A method of spin forming, comprising the steps of: providing a tool (20) having a first plurality of forming rollers (34, 36) spaced at a second plurality of distances from a spin axis (30); spinning around the spin axis at least one member of a set comprising (i) a work piece and (ii) the tool; and engaging the tool and a first end of the work piece. The method allows increased diameter reductions of a free end of a work piece in a single forming operation without collapse of the end of the work piece.
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METHOD FOR SPIN FORMING ARTICLES

Field of the Invention

This invention relates to a method of spin forming articles and articles of manufacture according to the method.

Background of the Invention

A typical catalytic converter includes a metal or ceramic substrate treated with a noble metal catalyst enclosed in a stainless steel casing made, for example, out of ASTM 409 stainless steel. A temperature-resistant and shock-absorbing ceramic or wire mesh mat is used to retain the substrate in the casing.

Many catalytic converters have a fusion welded clam shell half type casing to retain the substrate and mat in place. Other catalytic converters have tubular sections with various cross-sectional shapes and transition ends fusion welded in place. Still other catalytic converters have tubular sections with transition ends ram formed to the required dimension. While the ram forming technique is cost effective, it presents rather severe size limitations and, more specifically, ram forming offers a limited range of feasible tubular diameter reduction ratios.

Referring to figure 1, an example known catalytic converter 9 includes a tubular stainless steel shell 13 encasing a catalytic converter substrate 11, which is encircled by a mat (not shown). The stainless steel shell 13 has, welded at its ends, transition pieces 15, each typically comprising a stamped member including a generally conical portion 17 and a generally cylindrical portion 19. The cylindrical portion 19 is welded (or clamped) to the exhaust system of the vehicle.

Referring to figures 2-5, an example known spin forming machine 33 is shown. The spin forming machine 33 includes stand 55 with a single or plurality (three, as shown in figures 2 and 3) of forming rollers 25
rotatively attached thereto. The rollers 25 each have a tapered face 27 and are equally distant from a common axial centerline. The spin forming machine 33 has a mandrel 35 to internally support a tubular metal piece 29 to be operated on.

The spin forming machine 33 is supported on a platform 37. The piece 29 and/or stand 55 is rotated and, depending upon the material used for piece 29, the piece 29 is heated while the platform 37 is indexed toward the piece 29. Figure 3 illustrates the initial outer diameter 51 of the piece 29. As the roller tapered faces 27 make contact with the piece 29, the diameter of the portion of the piece 29 in the machine 33 is reduced to an outer diameter 53 shown in figure 4.

To achieve the amount of tapered reduction desirable in many types of articles, such as a catalytic converter to replace the converter shown in figure 1, two or more machines 33 applying two or more reduction steps to the piece 29 are necessary

Summary of the Invention

It is an object of this invention to provide a method of spin-forming articles according to claim 1.

Advantageously, this invention provides a method of spin-forming articles that reduces the number of spin forming steps to achieve a high diameter reduction ratio.

Advantageously, this invention allows increased diameter reduction ratios of a free end of a work piece in a single spin forming operation without collapse of the end of the work piece.

Advantageously, this invention provides a method of spin-forming articles useful in the manufacture of catalytic converters.

Advantageously, this invention provides a method of spin forming articles such as catalytic converters that achieves the desired diameter reduction ratio in a single spin forming step.
Advantageously, this invention provides a method of spin forming articles that utilizes a forming tool having a plurality of forming rollers spaced at different distances from a spin axis. The rollers extend from the tool a variety of lengths with the longest rollers spaced furthest from the spin axis. During spinning, the longest roller located at the furthest distance from the spin axis first engages the work piece, achieving a first diameter reduction of the end of the work piece. As the tool and work piece continue to engage, the second longest roller, located at a second furthest distance from the spin axis engages the end of the work piece that has been reduced in diameter by the first roller, so that the second roller continues to reduce the diameter of the end of the work piece while the first roller continues to operate further into the work piece.

Advantageously, additional rollers may be provided if desired, having successively shorter lengths and located successively closer to the spin axis to continue the diameter reduction of the work piece begun by the first two rollers. Advantageously, the progression of the work piece through the two or more rollers having different heights and different distances from the spin axis achieves multiple reduction steps of the work piece end in a single spin-forming operation.

Advantageously, according to an example, this invention provides a method of spin forming, comprising the steps of: spinning around a spin axis at least one member of a set comprising (i) a work piece and (ii) a tool; engaging the tool and a first end of the work piece to simultaneously form a plurality of conical diameter reduction portions on the first end of the work piece, wherein an axially aligned annular flat portion is formed between each two adjacent conical diameter reduction portions.

Advantageously, according to another example, this invention provides a method of spin forming, comprising the steps of: providing a first tool having a first plurality of forming rollers spaced at a second plurality of unequal distances from a spin axis; spinning around the spin axis at least one
member of a set comprising (i) a work piece and (ii) the first tool; and
impacting an axial movement on at least one member of the set to engage the
first tool and a first end of the work piece.

Advantageously, according to a preferred example, the first
plurality of forming rollers contains at least first and second forming rollers,
wherein the first forming roller is longer that the second forming roller and
wherein the first forming roller is at a first radial distance from the spin axis
greater than a second radial distance of the second forming roller from the
spin axis.

Advantageously, according to another preferred example, the
method of spin-forming according to this invention also comprises the steps
of: removing the first end of the work piece from the first tool and then
engaging a second end of the work piece on the first tool.

Advantageously, according to yet another preferred example, a
the method of spin-forming according to this invention also comprises the step
of: providing a second tool having a third plurality of forming rollers spaced
at a fourth plurality of unequal distances from the spin axis, wherein the step
of spinning imposes a relative spin movement between the work piece and the
second tool and wherein the step of imparting the axial movement also
engages the second tool to a second end of the work piece to simultaneously
form both the first and second ends of the work piece.

Brief Description of the Drawings

The present invention will now be described by way of example
with reference to the following drawings in which:

Figure 1 is a side elevation view of an example prior art
catalytic converter;

Figures 2 through 5 illustrate a prior art method of spin
forming an end of a tubular work piece before the present invention;
Figures 6 through 9 illustrate various views of an example apparatus used for spin forming a work piece according to the present invention;

Figure 10 is a partially sectioned side elevation view of an example catalytic converter formed according to an example of the present invention;

Figure 11 is an enlargement of a portion of the catalytic converter shown in figure 10;

Figure 12 is a view similar to figure 10 of another example catalytic converter formed according to an example of the present invention;

Figure 13 is an enlargement of a portion of the catalytic converter shown in figure 12;

Figure 14 is a view similar to figure 10 of another example catalytic converter formed according to an example of the present invention;

Figure 15 is an enlargement of a portion of figure 14; and

Figures 16, 17 and 18 are enlarged views similar to the view of figure 10 of another example catalytic converter formed according to an example of the present invention.

Description of the Preferred Embodiment

Referring to figures 6-9, spin forming machine 20 has a platform 22, which is translatable in the axial direction parallel to spin axis 30 toward the tubular work piece 50. The spin forming machine 20 has a stand 24 and a plurality of rollers 34, 36, 38, 40 and 42. Each of the aforementioned rollers are at a different radial distance from an axial centerline 30 (also referred to as the spin axis) of the tubular work piece 50 and mandrel 43 with the roller 42 being most radially inward and the rollers 40, 38, 36 and 34 being progressively more radially outward. The rollers 34, 36, 38, 40 and 42 project different lengths from the stand 24, with roller 42,
closest to the spin axis 30, being the shortest, and rollers 40, 38, 36 and 34 being progressively longer.

A motor-driven mechanism is provided for spinning the stand 24 along with the rollers 34, 36, 38, 40 and 42, or for spinning the work piece 50, about the spin axis 30, or for spinning both the stand 24 and the work piece 50 relative to each other. Such spinning mechanisms are well known to those skilled in the art and need not be set forth herein in detail. Before the work piece 50 and the stand 24 with rollers 34, 36, 38, 40 and 42 are engaged, supplemental heat may be provided to the work piece 50 in a well-known manner to allow the work piece 50 to be formed by the rollers 34, 36, 38, 40 and 42. Those skilled in the spin forming arts will readily recognize that such supplemental heat may not be necessary in all cases, as the requirement of supplemental heating depends upon the type of metal constituting work piece 50.

After a relative spin motion between stand 24 and work piece 50 is achieved, and supplemental heating is provided, if desired, the platform 22 is indexed parallel to axis 30 toward the work piece 50, carrying the stand 24 and rollers 34, 36, 38, 40 and 42 into engagement with the work piece 50. The roller 34, which is radially most outwardly and extends closest to the unengaged work piece, is the first to come in contact with the work piece 50.

Figure 8 illustrates the original diameter of the work piece 50 with respect to the position of rollers 34, 36, 38, 40 and 42. The starting diameter of the work piece 50 is of a size to engage the tapered end of roller 34. As engagement of the machine 20 and work piece 50 continues, roller 34 works on the end 174 of work piece 50 to reduce the diameter thereof to that of the annular axially aligned flat 158 (figure 7). With further engagement, the roller 36 begins operating on the end 174 of the work piece 50, reducing the diameter thereof to that of flat 156. As the engagement is continued to move the rollers onto the work piece 50, rollers 38, 40 and 42 sequentially begin engaging the end 174 of the work piece 50 to reduce its diameter.
progressively to the diameters indicated by flats 154, 152 and 150, respectively, wherein flat 150 is the final desired reduced diameter portion of the end of the work piece 50, and is supported during the spin forming operation by mandrel 43.

After complete engagement of the roller 42 and mandrel 43, the formed work piece 50 has a shape that progresses from its initial outer diameter 160, through a series of alternating tapered steps (also referred to as diameter reduction sections) 170, 168, 166, 164, 162 and flat sections (i.e., constant diameter sections) 158, 156, 154 and 152 to the final inner diameter 150. At this point, the formed work piece 50 may be removed from the machine 20 if desired.

It will be recognized that the spin forming described above is conducted in a progressive manner without having all rollers initiating contact with the tubular element 50 at the same time. This progressive feature helps prevent the tubular element 50 from collapsing and allows end 174 to be spin formed to a much smaller diameter 140 than previously allowable.

Each flat 152, 154, 156 and 158 adds hoop strength to the end 174 of the work piece 50 being operated on, providing structural support spaced at axial intervals along the portion of work piece 50 within the rollers 34, 36, 38, 40 and 42. Thus the formation of the flats 152, 154, 156 and 158 interposed between the diameter reduction sections 162, 164, 166, 168 and 170 advantageously helps prevent collapse or other undesirable deformation of the work piece during the spin forming. The flats 152, 154, 156 and 158 are achieved by selecting the height of each roller 34, 36, 38, 40 and 42 so that the tapered end of each roller 36, 38, 40 and 42 first engages the outer work piece 50 at a location axially spaced from the largest diameter end of the tapered head of the previous roller 34, 36, 38 and 40.

If it is not desirable to leave the finished work piece 50 with the series of flats 152, 154, 156 and 158 between the diameter reduction sections 162, 164, 166, 168 and 170, the flats can be removed by providing that each
of the rollers 36, 38, 40 and 42 be individually translatable in the axial
direction between two positions with respect to the work piece 50. This may
be achieved using a series of actuators either located in the stand 24 or the
platform 22 and coupled through the stand 24, i.e., through cam mechanisms
or other suitable coupling means well known to those skilled in the art, that
selectively operate on the rollers 36, 38, 40 and 42.

The rollers start in the positions shown in solid lines to achieve
the above-described operation. Then the individually translatable rollers 36,
38, 40 and 42 are operated sequentially to remove the flats 152, 154, 156 and
158 and merge the diameter reduction sections 162, 164, 166, 168 and 170
into a single diameter reduction section 172. First roller 36 is extended
axially, operating on diameter reduction portion 168, bringing it in line with
diameter reduction portion 170, eliminating the flat 158. Rollers 38, 40 and
42 are likewise extended in sequence to operate on the diameter reduction
sections 166, 164 and 162, respectively, eliminating flats 156, 154 and 152 so
that the work piece 50 achieves the single conical diameter reduction section
172 shown.

Referring to figures 10 and 11, according to one example, the
work piece 50 is operated on both ends to form the casing of catalytic
converter 46. A substrate 52 wrapped in multiple layered matting 54, which
includes a first inner layer 56 and an outer layer 58 is located within casing
50.

The casing 50 has two opposite transition pieces or ends 60.
The ends 60 have a first diameter 62, and a second diameter 64 which is
smaller than the first diameter 62. As shown in figures 10 and 11, each end
60 has a conical portion 66 with a base joined to the remainder of the casing
50. Additionally, each conical portion 66 has extending therefrom a
cylindrical extension 68, typically having a thickness 70 that is greater than
the thickness 72 of the portion of the casing 50 surrounding the substrate 52.
To manufacture the catalytic converter 46, the substrate 52 is wrapped in the matting 54. The wrapped substrate 52 is then inserted within the work piece 50 either after forming of one of the ends 60 or before forming of both of the ends 60. The ends 60 are spin formed by a spin forming machine 20, for example, as described above. If thermal insulation of the ends 60 is desired, before each end 60 is formed, a metal inner end cone 80 is placed on the mandrel 43 of the machine 20. When the work piece (casing) 50 engages the rollers, the rollers 34, 36, 38, 40 and 42 form end 60 radially exterior of the inner end cone 80. Inner end cone 80 is provided with a shape so that its conical portion 85 is space inward of the final formed position of end 60, allowing for an air gap to act as insulation. Alternatively, an insulating material 84, i.e., a matting of a known type, may be wrapped around the conical portion 85 of inner end cone 80 prior to the forming of end 60, so that, after forming, the matting material serves as insulation between the conical portion 85 of inner end cone 80 and the conical portion 66 of casing 50. During the spin forming of end 60 around inner end cone 80, the tubular extension 68 and tubular portion 86 of inner end cone 80 become fixedly joined, i.e., similar to a tight friction fit between the two pieces.

In another example for manufacturing the catalytic converter 46, two machines 20 are provided, one for operating on each end of the converter 46 to simultaneously form the ends 60. In this example, the substrate 52, wrapped in matting 54, is inserted into the work piece 50 before the roll forming of ends 60 is initiated. Inner end cones 80 are placed on both mandrels 43 of the machines 20 and, when either the work piece 50 or stands 24 are rotating, the stands 24 with the rollers are both indexed toward the work piece 50 to simultaneously form the ends 60.

In figures 12 and 13, catalytic converter 90 includes a spin formed casing 91 with a housing portion 192, within which substrate 52 is located, and two ends 160. Two ridges 74 (only one shown) extend radially outwardly from housing portion 192, one ridge 74 where housing portion 192
transitions to each end 160. The ridges 74 may be formed by the following method. Before forming each end 160, each end of the workpiece that will form casing 91 is formed, i.e., by roll forming or other suitable method, to expand the end to a slightly increased diameter 161 at transition points 73 (only one shown). The transition 73 from the original diameter of workpiece 91 to the increased diameter 161 occurs at the locations where ridges 74 are desired. When the ends are formed as described above, the longest roller is sized so that the largest diameter portion of end 160 occurs proximate to the transition 73, thus forming ridge 74. An external outer insulation tubular element 92 is then attached to the casing 91 by welding to the opposed external ridges 74 in a known manner.

Referring to figures 14 and 15, the catalytic converter 94 includes two annular L-shaped brackets 96 (only one shown), one located at each end of the substrate 52 to position the matting 54 and substrate 52. The brackets 96, similar to brackets known for use in prior art catalytic converters having metal monolith substrates, are locked in place within housing portion 97 of casing 95 when the ends 99 are formed as described above. An example heat shield 98 is provided with an annular lip 101 or a series of arcuately spaced tabs that extend radially until the shield 94 is placed over the casing 95, at which point the lip 101 or tabs are formed down on the ends 99 of casing 95 by a suitable pressing operation and may, if desired, also be welded in place.

Referring to Figure 16, catalytic converter 102 includes substrate 52 with end faces 132 (only one shown) extending a distance 104 in the axial direction past each base 112 of the conical ends 106 of casing 111. The housing portion 110 of casing 111 surrounds most of inner and outer mats 58 and 56, respectively, which also have ends 57 and 59 extending into the conical ends 106. During the forming of the conical ends 106, the ends 57, 59 of the mats 56, 58 are compressed in the distance 104 within the
conical ends 106. The resulting compressive force holds the mats 56, 58 and substrate 132 in place.

Referring to figure 17, at least one annular flat 118 is retained on the catalytic converter 116. The flat 118 offers added strength to the conical end 134 of the casing 135 and is positioned with an inner radius a distance 114 less than the outer radius of substrate 52 to direct the flow of gasses (right to left) into the substrate 52 and away from the matting 54.

Referring to figure 18, catalytic converter 120 has an inner end cone 164 that serves as an insulator similar to inner end cone 80 of figure 11. Inner end cone 164 includes an axial extension 165 that extends axially into the housing portion 51 of casing 50. An annular matting 126 is trapped between the axial extension 165 and casing 50 by the annular curved leg 130 on the end of the axial extension 165. The annular curved leg 130 extends a distance 122 into the matting 154 to help keep the matting 154 in place.
Claims:

1. A method of spin forming, comprising the steps of:
   providing a first tool (20) having a first plurality of
   forming rollers (34, 36) spaced at a second plurality of unequal distances from
   a spin axis (30);
   spinning around the spin axis at least one member of a
   set comprising (i) a work piece (50) and (ii) the first tool; and
   imparting an axial motion on at least one member of the
   set to engage the first tool and a first end of the work piece.

2. A method of spin forming according to claim 1, wherein
   the first plurality of forming rollers includes at least first and second forming
   rollers (34, 36), wherein the first forming roller is longer than the second
   forming roller and wherein the first forming roller is at a first radial distance
   from the spin axis greater than a second radial distance of the second forming
   roller from the spin axis.

3. A method of spin forming according to claim 1, also
   comprising the steps of:
   removing the first end of the work piece from the first
   tool; and
   engaging a second end of the work piece to the first
   tool.

4. A method of spin forming according to claim 2, wherein
   the first plurality of rollers also comprises third, fourth and fifth forming
   rollers (38, 40, 42), wherein the third forming roller is longer than the fourth
   forming roller and the fourth forming roller is longer than the fifth forming
   roller, wherein the third forming roller is at a third radial distance from the
spin axis greater than a fourth radial distance from the spin axis of the fourth forming roller and wherein the fourth radial distance from the spin axis is greater than a fifth radial distance from the spin axis of the fifth forming roller.

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5. A method of spin forming according to claim 1, wherein the engaging of the first end of the work piece to the first tool reduces a first diameter of the first end, also comprising the steps of:
   removing the work piece from the first tool;
   placing a substrate (52) within the work piece; and
   engaging a second end (60) of the work piece to the first tool, wherein a second diameter of a second end of the work piece is reduced, trapping the substrate substantially within an unreduced housing portion of the work piece.

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6. A method of spin forming according to claim 5, wherein the work piece is formed into a catalytic converter (46).

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7. A method of spin forming according to claim 5, also comprising the step of placing an annular L-shaped bracket (96) at each end of the substrate within the work piece before the engaging of the second end of the work piece to the first tool.

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8. A method of spin forming according to claim 5, also comprising the step of placing an insulating matting (54) material between an outer perimeter of the substrate and an inner perimeter of an unreduced portion of the work piece.

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9. A method of spin forming according to claim 8, wherein the first and second ends each have a conical shape, wherein the substrate and
matting material extend axially into the first and second ends, wherein the first and second ends compress portions (59) of the matting material extending axially into the first and second ends.

10. A method of spin forming according to claim 1, wherein the first end is spin formed around a conical shaped member (80).

11. A method of spin forming according to claim 10, wherein the conical shaped member (80) is spaced away from an inner wall of a diameter transition portion of the first end.

12. A method of spin forming according to claim 1, wherein individual rollers (36) of the first plurality of rollers extend to axial positions relative to one another so that, during engagement of the first tool and the first end of the work piece, at least two progressively decreasing diameter sections (170, 168) are formed on the first end of the work piece with a substantially axially aligned annular flat section (158) formed between the at least two progressively decreasing diameter sections.

13. A method of spin forming according to claim 12, wherein the annular flat section provides hoop strength to the first end during spin forming, thereby allowing increased diameter reduction of the first end while preventing against collapse thereof.

14. A method of spin forming according to claim 1, also comprising the step of, during engagement of the first tool and the first end of the work piece, selectively extending individual forming rollers (36) of the first plurality of forming rollers.
15. A method of spin forming according to claim 12, also comprising the step of extending at least one forming roller (36) of the first plurality of forming rollers to remove the annular flat section.

16. A method of spin forming according to claim 1, wherein, during engagement of the first tool and the first end of the work piece, a third plurality of progressively decreasing diameter sections (170, 168, 166, 164, 162) are formed on the first end of the work piece, wherein, between each two of the third plurality of progressively decreasing diameter sections that are adjacent to one another, a substantially axially aligned annular flat section (158, 156, 154, 152) is formed.

17. A method of spin forming according to claim 16, wherein the substantially axially aligned annular flat portions provide hoop strength to the end being formed, thereby allowing increased diameter reduction of the first end while preventing against collapse thereof.

18. A method of spin forming according to claim 16, also comprising the step of selectively extending individual forming rollers (36, 38, 40, 42) of the first plurality of forming rollers to remove at least some of the flats.

19. A method of spin forming according to claim 2, wherein the first and second forming rollers extend axially relative to each other, wherein the first forming roller forms on the first end a first tapered portion (170) reducing a diameter of the first end of the work piece to a first value and the second forming roller forms a second tapered portion (168) reducing the diameter of the first end of the work piece to a second value, wherein the second value is less than the first value, wherein a substantially axially aligned flat (158) is formed between the first and second tapered portions.
20. A method of spin forming according to claim 19, also comprising the step of axially extending the second forming roller (36) relative to the first forming roller to remove the flat.

21. A method of spin forming according to claim 6, wherein a flat (118) is formed on the first end adjacent to an axial end of the substrate, wherein the flat has an inner diameter at least as small as an outer diameter of the substrate (52).

22. A the method of spin-forming according to claim 1, also comprising the step of: providing a second tool (20) having a third plurality of forming rollers (34, 36) spaced at a fourth plurality of unequal distances from the spin axis (30), wherein the step of spinning imposes a relative spin movement between the work piece and the second tool and wherein the step of imparting the axial movement also engages the second tool to a second end of the work piece to simultaneously form both the first and second ends of the work piece.

23. A method of spin forming, comprising the steps of: spinning around a spin axis (30) at least one member of a set comprising (i) a work piece (50) and (ii) a first tool (20); engaging the first tool and a first free end of the work piece to simultaneously form a plurality of tapered diameter reduction portions (170, 168, 166, 164, 162) on the first end of the work piece, wherein an axially aligned annular flat portion (158, 156, 154, 152) is formed between each two adjacent tapered diameter reduction portions.

24. A method of spin forming according to claim 23, wherein each flat portion provides hoop strength to the first end, thereby
allowing increased diameter reduction of the first end while preventing against collapse thereof.

25. A method of spin forming according to claim 23, wherein the first tool includes at least first and second forming rollers (34, 36) spaced at first and second distances from the spin axis, wherein the first distance is unequal to the second distance.

26. A method of spin forming according to claim 25, also comprising the step of extending the second forming roller (36) to remove at least one of the flat portions.

27. A method of spin forming according to claim 25, wherein the first forming roller is longer than the second forming roller, and wherein the first distance is greater than the second distance.

28. A method of spin forming according to claim 23, also comprising the steps of:
   removing the first end of the work piece from the first tool; and
   engaging a second end of the work piece to the first tool.

29. A method of spin forming according to claim 23, wherein the step of engaging the first end of the work piece to the first tool reduces a first diameter of the first end, also comprising the steps of:
   removing the work piece from the first tool: placing a substrate (52) within the work piece; and engaging a second end of the work piece to the first tool, wherein a second diameter of a second end of the work piece is reduced,
trapping the substrate substantially within an unreduced housing portion of the work piece.

30. A method of spin forming according to claim 29, wherein the work piece is formed into a catalytic converter (46).

31. A method of spin forming according to claim 29, also comprising the step of placing an annular L-shaped bracket (96) at each end of the substrate within the work piece before the engaging of the second end of the work piece to the first tool.

32. A method of spin forming according to claim 29, also comprising the step of placing an insulating matting material (54) between an outer perimeter of the substrate and an inner perimeter of an unreduced portion of the work piece.

33. A method of spin forming according to claim 32, wherein the first and second ends each have a conical shape, wherein the substrate and matting material extend axially into the first and second ends, wherein the first and second ends compress portions (59) of the matting material extending axially into the first and second ends.

34. A method of spin forming according to claim 298, wherein a flat (118) is formed on the first end adjacent to an axial end of the substrate, wherein the flat has an inner diameter at least as small as an outer diameter of the substrate.

35. A method of spin forming according to claim 23, wherein the first end is spin formed around a conical shaped member (80).
36. A method of spin forming according to claim 29, wherein the substrate is wrapped in a matting material (54).

37. A method of spin forming according to claim 36, wherein the first end is spin formed around a conical shaped member (80), wherein the conical shaped member includes an axially extending end (165) that extends into contact with the matting material to maintain the matting material in place.

38. A the method of spin-forming according to claim 23, also comprising the steps of:
   providing a second tool, wherein the step of spinning imposes a relative spin movement between the work piece and the second tool; and
   engaging the second tool and a second free end of the work piece, wherein the first and second free ends of the work piece are simultaneously formed.

39. A method of spin forming, comprising the steps of:
   providing a tool (20) having a plurality of forming rollers (34, 36), wherein the forming rollers extend from the tool a variety of lengths, wherein members of the plurality of rollers with longer axial lengths are spaced further from a spin axis than members of the plurality with shorter axial lengths, wherein the plurality includes at least one longest forming roller (34) and one second longest forming roller (36);
   imparting a relative spinning motion about the spin axis between the tool and a work piece (50);
   moving the tool and the work piece together, wherein the longest forming roller, located at a furthest distance from the spin axis, first engages the work piece, achieving a first diameter reduction (170) of the
end of the work piece, wherein, as the tool and the work piece are moved
further together, the second longest roller, located at a second furthest
distance from the spin axis, engages the end of the work piece that has been
reduced in diameter by the longest forming roller, wherein the second forming
roller continues to reduce (168) the diameter of the end of the work piece
while the first forming roller continues to operate further, in an axial
direction, into the work piece.

40. A method according to claim 22, also comprising the
step of placing a substrate (52) within the work piece prior to the
simultaneous forming of the first and second ends of the work piece.

41. A method according to claim 38, also comprising the
step of placing a substrate (52) within the work piece prior to the
simultaneous forming of the first and second free ends.

42. A method according to claim 40, wherein the work
piece is formed into a catalytic converter (46).

43. A method according to claim 41, wherein the work
piece is formed into a catalytic converter (46).
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 B21D22/14 B21D41/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
IPC 6 B21D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
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<tbody>
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<td>PATENT ABSTRACTS OF JAPAN vol. 008, no. 201 (M-325), 14 September 1984 &amp; JP 59 092123 A (TOSHIBA KIKAI KK), 28 May 1984, see abstract</td>
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<td>A</td>
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<tr>
<td>A</td>
<td>PATENT ABSTRACTS OF JAPAN vol. 007, no. 055 (M-198), 5 March 1983 &amp; JP 57 202930 A (YAZAKI KAKOU KK), 13 December 1982, see abstract</td>
<td>---</td>
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<tr>
<td>A</td>
<td>US 3 815 397 A (HOLLENCAMP E) 11 June 1974</td>
<td>---</td>
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<tr>
<td>A</td>
<td>DE 27 31 965 A (LOESER PETER) 1 February 1979</td>
<td>---</td>
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Date of the actual completion of the international search
25 March 1998

Date of mailing of the international search report
01/04/1998

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<tbody>
<tr>
<td>A</td>
<td>DE 34 23 223 C (MANNESMANN AG) 6 February 1986</td>
<td></td>
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<tr>
<td>Patent document cited in search report</td>
<td>Publication date</td>
<td>Patent family member(s)</td>
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<tr>
<td>US 3815397 A</td>
<td>11-06-74</td>
<td>NONE</td>
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<tr>
<td>DE 2731965 A</td>
<td>01-02-79</td>
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<td>06-02-86</td>
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