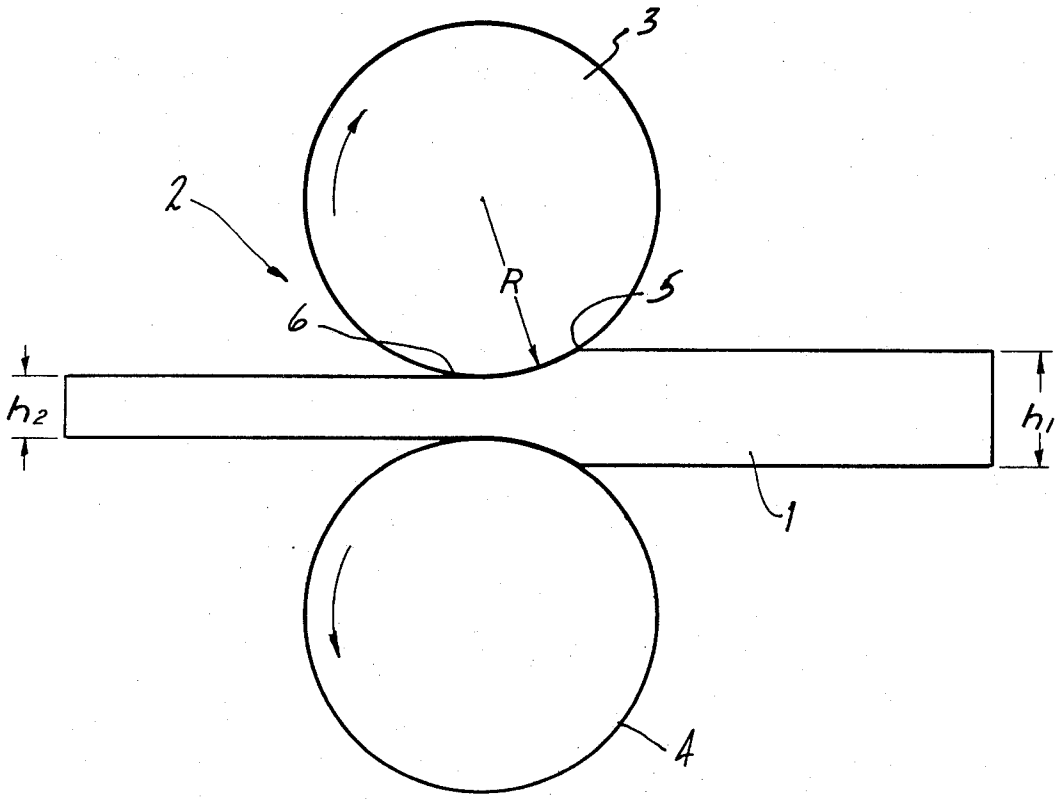


FIG-1

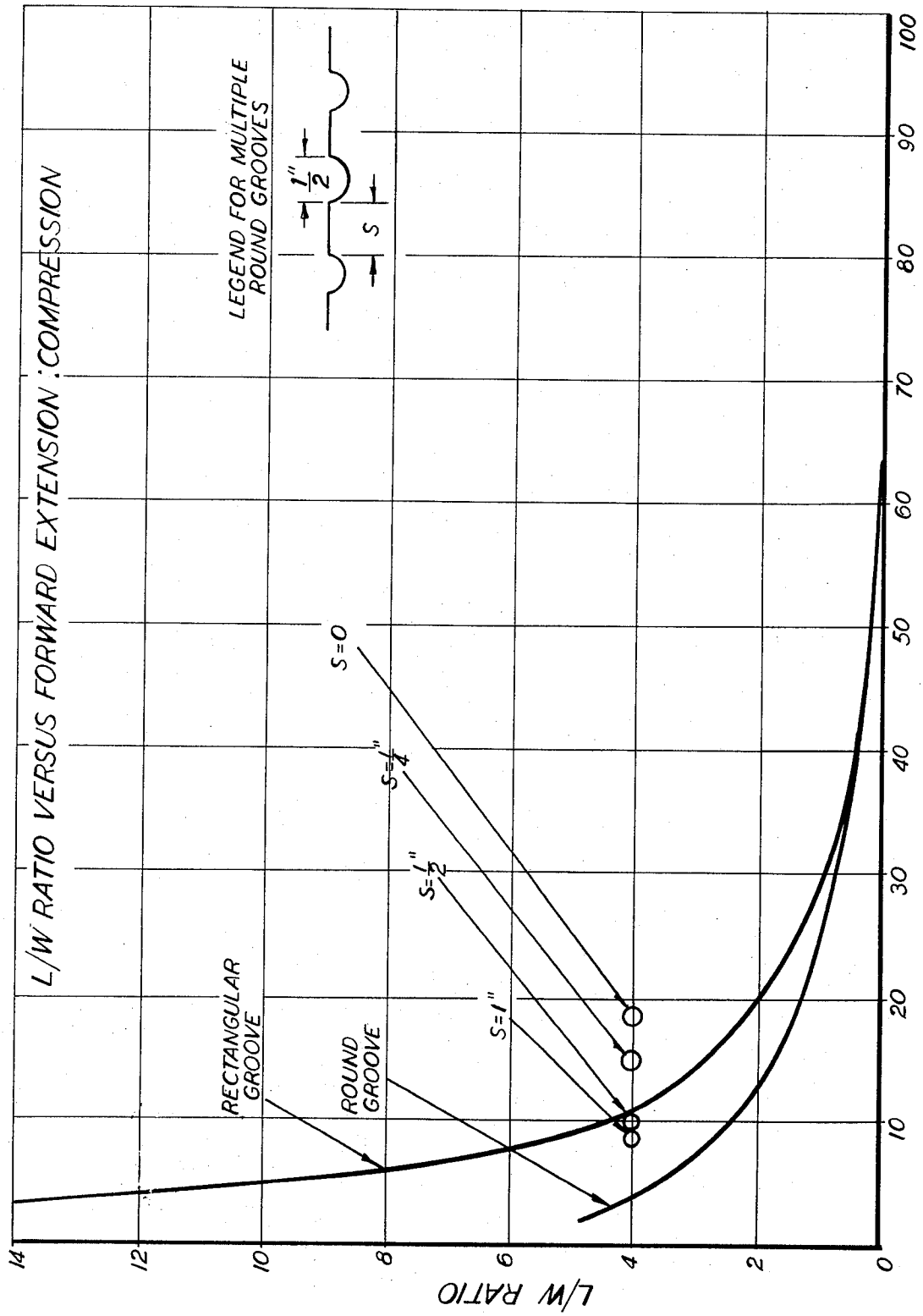

L/W RATIO VERSUS FORWARD EXTENSION : COMPRESSION
LEGEND FOR MULTIPLE ROUND GROOVES
1"/2
S
S=0
S=1/4"
S=1/2"
S=1"
RECTANGULAR GROOVE
ROUND GROOVE
L/W RATIO
FORWARD EXTENSION, %
0
2
4
6
8
10
12
14
10
20
30
40
50
60
70
80
90
100

FIG-2

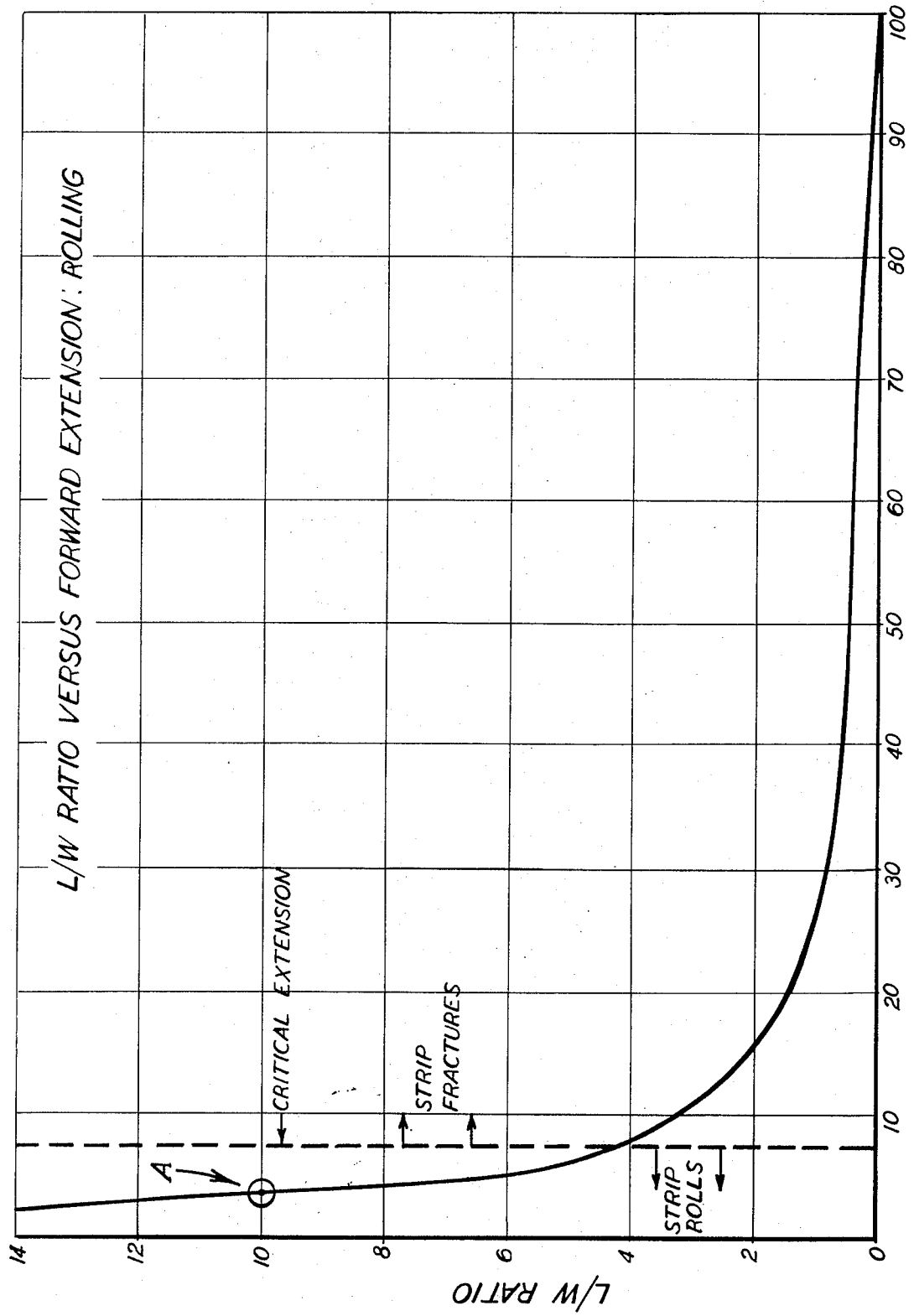

L/W RATIO VERSUS FORWARD EXTENSION: ROLLING
L/W RATIO
FORWARD EXTENSION, %
CRITICAL EXTENSION
STRIP FRACTURES
STRIP ROLLS
A
0
2
4
6
8
10
12
14
10
20
30
40
50
60
70
80
90
100

FIG-3

METHOD FOR PRODUCING MULTIPLE GAUGE STRIP

BACKGROUND OF THE INVENTION

This invention relates to a method for the preparation of multiple gauge metal strip by a grooved rolling operation whereby strip reduction is confined to the area of contact with the grooves.

In many applications, such as the production of copper strip for the formation of electrical connectors and the like, it is necessary to provide a multiple gauge thickness in the metal strip. Heretofore, such conventional procedures as continuous milling and continuous scarfing have been employed to produce the desired variations in gauge. Such processes suffer from the disadvantages of being both high scrap intensive and time consuming.

Another procedure which has been investigated in the art is the reduction to gauge by a rolling operation. Rolling operations in production are normally only accurate to about **10%** and are not good enough to provide products meeting commercial tolerances that are free from structural defects such as camber, edge waves, buckling or longitudinal cracking. Rolling is employed in the steel where a variety of multiple gauge shapes are produced by hot rolling processes on blooming mills. Such processes are multipass operations which involve controlled incremental shape changes on each pass. Capital costs for such processes are high, but are justified for the steel industry by the high tonnage involved in the products. In industries such as the copper and brass industry, however, the annual tonnage for a particular multiple gauge part is small, and, therefore, any manufacturing method should ideally have low capitalization. Specifically, the use of a rolling operation to form multiple gauge products should be based on the capability of attaining final gauge in one pass.

SUMMARY OF THE INVENTION

In accordance with this invention, it has been found that a rolling operation for the production of multiple gauge metal strip may be employed which comprises passing the strip through a grooved roll assembly whereby strip reduction is confined to the area of contact with the grooves. The roll assembly employs a grooved upper roll whose dimensions are defined by the ratio of the length of the arc of contact of the upper roll with the strip to the width of the groove. In addition, the method of this invention may be practiced utilizing a single pass procedure.

The method of this invention possesses the advantages of generating little or no scrap, and of greatly reducing the time necessary to manufacture the various multiple gauge products. The products of this invention possess unexpectedly improved dimensional precision, and are free from structural defects, such as strip curvature, buckling, and fracture.

It is, accordingly, a principle object of this invention to provide an improved method for the manufacture of multiple gauge metal strip which yields products possessing improved dimensional precision and freedom from structural defects.

It is another object of this invention to provide a method as aforesaid which generates little or no scrap and which requires reduced production time.

It is a further object of this invention to provide a method as aforesaid which comprises a rolling operation employing a dimensionally defined grooved upper roll in such manner as to confine strip reduction to the area of the grooves.

It is yet a further object of this invention to provide a method for the preparation of multiple gauge metal strip which comprises a rolling operation which may employ a single pass procedure.

Other objects and advantages will become more apparent to those skilled in the art as a detailed description follows with reference to the drawings.

DESCRIPTION OF THE DRAWINGS

FIG. **1** shows a schematic representation of a flat strip being passed through a conventional roll assembly.

FIG. **2** is a graph of L/W ratio and forward extension measured from samples employed in compression experiments.

FIG. **3** is a graph of L/W ratio and forward extension measured from samples employed in rolling experiments.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In accordance with this invention, a method for the preparation of multiple gauge metal strip is provided which yields dimensionally precise products free from structural defects, is less time consuming and produces little or no scrap.

The method of this invention comprises passing the strip through a grooved roll assembly such that strip reduction is confined to the area of contact with the grooves. The roll assembly of this invention employs a grooved upper roll whose dimensions are defined by the ratio of the length of the arc of contact of the upper roll with the strip to the width of the groove.

In a rolling operation, material in the roll bite flows in the direction of least resistance so as to accomodate the compressive deformation imposed by the rolls. The direction of least resistance is determined by two parameters, those being the forward and lateral lengths of contact, respectively, of the material with the rolls, such that the greater the length of contact in either direction, the greater the resistance to deformation in that direction. Thus, when rolling wide strip, lateral extension is limited and all of the deformation goes into lengthening the strip, or forward extension, according to the ratio of the two aforementioned contact lengths.

The above ratio is symbolically represented as L/W, where L is the forward length of contact and corresponds to the length of the arc of contact of the roll with the strip, and W is the lateral length of contact and corresponds to the width of the strip. The value of W is directly measured, however, the value of L as determined by the expression $L = \sqrt{R\Delta h}$, where, R is the radius of the roll, and Δh is the roll bite.

For assistance in illustrating the components of the above expression, reference is made to FIG. **1**, which is a schematic representation of a flat strip **1** being passed through a roll assembly **2** comprising an upper roll **3** and a lower roll **4**. Conventionally, and as depicted herein, both rolls take the same reduction on the strip, however, for purposes of illustration only, the value of L is determined in relation to upper roll **3**. L may, therefore, be visualized as the distance on the cir-

cumference of upper roll **3** which lies between the point **5**, where upper roll **3** first contacts strip **1**, and point **6**, where such contact ends.

As stated above, the value of L is determined by the expression $L = \sqrt{R\Delta h}$. Referring again to FIG. **1**, the roll radius, R, is depicted on upper roll **3**. The roll bite, Δh, is not directly measured, however, as it corresponds to the reduction in strip thickness due to the rolling pass, and is represented as follows:

$\Delta h = h_1 - h_2$

where,

h_1 is the thickness of strip **1** before passing through roll assembly **2**; and

h_2 is the thickness of strip **1** resulting from the pass.

Thus, having determined Δh by the above equation, the roll radius, R, may then be measured and both values substituted into the expression so as to determine the value of L.

The nature of a multiple gauge strip rolling operation is such that unequal reduction across the strip width occurs which normally causes unequal forward extension and results in strip curvature, buckling or fracture. Unequal reduction can only be successfully conducted if forward extension of the strip is minimized and lateral extension promoted. Expressed in terms of L and W, this means that high ratios of L/W are necessary. Such high L/W ratios may be attained by using rolls of large radius, taking large reductions in rolling and rolling narrow strip.

It has been found, in accordnce with this invention, that the successful formation of multiple gauge strip may be accomplished by a rolling operation if a grooved upper roll is employed which is set so as to confine the strip deformation to the area of contact of the strip with the grooves. The result of confining strip contact to the grooves is that the areas of the grooves provide the only lateral length of contact of the strip with the roll, which causes effective reduction in strip width, W, and thereby increases the L/W ratio. Additionally, when the confinement of strip reduction is practiced together with the use of large radius rolls and large reductions taken during the rolling pass, both the L/W ratio and the rolling speed are increased, and the number of rolling passes may be reduced so that final gauge is attained in one pass.

Those skilled in the art will readily appreciate that a wide range of roll sizes, roll reductions and groove widths may be selected within the scope of this invention which will maintain a high L/W ratio and yield satisfactory products. Likewise, the selection of operable L/W ratios is well within the ordinary skill of the art, and may vary according to the configuration of the rolled product desired.

In a preferred embodiment of the invention, it was determined that successful rolling of multiple gauge strip could be achieved if the L/W ratio is at least about 4:1, and preferably about 10:1. This value was derived from a series of experiments illustrating the principles of the invention which simulated the conditions encountered in the rolling of grooves in metal strip, and which are set forth in detail hereinbelow.

The following experiments are presented for purposes of illustration only, and should not be construed as limitative of the invention.

I - COMPRESSION EXPERIMENTS - SINGLE GROOVES

In order to investigate the partitioning of deformation into the forward and lateral directions as a function of contact lengths in those directions, single round and rectangular grooves were pressed into ½ inch thick plasticene plates. As deformation was conducted with flat grooved plates the value of L, like that of groove width W, could be directly measured. L/W was varied by changing the length of the plasticene plate and the width of the rectangular groove and forward extension was measured after each impression. The data which was gathered is presented in Tables I and II below.

TABLE I

COMPRESSION DATA: RECTANGULAR GROOVE

Groove Width, in.	Groove Length, in.	L/W	Forward Extension, %
0.275	0.125	0.45	100
0.275	0.260	0.94	73
0.275	0.520	1.90	44
0.275	1.100	4.00	14
0.760	0.180	0.24	73
0.760	0.350	0.46	85
0.760	0.740	0.97	53
0.760	1.480	1.95	28
0.760	2.680	3.52	12
1.550	0.400	0.26	87
1.550	0.750	0.48	86
1.550	1.580	1.00	42
1.550	3.100	2.00	21

TABLE II

COMPRESSION DATA: ROUND GROOVE

Groove Width, in.	Groove Length, in.	L/W	Forward Extension, %
½	0.125"	0.25	60
½	0.250"	0.50	40
½	0.500"	1.00	30
½	1.0"	2.00	12
½	2.0"	4.00	4

From the above Tables, it is apparent that, as L, represented by the groove length, increases in relation to the groove width, W, and the value of the L/W ratio increases, forward extension is significantly reduced. In addition, comparision of Tables I and II suggests that a difference in forward extension at a given L/W exists between rectangular and round grooves. Thus, for example, at a L/W ratio of 4.00, forward extension of the rectangular groove sample was 14 percent, while forward extension of the round groove was only 4 percent.

The data from Tables I and II is also presented in the graph in FIG. **2**, wherein L/W ratio is plotted as a function of forward extension (percent). Referring to FIG. **2**, the strong dependency of the degree of forward extension upon the L/W ratio is clearly shown. Further, FIG. **2** shows that the forward extension decreases at a faster rate for round rather than for rectangular groove samples, as the L/W ratio increases from about 0.400. Thus, the degree of forward extension is also dependent upon the shape of the groove. It is believed that round grooves cause less forward extension at a given L/W than rectangular grooves, because the area undergoing reduction is less for the former than for the latter, and the geometry at the bottom of the groove more easily promotes lateral flow.

II - COMPRESSION EXPERIMENTS - MULTIPLE GROOVES

This experiment was conducted in the same manner as discussed above, with the exception that multiple round grooves were formed. Four tests were conducted holding groove length and groove width, and thus, the L/W ratio, constant, while varying the distance maintained between the grooves. The data collected for samples is set forth in Table III below.

TABLE III

COMPRESSION DATA: MULTIPLE ROUND GROOVES

Groove Width, in.	Groove Length, in.	Groove Spacing, in.	L/W	Forward Extension, %
0.50	2	0.00	4	19
0.50	2	0.25	4	15
0.50	2	0.50	4	10
0.50	2	1.00	4	9

Referring to Table III, it can be seen that, as the distance between grooves, expressed as groove spacing, is increased at a constant value of L/W, forward extension decreases, and thus the forward extension is also dependent upon the spacing between grooves in a multiple groove deformation.

Data points are also plotted on FIG. 2 representing the four samples of the multiple groove experiment. As indicated in the legend provided with the graph, S represents the distance between the grooves. In this experiment, the groove widths were all maintained at ½ inch. The value of S which corresponds to a particular data point is indicated by an arrow.

Referring again to FIG. **2,** the data points are displaced about the curve which represents the rectangular groove data. The values of S which are less than groove width, W, are to the right of the curve, and, thus, exhibit the behavior of a single wide groove. The forward extension is increased, and the effective L/W ratio is decreased, with the result that groove formation is unsatisfactory. The data points based on values of S equal to or greater than groove width are to the left of the curve, exhibit the characteristics of a single rectangular groove and result in satisfactory groove formation.

III - ROLLING EXPERIMENTS

The rolling experiments were conducted on a hand driven rolling mill with 5 inch diameter rolls possessing rectangular grooves, and were performed on 4 inch × 6 inch × ½ inch plasticene sheets using liquid silicone as a lubricant. The validity of the compression experiment was checked by rolling the rectangular grooves of varying width and measuring the forward extension as a function L/W. A critical aspect of these experiments was that reduction was only taken in the grooves and not between them. The results of the rolling experiments are presented in Table IV, below.

TABLE IV

ROLLING DATA - RECTANGULAR GROOVE

Groove Width, in.	Roll Contact Length, in.	L/W	Forward Extension, %
0.25	1	4	7.3
0.50	1	2	15
1.00	1	1	27

Of the samples which were rolled in accordance with this experiment, only the sample possessing the groove with L/W equaling **4** rolled without strip fracture or buckling. Thus, a minimum L/W ratio of about **4** defines the maximum amount of lateral extension which could be tolerated in multiple gauge strip rolling.

The data compiled in Table IV is presented in FIG. **3,** which, like FIG. **2,** is a graph wherein L/W is plotted against forward extension. Referring to FIG. **3,** a dotted line intersects the curve at an L/W value of about **4** and represents the maximum forward extension tolerable to achieve a satisfactory rolled product. The line is set at about 7 percent and corresponds to the forward extension measured on the samples with the L/W ratio equaling **4** that rolled without strip fracture or buckling. In situations where the dimensional properties of the resulting strip product are more stringent, a preferred ratio of about 10:1 is suggested. This preferred L/W ratio has been circled and labeled "A" on FIG. **3.**

This invention may be embodied in other forms or carried out in other ways without departing from the spirit or essential characteristics thereof. The present embodiment is therefore to be considered as in all respects illustrative and not restrictive, the scope of the invention being indicated by the appended claims and all changes which come within the meaning and range of equivalency are intended to be embraced therein.

What is claimed is:

1. Method for the preparation of multiple gauge metal strip possessing improved structural quality and dimensional precision which comprises passing the strip through a grooved roll assembly comprising a dimensionally defined grooved upper roll, whereby strip reduction is confined to the area of groove contact and is determined by the ratio of L/W, L is defined as the length of the arc of contact of said upper roll with said strip, and W is defined as the width of the groove, and said L/W ratio is at least about **4.**

2. The method of claim **1** wherein said ratio is about 10:1.

3. The method of claim **1** wherein a single groove is defined by said upper roll.

4. The method of claim **3** wherein said single groove is of rectangular cross-sectional shape.

5. The method of claim **3** wherein said single groove is round in shape.

6. The method of claim **1** wherein at least two grooves are defined by said upper roll.

7. The method of claim **6** wherein said grooves are of rectangular cross-sectional shape.

8. The method of claim **6** wherein said grooves are round in shape.

9. The method of claim **6** wherein the distance between said grooves is substantially the same as or larger than the width of said grooves.

10. The method of claim **1** wherein strip reduction is conducted in one pass through said roll assembly.

11. The roll assembly for the preparation of multiple gauge metal strip possessing improved structural quality and dimensional precision which comprises a grooved upper roll whose dimensions are defined by the ratio of L/W, wherein L is defined as the arc of contact of said upper roll with said strip, W is defined as the width of the groove, and said L/W ratio is at least about 4.

12. The roll assembly of claim **11** wherein said ratio is about 10:1.

13. The roll assembly of claim 11 wherein said grooved upper roll defines a single groove.

14. The roll assembly of claim 13 wherein said single groove is of rectangular cross-sectional shape.

15. The roll assembly of claim 13 wherein said single groove is round in shape.

16. The roll assembly of claim 11 wherein said grooved upper roll defines at least two grooves.

17. The roll assembly of claim 16 wherein said grooves are of rectangular cross-sectional shape.

18. The roll assembly of claim 16 wherein said grooves are round in shape.

19. The roll assembly of claim 16 wherein the distance between said groove is substantially the same as or larger than the width of said grooves.

* * * * *