(21) International Application Number: PCT/US00/048099

(22) International Filing Date: 25 February 2000 (25.02.00)

(30) Priority Data:
09/259,516 26 February 1999 (26.02.99) US
09/259,518 26 February 1999 (26.02.99) US

(63) Related by Continuation (CON) or Continuation-in-Part (CIP) to Earlier Applications
US 09/259,516 (CIP)
Filed on 26 February 1999 (26.02.99)

US 09/259,518 (CIP)
Filed on 26 February 1999 (26.02.99)

(71) Applicant (for all designated States except US): MORGANITE INCORPORATED [US/US]; One Morganite Drive, Dunn, NC 28343 (US).

(72) Inventors; and
(75) Inventors/Applicants (for US only): HOCKADAY, Shepard, L. [US/US]; 7726 NC 50 South, Benson, NC 27504 (US).
FARTHING, Alvin, Leon [US/US]; 243 Feedmill Road, Roseboro, NC 28382 (US).
HALL, Tony, Earl [US/US]; 4900 NC 50 South, Benson, NC 27504 (US).
REECE, John, David, Jr [US/US]; 208 Pineview Drive, Erwin, NC 28339 (US).


Published
Without international search report and to be republished upon receipt of that report.

(51) International Patent Classification 7:
H01R 39/06, 43/06

(11) International Publication Number: WO 00/51210

(43) International Publication Date: 31 August 2000 (31.08.00)

(54) Title: METHODS AND RESULTS OF MANUFACTURING COMMUTATORS

(57) Abstract

Addressed herein are commutators and methods of manufacturing them. The methods permit the carbonaceous material and core of a commutator to be molded simultaneously, rather than in a two-step process, and can eliminate one of two curing procedures used in connection with other manufacturing techniques. The necessity of machining the inner surface of the commutator shell to remove undesired excess phenolic or other material additionally is avoided by use of the techniques detailed herein. Commutators formed according to these methods may have increased useful lives and provide better performance than others presently available. An alternative commutator design addressed herein incorporates a system for anchoring its conductive segments. One or more undercuts in either or both of the metal shell and insulating core of the commutator receive protruding portions of the conductive material to prevent its axial displacement. The metal shell, which for protective purposes may extend above the face of the conductive material during some or all of the manufacturing process, minimizes radial displacement of the segments formed of the conductive material. Differing or non–concentric curvature of the inner surface of the shell and the outer surface of a portion of the insulating core restrict undesired circumferential movement of the segments.
FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

<table>
<thead>
<tr>
<th>AL</th>
<th>Albania</th>
<th>ES</th>
<th>Spain</th>
<th>LS</th>
<th>Lesotho</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM</td>
<td>Armenia</td>
<td>FI</td>
<td>Finland</td>
<td>LT</td>
<td>Lithuania</td>
</tr>
<tr>
<td>AT</td>
<td>Austria</td>
<td>FR</td>
<td>France</td>
<td>LU</td>
<td>Luxembourg</td>
</tr>
<tr>
<td>AU</td>
<td>Australia</td>
<td>GA</td>
<td>Gabon</td>
<td>LV</td>
<td>Latvia</td>
</tr>
<tr>
<td>AZ</td>
<td>Azerbaijan</td>
<td>GB</td>
<td>United Kingdom</td>
<td>MC</td>
<td>Monaco</td>
</tr>
<tr>
<td>BA</td>
<td>Bosnia and Herzegovina</td>
<td>GE</td>
<td>Georgia</td>
<td>MD</td>
<td>Republic of Moldova</td>
</tr>
<tr>
<td>BB</td>
<td>Barbados</td>
<td>GH</td>
<td>Ghana</td>
<td>MG</td>
<td>Madagascar</td>
</tr>
<tr>
<td>BE</td>
<td>Belgium</td>
<td>GN</td>
<td>Guinea</td>
<td>MK</td>
<td>The former Yugoslav Republic of Macedonia</td>
</tr>
<tr>
<td>BF</td>
<td>Burkina Faso</td>
<td>GR</td>
<td>Greece</td>
<td>ML</td>
<td>Mali</td>
</tr>
<tr>
<td>BG</td>
<td>Bulgaria</td>
<td>HU</td>
<td>Hungary</td>
<td>MN</td>
<td>Mongolia</td>
</tr>
<tr>
<td>BJ</td>
<td>Benin</td>
<td>IE</td>
<td>Ireland</td>
<td>MR</td>
<td>Mauritania</td>
</tr>
<tr>
<td>BR</td>
<td>Brazil</td>
<td>IL</td>
<td>Israel</td>
<td>MW</td>
<td>Malawi</td>
</tr>
<tr>
<td>BY</td>
<td>Belarus</td>
<td>IS</td>
<td>Iceland</td>
<td>MX</td>
<td>Mexico</td>
</tr>
<tr>
<td>CA</td>
<td>Canada</td>
<td>IT</td>
<td>Italy</td>
<td>NE</td>
<td>Niger</td>
</tr>
<tr>
<td>CF</td>
<td>Central African Republic</td>
<td>JP</td>
<td>Japan</td>
<td>NL</td>
<td>Netherlands</td>
</tr>
<tr>
<td>CG</td>
<td>Congo</td>
<td>KE</td>
<td>Kenya</td>
<td>NO</td>
<td>Norway</td>
</tr>
<tr>
<td>CH</td>
<td>Switzerland</td>
<td>KG</td>
<td>Kyrgyzstan</td>
<td>NZ</td>
<td>New Zealand</td>
</tr>
<tr>
<td>CI</td>
<td>Cote d'Ivoire</td>
<td>KP</td>
<td>Democratic People's Republic of Korea</td>
<td>PL</td>
<td>Poland</td>
</tr>
<tr>
<td>CM</td>
<td>Cameroon</td>
<td>KR</td>
<td>Republic of Korea</td>
<td>PT</td>
<td>Portugal</td>
</tr>
<tr>
<td>CN</td>
<td>China</td>
<td>KZ</td>
<td>Kazakhstan</td>
<td>RO</td>
<td>Romania</td>
</tr>
<tr>
<td>CU</td>
<td>Cuba</td>
<td>LC</td>
<td>Saint Lucia</td>
<td>RU</td>
<td>Russian Federation</td>
</tr>
<tr>
<td>CZ</td>
<td>Czech Republic</td>
<td>LI</td>
<td>Liechtenstein</td>
<td>SD</td>
<td>Sudan</td>
</tr>
<tr>
<td>DE</td>
<td>Germany</td>
<td>LK</td>
<td>Sri Lanka</td>
<td>SE</td>
<td>Sweden</td>
</tr>
<tr>
<td>DK</td>
<td>Denmark</td>
<td>LR</td>
<td>Liberia</td>
<td>SG</td>
<td>Singapore</td>
</tr>
<tr>
<td>EE</td>
<td>Estonia</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SI</td>
<td>Slovenia</td>
<td>SK</td>
<td>Slovakia</td>
<td>SN</td>
<td>Senegal</td>
</tr>
<tr>
<td>SZ</td>
<td>Swaziland</td>
<td>TD</td>
<td>Chad</td>
<td>TG</td>
<td>Togo</td>
</tr>
<tr>
<td>TJ</td>
<td>Tajikistan</td>
<td>TM</td>
<td>Turkmenistan</td>
<td>TR</td>
<td>Turkey</td>
</tr>
<tr>
<td>TT</td>
<td>Trinidad and Tobago</td>
<td>UA</td>
<td>Ukraine</td>
<td>UA</td>
<td>Uganda</td>
</tr>
<tr>
<td>US</td>
<td>United States of America</td>
<td>US</td>
<td>United States of America</td>
<td>UZ</td>
<td>Uzbekistan</td>
</tr>
<tr>
<td>VN</td>
<td>Viet Nam</td>
<td>YU</td>
<td>Yugoslavia</td>
<td>ZW</td>
<td>Zimbabwe</td>
</tr>
</tbody>
</table>
METHODS AND RESULTS OF MANUFACTURING COMMUTATORS

FIELD OF THE INVENTION

This invention relates to rotary switches and more particularly, although not exclusively, to "flat" or "face-style" commutators for use with electric motors and methods of manufacturing such commutators.

BACKGROUND OF THE INVENTION

U.S. Patent No. 5,491,373 to Cooper, et al., incorporated herein in its entirety by this reference, discloses an exemplary high-speed rotary switch or commutator. Denoted a "barrel-style" device, the commutator illustrated in the Cooper, et al. patent includes multiple electrically-conductive segments arranged into a cylinder on the outer diameter of a non-conductive core. An electrical brush passes along the outer diameter of the core to form a conductive path with the one or more segments in contact with it at any given instant.

Described in U.S. Patent Nos. 5,760,518 and 5,826,324 to Abe, et al. (also incorporated herein in their entireties by this reference) is a commutator whose face, rather than outer diameter or edge, conducts electricity. This face-style commutator is an alternative to a barrel-style device and is often used in devices exposed to corrosive environments or immersed in fuel. Figures 1 and 2 of the Abe, et al. patents illustrate aspects of such a commutator, with electrically-conductive segments 3 consisting principally of graphite.

Also shown in Figure 2 of the Abe, et al. patents is metal shell or plate 5, whose terminal 6 admits connection to windings of a motor, and an electrically-insulating support 1. Plate 5 includes on its inner surface "small projections 7," which function to anchor the graphite segments 3 from displacement as the commutator operates. According to the Abe, et al. patents, a separate, unillustrated "part of . . . metal plate 5 is embedded in the electrically insulating support 1" to retain the relative positions of the plate and support.

Listed on the faces of the Abe, et al. patents as their assignee is Aupac Co., Ltd. ("Aupac"). A commutator made by Aupac includes two sets of anchors in the plate or shell. One set, analogous to the unshown portions of metal plate 5 discussed in the Abe, et
al. patents, retains the position of the insulating support or core of the commutator, while the other (analogous to "small projections 7") assists in anchoring the conductive segments relative to the plate or shell. However, unlike projections 7 of the Abe, et al. patents, which extend radially inward from an inner surface of the plate or shell, the analogous anchors of the Aupac commutator are formed by bending radially inward axially-extending protrusions on an edge of the plate or shell (rather than as protrusions from its side).

FIGS. 1-6 illustrate, essentially identically, aspects of the Aupac commutator 100. Detailed in FIGS. 1-3 is metal shell 104 in which anchors 108 are formed. Such anchors 108 extend radially inward from shell 104 and are used to moor an electrically-insulating core 110 (see FIG. 4). Also shown in FIGS. 1-3 are terminals 112 (which ultimately will be bent into tangs or hooks) and projections 116. As noted in the preceding paragraph, projections 116 are not formed in inner surface 120 of shell 104 but rather extend from its edge 124 before being bent inward.

Manufacture of the Aupac commutator 100 is relatively complex. Initially, shell 104 must be blanked and formed in the manner of FIGS. 1-3 so as to create anchors 108, terminals 112, and projections 116. Core 110 must then be molded into shell 104, as shown in FIG. 4, so that its phenolic material surrounds anchors 108. Molding core 110 in this manner effectively embeds anchors 108 therein, helping fix the position of core 110 relative to shell 104.

After the phenolic material of core 110 is molded and cured, excess material (typically denoted "flash") must be removed from inner surface 120. Failure to remove such excess material can be problematic, as it can adversely affect the electrical continuity between shell 104 and the electrically-conductive graphite segments 126 (see FIG. 6) ultimately forming the face of the Aupac commutator 100. Machining, furthermore, is required to delete flash from inner surface 120 once core 110 has been molded and cured.

After the material of core 110 is cured and the flash is removed from inner surface 120 of shell 104, projections 116 must be bent radially inward as illustrated in FIG. 5. Concurrently terminals 112 may be formed into tangs or hooks 128 for subsequent attachment to the windings of a motor. Only then are conductive segments 126 created as shown in FIG. 6.
Included in FIG. 6 are the segments 126, which initially consist of graphite powder or material. The material is molded, or pressed, into recess 132 (see FIG. 5) so that it abuts core 110 and projections 116 are embedded within. Doing so anchors the material of segments 126 to shell 104, after which the material is cured and slotted to form the segments 126.

Surface 136 contacts electrical brushes, and thereby wears, in use. As is readily visible in FIG. 6, a substantial portion of each segment 126 lies further from surface 136 than projections 116 (and thus is not within the depth D₂ shown in that figure). It hence is unavailable as a contact surface, resulting in significant waste of the graphite material.

Moreover, to applicants' knowledge, at no time does shell 104 of the Aupac commutator 100 extend beyond surface 136. Shell 104 indeed cannot readily do so, as projections 116 must be bent inward in order to be embedded within segments 126. Similarly, neither commutator of the Abe, et al. patents contemplates having a plate 5 extending at any time above the exposed face of the carbonaceous material. Even though theoretically not impossible to extend plates 5 (upward as oriented in Figures 2 and 3 of the Abe, et al. patents) beyond pieces 3, no basis for such extension appears in the Abe, et al. patents.

SUMMARY OF THE INVENTION

Manufacturing methods of the present invention are substantially simpler than those used to produce both the Aupac commutator and those of the Abe, et al. patents. Unlike those utilized to create the Aupac commutator, for example, the methods employed with the present invention reverse the sequence of inserting a carbonaceous (typically at least slightly deformable) pre-form and (phenolic or other) insulating core into the commutator shell. As a consequence, the carbonaceous material and core can be molded simultaneously rather than in the two-step process described in the preceding section.

Methods of the present invention likewise eliminate one of two curing procedures involved in manufacturing the Aupac commutator. Because the insulating core of the Aupac commutator forms a base against which the carbonaceous material is forced under pressure, the core must be cured prior to molding of the carbonaceous material. Otherwise, the core will lack sufficient strength and rigidity to admit proper molding of the
carbon segments as it encounters such pressure. With the present invention, however, curing of the carbonaceous material and core can occur simultaneously.

The necessity of machining the inner surface of the commutator shell to remove flash additionally is avoided by use of the present techniques. By having the annular (or otherwise-shaped) carbonaceous pre-form inserted into the shell prior to molding the insulating core, these techniques allow the pressure caused by the molding of the core to force the material of the pre-form outward so that it abuts the inner surface of the shell. This action prevents the core material from migrating to the inner surface of the shell and becoming undesired flash.

Noted in the preceding section are the two sets of anchors required for making the Aupac commutator. Although commutators of the present invention similarly may be made with two (or more) sets of anchors, only one set is necessary, as such set is adapted not only to secure both the core and carbonaceous material to the shell, but also to provide electrical continuity between the shell and carbonaceous material. Whereas the core of the Aupac commutator is already cured (and nonreactive) when the carbonaceous material is molded and thus no chemical bonding of the two substances occurs, the core and carbon pre-forms of the commutators of the present invention bond, or interlock, both chemically and mechanically as their simultaneous molding transpires. The result is increased mooring of the carbonaceous material to the core within the shell without the need to form additional anchors in the shell itself.

Avoiding projections 116 of the Aupac commutator enhances the useful lives of commutators of the present invention. By permitting use of essentially the entirety of their electrically-conductive segments, commutators according to the present invention likewise reduce waste of carbonaceous material. These commutators further are formed so that the molding of the carbonaceous material produces higher density, more uniform material, advantageous properties for many of their intended uses.

Commutators of the invention also may have shells of extended height during part or all of the manufacturing process. Increasing the height of the shell protects the integrity of the carbonaceous (or other) face material of each device, reducing its exposure to being chipped, scratched, or otherwise damaged during manufacture. The shell can be
sheared at the end of the manufacturing process if desired so as not to protrude, or to protrude only a selected amount, beyond the commutator face.

Alternative commutators disclosed herein provide an anchoring system in which one or more undercuts or recesses in either or both of the shell and insulating core receive flange-like protrusions of the carbonaceous (or other conductive) material to prevent its axial displacement. Unlike as in Figure 2 of the Abe, et al. patents, therefore, no special projections need be formed for such purpose in the metal plate or shell. The undercuts, furthermore, may be wholly or partially annular and created using the same tool used to remove excess material utilized to mold the insulating core. They thus do not require any special tooling to make and can be established when such excess material is removed.

Unlike the holes (numbered 8 and 9 in Figure 3) of the Abe, et al. patents, moreover, any undercut present in the inner diameter of the shell in connection with these commutators need not extend the entire depth of the shell. If such undercut were annular, it obviously could not extend the depth of the shell, as to do so would cut the shell into two pieces. Partially-annular undercuts conceivably could penetrate the exterior of the shell, although applicants believe in such cases at least certain performance attributes of the resulting commutator might be compromised. Complete-penetration undercuts also likely would require a separate tool, undermining the cost-effectiveness of this particular version of the present design.

Providing the core of these types of commutators with a non-circular collar surrounding the opening for the motor shaft additionally provides an improvement over the anchoring system of some existing designs, as the differing curvatures of the (circular) inner diameter of the shell and the (non-circular) collar cooperate to restrict circumferential displacement of the carbonaceous material once divided into individual segments.

Alternatively, the collar may be circular if not concentric with the inner diameter of the shell.

It is therefore an object of the invention to provide an anchoring system for one or more conductive segments of a rotary switch or commutator.

It is also an object of the present invention to provide such a system which permits use of the commutator until the segments are substantially completely worn.
It further is an object of the present invention to provide methods of forming commutators in which either or both of the processes of molding and curing the core and carbonaceous material can occur simultaneously.

It additionally is an object of the present invention to provide methods of forming commutators in which unwanted insulating material of the core (i.e. flash) is either not deposited, or deposited in reduced amounts, on the interior surface of the shell.

It is, moreover, an object of the present invention to provide commutators having improved characteristics and longer useful lives that at least certain other commutators discussed herein.

It is an additional object of the present invention to provide a commutator whose expense and difficulty of manufacture is decreased and whose shell may extend beyond the face of the segments during at least part of the manufacturing process.

It is another object of the present invention to provide an anchoring system for certain commutators in which one or more undercuts in either a metal (or other) shell or insulating core receive portions of the segments and restrict their axial movement.

It yet additionally is an object of the present invention to provide certain commutators avoiding any requirement to have protrusions extending from its inner diameter to anchor any conductive segments.

It is, moreover, an object of the present invention to provide various commutators in which conductive segments are fitted between a shell and the collar of an insulating core, with the inner surface of the shell and the outer surface of the collar either not having identical curvature or, if of identical curvature, not both centered on the rotational axis of the commutator.

It is still another object of the present invention to provide a particular commutator whose shell has a circular inner diameter and whose collar is multi-sided, consistent with the preceding paragraph, so as to restrict any circumferential movement of the segments as the commutator rotates.

Other objects, features, and advantages of the present invention will be apparent with reference to the remainder of the text and to the drawings of this application.
BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a plan view of, essentially, the shell of the Aupac commutator.
FIG. 2 is an elevational view of the shell of the Aupac commutator of FIG. 1.
FIG. 3 is a cross-sectional view of the shell of the Aupac commutator taken
along lines A-A of FIG. 1.
FIGS. 4-5 are cross-sectional views of the Aupac commutator of FIG. 6 illustrating aspects of its formation.
FIG. 6 is a cross-sectional view of the Aupac commutator incorporating the shell of FIG. 1.
FIG. 7 is a cross-sectional view of a commutator of the present invention.
FIGS. 8-10 are cross-sectional views of the commutator of FIG. 7 illustrating aspects of its formation.
FIG. 11-12 are cross-sectional view of an alternative, barrel-style commutator made consistent with techniques of the present invention.
FIG. 13 is a cross-sectional view of a commutator of the present invention taken along lines A-A of FIG. 14.
FIG. 14 is a plan view of the commutator of FIG. 13.
FIG. 15 is a cross-sectional view of the commutator of FIG. 13 (taken along lines A-A of FIG. 14) prior to removing an extended portion of its exterior shell.

DETAILED DESCRIPTION

FIG. 7 provides a cross-sectional view of an exemplary commutator 10 of the present invention. Commutator 10 includes multiple conductive segments 14, whose exposed surfaces 18 are intended to contact one or more conductive brushes in use.
Intermediate adjacent segments 14 are gaps or slots (not illustrated), which isolate the adjacent segments 14 and permit commutator 10 to operate as a high-speed rotary switch.
Also shown in FIG. 7 are core 26 and "blank" or shell 30. Core 26 is made of electrically-insulating material, typically (although not necessarily) phenolic, and defines a central aperture 34 for receiving a spindle or shaft in use. Core 26 additionally defines collar 38, which circumscribes aperture 34 in the area of segments 14.
Usually manufactured from a curled strip of copper or other suitable metal, shell 30 constitutes the outer diameter of commutator 10. Formed into shell 30 are multiple tangs 42, which may be bent into hooks. Additionally included in shell 30 are internal anchors 46 and, if desired, one or more grooves. As shown in FIG. 8, both tangs 42 and anchors 46 typically are formed following the blanking of shell 30.

Thereafter, pre-form 50 (which may, but need not necessarily, be deformable and in some cases may consist of raw or other powder) for segments 14 may be placed within shell 30. Consistent with FIG. 9, pre-form 50 may be inserted so that its inner face 54 is penetrated by anchors 46, thereby at least partially securing it in position within shell 30. Contact between anchors 46 and inner face 54 additionally provides further electrical connection between shell 30 and the pre-form 50. As shown in FIG. 9, shell 30 may extend beyond outer face 58 of pre-form 50, thereby protecting it to some extent during the remainder of the manufacturing process.

Although anchors 46 are shown as extending at an acute angle from shell 30, those skilled in the art will recognize that anchors 46 may be shaped or positioned differently if appropriate or desired. Anchors 46 additionally need not necessarily penetrate pre-form 50 if other securing mechanisms are adequate, but rather may instead merely abut or otherwise contact it. Likewise, shell 30 is not required to extend beyond outer faces 58, notwithstanding the advantages obtained when such extension exists.

Following placement of pre-form 50 within shell 30, the material of core 26 is injected and molded onto pre-form 50. The act of such molding, illustrated in FIG. 10, embeds portions of anchors 46 within core 26, thereby securing its position relative to shell 30. The high pressures and temperatures used to mold core 26 likewise concurrently mold pre-form 50, bonding core 26 to inner face 54 (typically via cross-linking or other bonding of resins contained in both core 26 and pre-form 50) and mechanically interlocking features (i.e. protrusions and cavities represented diagrammatically in FIG. 10) on their adjoining surfaces (or possibly created by at least slight deformation of either or both components during the molding process). This chemical bonding and mechanical interlock between core 26 and pre-form 50 functions further to anchor pre-form 50 within shell 30.

FIGS. 9-10 additionally illustrate the flash-avoidance aspects of the present invention. Because pre-form 50 is inserted into shell 30 before core 26 is molded, the
pressure used to mold core 26 forces the material of pre-form 50 to expand outward against
the inner surface 62 of shell 30. This expansion prevents excess material of core 26 from
coming between pre-form 50 and inner surface 62, thus both preventing flash within shell 30
and avoiding any need to remove it. Further anchoring of pre-form 50 conceivably could
occur if inner surface 62 contains a groove or other recess into which a portion of pre-form
50 could be fitted (or protrude when deformed).

To the extent any flash exists on outer surface 66 of shell 30, it can be
removed using conventional mechanical-abrasion (or other) methods. As denoted in FIG.
10, height A₁ is greater than the sum of the depth A₂ to which core 26 is positioned within
shell 30 and the height A₃ of pre-form 50. If shell 30 is abraded mechanically, its added
height can advantageously protect outer face 58 from certain types of damage associated
with such abrasion. Thereafter the material of both core 26 and pre-form 50 can be cured
together and any added height of shell 30 (as well as the outermost layer of outer face 58)
removed. Slotting additionally can occur to create segments 14, with contact surfaces 18,
from pre-form 50.

As shown in FIG. 7, most or all of the depth D₁ of segments 14 is available as
a contact surface for the electrical brushes used in conjunction with commutator 10. The
useful life of commutator 10 is thus increased over that of the Aupac commutator, as the
commutator 10 can continue to operate until surface 18 of each segment 14 is worn
substantially the entirety of depth D₁. By contrast, only the portions of segments 124 within
depth D₂ of FIG. 6 are available for contact and wear.

Certain performance aspects of commutator 10 additionally are enhanced
through use of the present techniques, as they permit more consistent and higher density
molding of pre-form 50. Because the present invention reduces the likelihood of damage to
core 26 as commutator 10 is formed, greater pressure can be used to mold core 26 and pre-
form 50. The greater pressure increases the ability of the core 26 to conform to the shape of
pre-form 50 and for the two to link together. Greater uniformity of temperature
conditioning also is achieved, because the material of core 26 being molded is at
approximately the same temperature as the tooling being used and the portion of shell 30
surrounding pre-form 50.
FIGS. 11-12 illustrate a barrel-style commutator 200 according to the present invention. Commutator 200 includes shell 204 from which tangs 208 and anchors 212 are formed. Carbonaceous pre-form 216 can be placed so that shell 204 penetrates it, thereby partially (directly) securing pre-form 216 to shell 204. Core 220 can then be injected within shell 204 and molded onto pre-form 216, with the joint molding of core 220 and pre-form 216 chemically and mechanically interlocking them.

As shown in FIGS. 11-12, anchors 212 are embedded within core 220. If other fixing mechanisms are adequate, anchors 212 need not necessarily be used. Alternatively, anchors 212 (if present) could be repositioned so as to contact pre-form 216 as well.

FIGS. 13-15 illustrate aspects of commutator 310 of the present invention. Commutator 310 includes multiple conductive segments 314, whose exposed surfaces 318 (which form the face of commutator 310) are intended to contact one or more conductive brushes in use. Intermediate adjacent segments 314 are gaps or slots 322, which isolate the adjacent segments 314 and permit commutator 310 to operate as a high-speed rotary switch.

Also shown in FIGS. 13-15 are core 326 and "blank" or shell 330. Core 326 is made of electrically-insulating material, typically (although not necessarily) phenolic, and defines a central aperture 334 for receiving a spindle or shaft in use. Core 326 additionally defines collar 338, which circumscribes aperture 334 in the area of segments 314.

As detailed in FIG. 14, the outer diameter of collar 338 is not circular, but rather decagonal in shape, consisting of a series of flat edges 342, each abutting the inner edge 346 of a segment 314. Because the outer edge 350 of each segment 314 adjacent shell 330 is curved differently than edges 342 (i.e. it forms an arc), the segments 314 are fitted between collar 338 and shell 330 so as not to be displaceable circumferentially. Stated differently, because edges 342 are not circles or part-circles centered on rotational axis 352, segments 314 are not displaced circumferentially as commutator 310 rotates.

Those skilled in the art will recognize that the outer diameter of collar 338 need not be decagonal as shown in FIG. 14, but may assume any shape other than that of outer edge 350 and appropriate for the number of segments 314 to be incorporated into commutator 310. Alternatively, the outer diameter of collar 338 may have the same shape as outer edge 350 and continue to restrict circumferential displacement of segments 314 as long
as the outer diameter of collar 338 and outer edge 350 do not form concentric arcs centered about axis 352. If circumferential displacement of segments 314 is, for whatever reason, not an issue of concern, collar 338 and outer edge 350 indeed may form concentric circles or part circles about axis 352. Likewise, although FIG. 14 illustrates ten segments 314, fewer or greater numbers of such segments 314 may be incorporated into the commutator 310.

Usually manufactured from a curled strip of copper or other suitable metal, shell 330 constitutes the outer diameter of commutator 310. Formed into shell 330 are multiple tangs 354, which may be bent into hooks as detailed primarily in FIGS. 13 and 15. Additionally typically included in shell 330 are anchors 358. When material for core 326 is injected into shell 330 and cured (as described in the Cooper, et al. patent), anchors 358 become embedded in the core 326, thereby retaining its position relative to the remainder of commutator 310.

An undercut is the result of cutting away material from the underside or lower portion of an object to leave an overhanging portion in relief. FIGS. 13 and 15 also illustrate annular recesses or undercuts 362A and 362B which may be present in inner surface 364 of shell 330. Similar undercuts 366A and 366B may be formed in edges 342 of collar 338. Collectively, undercuts 362A-B and 366A-B function to anchor segments 314 against axial displacement as commutator 310 operates. As detailed in FIGS. 13 and 15, portions 368 of segments 314 are pressed or otherwise fitted into the undercuts 362A-B and 366A-B, effectively locking segments 314 into position axially.

Because undercuts 362A-B and 366A-B anchor segments 314, no metal projections such as disclosed in the Abe, et al. patents are required. As a result, most or all of the depth D_r of segments 314 is available as a bearing surface for the electrical brushes used in conjunction with commutator 310. The useful life of commutator 310 is thus increased, as the commutator 310 can continue to operate until surface 318 of each segment 314 is worn substantially the entirety of depth D_r.

Although four undercuts (362A, 362B, 366A, and 366B) are illustrated in FIGS. 13 and 15, those skilled in the art will recognize that more or fewer undercuts or recesses may exist instead. In particular, undercuts need not necessarily be created in both shell 330 and collar 338, but rather may be formed in one or the other. Additionally, in some
cases a single annular undercut (in either shell 330 or collar 338) may be adequate to anchor segments 314 against axial movement.

In yet other cases, the one (or more) undercuts need not be wholly continuous or annular, but rather may be made of discrete sections in which portions of segments 314 are fitted. In these latter cases the undercuts conceivably could extend through shell 330 from inner surface 364 to outer surface 370, although applicants believe doing so might compromise at least certain performance attributes of the resulting commutator 310. Typically, therefore, any undercut is likely to be a recess extending a greater distance circumferentially than axially in either shell 330 or collar 338. It need not, however, have the partially-rectangular cross-sectional shape shown in FIGS. 13 and 15, but rather may have any desired or appropriate such shape.

Formation of commutator 310 is straightforward. Unlike the devices of the Abe, et al. patents, no projections in shell 330 to anchor segments 314 need be created or bent—much less created and bent before the material from which segments 314 are made is inserted into the shell 330. Instead, only anchors 358 for core 326 need be formed from the blank or shell 330. In certain embodiments of commutator 310, core 326 is then injected into shell 330 and cured. In such cases the same lathe or conventional tool used to remove excess phenolic material of core 326 can create any desired undercuts in either or both of inner surface 364 of shell 330 and edges 342 of collar 338, which undercuts form the one or more recesses (i.e. 362A-B and 366A-B) described above. After any undercuts are created, a cylindrical ring of graphite or other material used to make segments 314 can be inserted (typically under substantial pressure) into shell 330 and deformed so that portions 368 are forced to enter, or "key-in" to, the undercuts. Alternatively, any undercuts 362A-B or 366A-B can be made prior to injection of core 326 into shell 330. Thereafter, the carbonaceous or other material can be slotted as shown in FIG. 14 to form individual segments 314, and shell 330 can be slotted as well.

Illustrated in FIG. 15 is a version of commutator 310 in which shell 330 extends beyond surface 318 by a distance $D_2$. Increasing the height of shell 330 in this manner protects the integrity of surface 318, reducing likelihood of it being chipped, scratched, or otherwise damaged during manufacture of commutator 310. Shell 330
(possibly together with a fine portion of surface 318) can be sheared toward (or at) the end of the manufacturing process to produce the design of commutator 310 shown in FIG. 13.

The foregoing is provided for purposes of illustrating, explaining, and describing embodiments of the present invention. Further modifications and adaptation to these embodiments will be apparent to those skilled in the art and may be made without departing from the scope or spirit of the invention. Moreover, aspects of the invention may be useful or applicable other than in connection with switching devices, so that the invention need not be construed as in any way limited to that particular field of endeavor.
We claim:

1. A method of manufacturing a commutator comprising:
   a. providing a shell;
   b. positioning an electrically-conductive material at least partially within the shell; and
   c. thereafter molding an electrically-insulating core and the electrically-conductive material together at least partially within the shell.

2. A method according to claim 1 further comprising curing the core and electrically-conductive material together.

3. A method according to claim 1 further comprising forming a radially-inwardly extending anchor from the shell.

4. A method according to claim 3 in which the electrically-conductive material is a pre-form and positioning the pre-form at least partially within the shell comprises penetrating the pre-form with the anchor.

5. A method according to claim 4 in which molding the core and the pre-form together comprises embedding at least part of the anchor in the core.

6. A method according to claim 5 in which molding the core and the pre-form together further comprises chemically bonding the core and pre-form.

7. A method according to claim 6 in which molding the core and the pre-form together further comprises mechanically interlocking the core and pre-form.

8. A method according to claim 1 in which the shell has an inner surface, the electrically-conductive material is a pre-form, and molding the core and the pre-form together comprises causing the pre-form to change shape so that it contacts the inner surface of the shell.

9. A method according to claim 1 further comprising:
   a. shearing the shell so as to expose more completely the electrically-conductive material; and
   b. slotting the electrically-conductive material into commutator segments.

10. A method of manufacturing a flat-type commutator comprising:

    a. providing a shell having an approximate height $A_1$;
b. retaining an electrically-insulating core at least partially within the shell to an approximate depth \( A_2 \); and

c. retaining wholly within the shell an electrically-conductive material having an approximate height \( A_3 \) and a face adapted for contacting an electrical brush in use so that height \( A_1 \) is greater than the sum of depth \( A_2 \) and height \( A_3 \), thereby at least partially shielding the face of the electrically-conductive material.

11. A method according to claim 11 further comprising reducing the height of the shell to approximately the sum of depth \( A_2 \) and height \( A_3 \).

12. A method of manufacturing a switching device comprising:
   a. providing a metallic member;
   b. positioning an electrically-conductive material in contact with the metallic member, and
   c. thereafter molding an electrically-insulating core and the electrically-conductive material together.

13. A commutator comprising:
   a. a shell;
   b. an electrically-conductive material positioned at least partially within the shell and having an inner face and an outer face, the outer face adapted to contact an electrical brush in use; and
   c. an insulating core molded onto the electrically-conductive material so as to be chemically bonded to the inner face.

14. A commutator comprising:
   a. a shell having a thickness;
   b. an electrically-insulating core anchored at least partially within the shell, at least one of the shell and core having an undercut therein; and
   c. an electrically-conductive material having a portion fitted into the undercut; and
   in which, if no undercut is present in the core, at least part of the undercut in the shell has depth less than the thickness of the shell.
15. A method of manufacturing a commutator comprising:
   a. creating a generally-cylindrical shell having an inner surface and a thickness;
   b. forming an undercut in the inner surface of the shell, the thickness of the
      undercut being less than the thickness of the shell; and
   c. placing an electrically-conductive material at least partially within the shell so
      that a portion of the electrically-conductive material is caused to go into the
      undercut.
Excess Phenolic (flash) must be removed from this area.

Usable Carbon Wear Depth.
Process step - "Bottom" anchors must be formed into inside diameter of shell.

Process step - Carbon is molded into "bottom" portion of shell to anchor carbon to shell and Phenolic and provide electrical interface between carbon and shell. The carbon is pressed directly against the previously molded and cured Phenolic.
Process step - Phenolic is molded onto carbon pre-form under high pressure and temperature. Allows both molding processes to be done at one time.

Fig. 9

Top Anchor 4c
Penetrates Carbon

Unmolded Carbon Pre-form SB

Excess Shell Extending Past Carbon to Protect Carbon During Wheelabrator

Fig. 10

Phenolic Molded Onto Unmolded Carbon Pre-form

“Natural” Bond Between Phenolic and Carbon

Phenolic Pressure Forces Unmolded Carbon Pre-form Outward to Prevent Phenolic Flash in This Region
Undercuts in copper and phenolic anchor carbon axially.
Fig. 14

Flats on phenolic anchor carbon

Circumferential
Undercuts in copper and phenolic anchor carbon axially and radially.

Copper

Phenolic

Carbon

Copper