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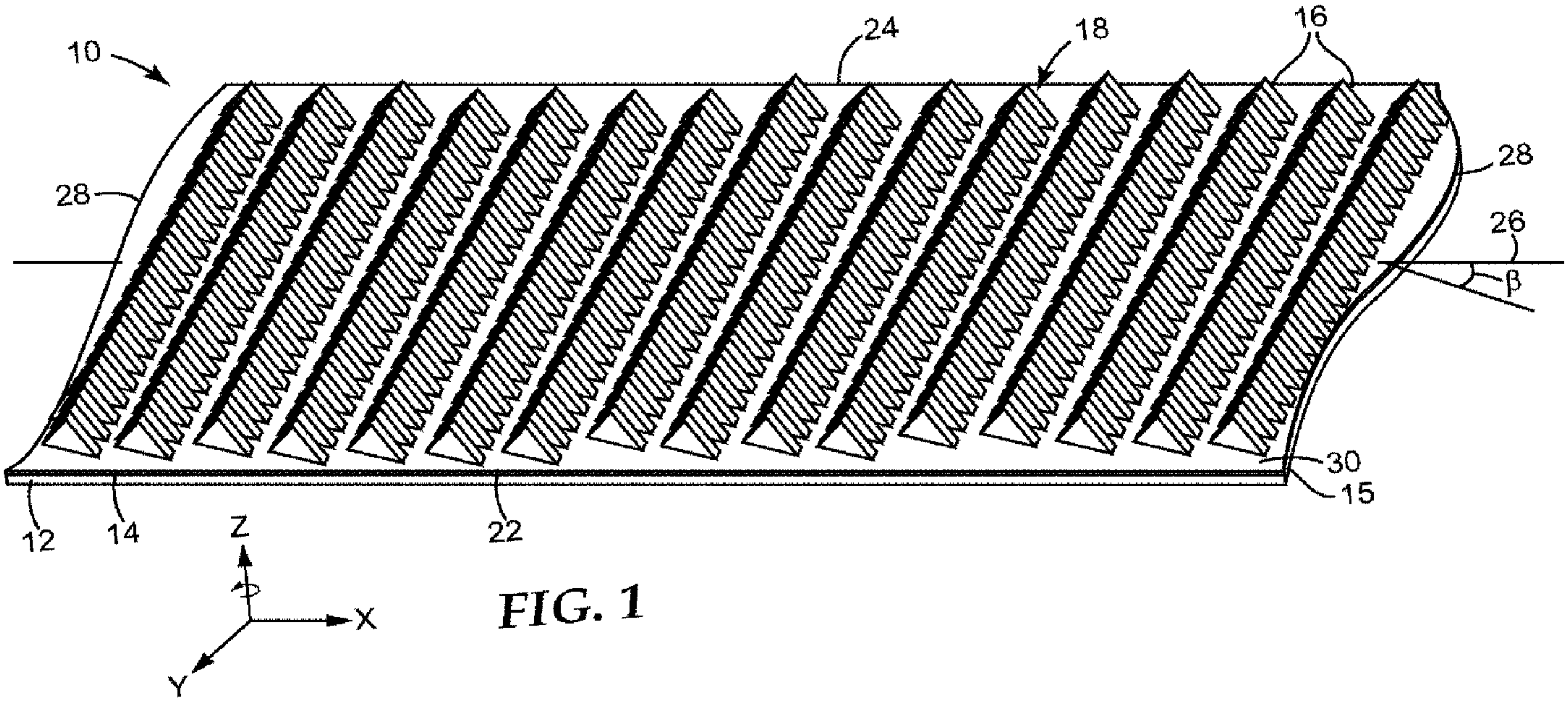

FIG. 1

(57) Abrégé/Abstract:
An abrasive belt having a backing and an abrasive layer adhered to the backing by a make coat resin and the abrasive layer comprising a plurality of shaped abrasive particles. A first belt side and a second belt side opposing the first belt side with the first and second belt sides generally aligned with a longitudinal axis of the grinding belt. The belt having at least 30% of the shaped abrasive particles in the abrasive layer having a first face and placed onto the backing such that an angle between the first face and the longitudinal axis is greater than 0 degrees and less than or equal to 20 degrees.

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(54) **Title**: ABRASIVE BELT WITH ANGLED SHAPED ABRASIVE PARTICLES

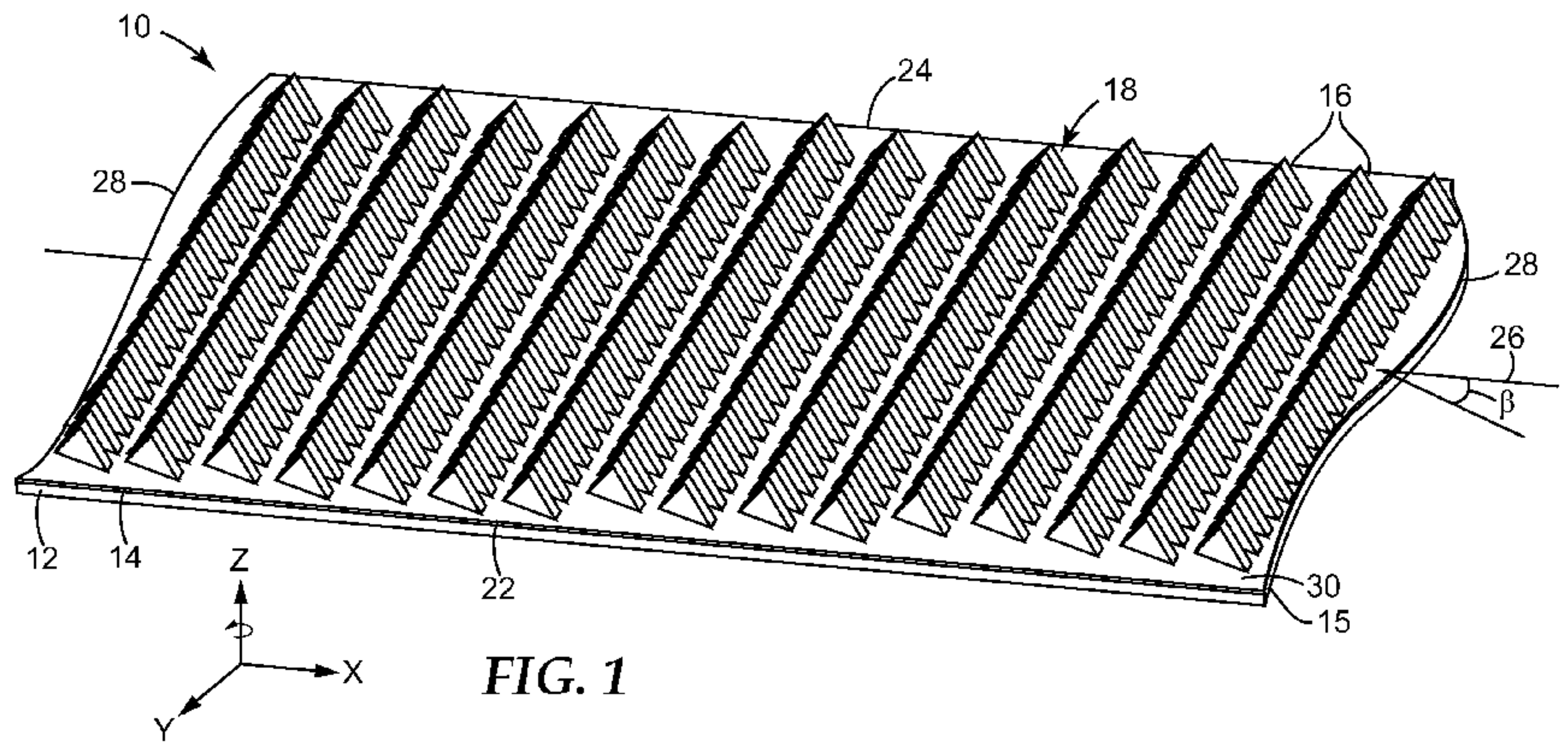

FIG. 1

(57) **Abstract**: An abrasive belt having a backing and an abrasive layer adhered to the backing by a make coat resin and the abrasive layer comprising a plurality of shaped abrasive particles. A first belt side and a second belt side opposing the first belt side with the first and second belt sides generally aligned with a longitudinal axis of the grinding belt. The belt having at least 30% of the shaped abrasive particles in the abrasive layer having a first face and placed onto the backing such that an angle between the first face and the longitudinal axis is greater than 0 degrees and less than or equal to 20 degrees.

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ABRASIVE BELT WITH ANGLED SHAPED ABRASIVE PARTICLES

BACKGROUND

Abrasive belts having precisely shaped abrasive composites formed from small abrasive particles dispersed in a cured resin binder and molded into shaped structures can be aligned at an angle other than zero or ninety degrees with respect to the edge of the belt as disclosed in US patent 5,489,235 to Gagliardi. See Figure 1. The abrasive composites on the abrasive belt create a scratch pattern that crosses the previous scratch pattern (non-scribing pattern). The crossing patterns lead to a more random, less uniform scratch pattern which provides finer surface finishes.

SUMMARY

Shaped abrasive particles, as disclosed for example in US patent 8,142,531, provide significantly improved cut over the shaped abrasive composites disclosed in Gagliardi. When attempting to rotate the shaped abrasive particles with the significantly improved cut for positioning on a belt as disclosed in Gagliardi, a new problem was discovered. Namely, the shaped abrasive particles, when aligned at an angle other than zero or ninety degrees to the longitudinal axis of the belt, created a significant side force or side load that must be counteracted in order for the belt to track properly. No such side force or side loads were created by the belt disclosed in Gagliardi when using the abrasive composites.

The inventors discovered that when the shaped abrasive particles are rotated a significant angular amount relative to the longitudinal axis of the belt, due to the aggressive cut of the shaped abrasive particles, the belt may have a tendency to track off to the side of the grinding machine; especially, as the load on the work piece is significantly increased. This can be especially problematic in situations when a high work piece load is applied for a short duration, the work piece removed from the belt, and then reapplied for another short duration high load cycle. The belt tracking system of the grinding machine sees repeated cycles with high belt side load and then no belt side load. Adjusting the belt to track properly with no side load present can cause the belt to not track properly when the side load is present and vice versa. This problem is most acute for abrasive belts that are short, narrow, or under low tension and contain larger sized shaped abrasive particles.

The inventors determined that one way to solve this problem was to limit the angular rotation of the shaped abrasive particles on the belt thereby limiting the generated side loads during grinding while still providing a non-scribing, finer finish on the work piece.

Hence, in one embodiment, the invention resides in an abrasive belt comprising: a backing and an abrasive layer adhered to the backing by a make coat resin and the abrasive layer comprising a plurality of shaped abrasive particles; a first belt side and a second belt side opposing the first belt side with the first and second belt sides generally aligned with a longitudinal axis of the grinding belt; at least 30% of the shaped abrasive particles in the abrasive layer having a first face and placed onto the backing such that an angle between the first face and the longitudinal axis is greater than 0 degrees and less than or equal to 20 degrees.

As used herein, the term "shaped abrasive particle", means a ceramic abrasive particle with at least a portion of the abrasive particle having a predetermined shape. Shaped abrasive particles exclude abrasive composites formed from abrasive particles dispersed in a cured resin binder and molded into shaped structures as used for example in US patent 5,489,235. Ceramic shaped abrasive particles are generally homogenous or substantially uniform and maintain their sintered shape without the use of a binder such an organic or inorganic binder that bond smaller abrasive particles into an agglomerated structure and excludes abrasive particles obtained by a crushing or comminution process that produces abrasive particles of random size and shape. In many embodiments, the ceramic shaped abrasive particles comprise a homogeneous structure of sintered alpha alumina or consist essentially of sintered alpha alumina. In many embodiments, the ceramic shaped abrasive particle is made from a boehmite sol gel that is molded, dried, calcined and sintered to form a ceramic alpha alumina shaped abrasive particle. Often the shape is replicated from a mold cavity used to form the precursor shaped abrasive particle. Except in the case of abrasive shards (e.g. as described in U.S. application Ser. No. 12/336,877), the shaped abrasive particle will generally have a predetermined geometric shape that substantially replicates the mold cavity that was used to form the shaped abrasive particle. The mold cavity could reside on the surface of an embossing roll or be contained within a flexible belt or production tooling. Alternatively, the shaped abrasive particles can be precisely cut from a sheet of dried sol-gel by a laser beam into the desired geometric shape. Suitable shaped abrasive particles are disclosed in the following non-limiting patents and publications:

US2014290147 (Everts et al.); US2014007518 (Breder et al.); US2013337262 (Barnes et al.); US8840696 (Czerepinski et al.); US8753742 (Arcona et al.); US8758461 (Czerepinski et al.); US2013263525 (Erickson); US8728185 (Adefris); US2013040537 (Adefris et al.); US2012227333 (Adefris et al.); US8764865 (Adefris et al.); US2010319269 (Erickson); US8034137 (Adefris et al.); US8142532 (Adefris et al.); US8142531 (Adefris et al.); US8142891 (Adefris et al.); US5984988 (Berg et al.); EP2692815 (Frei et al.); EP2692814 (Fuenfschilling et al.); EP2692816 (Fuenfschilling et al.); EP2692817 (Fuenfschilling et al.); EP2692820 (Fuenfschilling et al.); EP2692813 (Buehler et al.); EP2692819 (Fuenfschilling et al.); and EP2692821 (Fuenfschilling et al.)

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of an abrasive belt.

FIG. 2 is a perspective view of a shaped abrasive particle.

FIG. 3 is a graph of Side Force vs Cycle for various abrasive belts.

FIG. 4 is a graph of Cut vs Cycle for various abrasive belts.

DETAILED DESCRIPTION

Coated Abrasive Article

Referring to FIG. 1, a coated abrasive article in the form of an abrasive belt 10 comprises a backing 12 having a first layer of binder, hereinafter referred to as the make coat resin 14, applied over a first major surface 15 of the backing 12. Attached or partially embedded in the make coat 14 are a plurality of shaped abrasive particles 16 forming an abrasive layer 18. In some embodiments, the abrasive layer 18 comprises a patterned abrasive layer with at least some of the shaped abrasive particles spaced and positioned onto the backing in a pre-determined pattern. The shaped abrasive particles can be spaced from each other a pre-determined amount in the X and Y directions and have a specified angular rotation about the Z-axis that is parallel to a shaped abrasive particle longitudinal axis 20 of an individual shaped abrasive particle.

The abrasive belt has a first belt side 22, a second belt side, 24, and a belt longitudinal axis 26. The belt can be left as shown in FIG. 1 for use in a cartridge grinder where the belt is unwound, directed over the work piece, and then rewound. Alternatively, the ends 28 of the belt can be spliced and joined together to form an endless abrasive belt in the form of a loop using readily known methods.

Over the shaped abrasive particles 16 a second layer of binder, hereinafter referred to as the size coat resin 30 can be applied. The size coat has been minimized in FIG. 1 to better illustrate the orientation of the shaped abrasive particles. The purpose of make coat resin 14 is to secure shaped abrasive particles 16 to backing 12 and the purpose of size coat 30 is to reinforce shaped abrasive particles 16 in the abrasive layer 18 to better secure them within the abrasive layer and to the backing.

Referring now to FIG. 2, one embodiment of a shaped abrasive particle 16 is shown. The shaped abrasive particle 16 has a first face 32 and an opposing second face 34 separated by a thickness t. The first face and the second face are joined to each other by a sidewall 36. In some embodiments, the sidewall is a sloping sidewall having a specific draft angle, α, between the second face and the sidewall as disclosed in US patent 8,142,531. The shaped abrasive particle has a length, l, measured along the shaped abrasive particle longitudinal axis 20. A perimeter of both the first face and the second face is triangular, and in some embodiments the perimeter is an equilateral triangle. Other shaped abrasive particles can be used as listed in the definition above.

In some embodiments, at least 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, or 95 percent of the shaped abrasive particles 16 in the abrasive layer 18 are placed onto the backing such than an offset angle, β, between the first face 32 and the belt longitudinal axis 26 is greater than 0 degrees and less than or equal to 20 degrees. In other embodiments, at least 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, or 95 percent of the shaped abrasive particles 16 in the abrasive layer 18 are placed onto the backing such than an offset angle, β, between the first face 32 and the belt longitudinal axis 26 is greater than 0 degrees and less than or equal to 10 degrees. In other embodiments, at least 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, or 95 percent of the shaped abrasive particles 16 in the abrasive layer 18 are placed onto the backing such than an offset angle, β, between the first face 32 and the belt longitudinal axis 26 is greater than 0 degrees and less than or equal to 5 degrees. As will be shown later in the Examples, a specified range for the angle, β, has been shown to limit the side load or side force generated by the abrasive layer with the rotated shaped abrasive particles.

As used herein in referring to shaped abrasive particles, the term "length" refers to the maximum dimension of a shaped abrasive particle and is typically along the shaped abrasive particle longitudinal axis 20. "Width" refers to the maximum dimension of the shaped abrasive particle that is perpendicular to the length and is typically perpendicular to the shaped abrasive particle longitudinal axis 20. The terms "thickness" or "height" refer to the dimension of the shaped abrasive particle that is perpendicular to the length and width. See Fig. 2 where length and thickness are shown for the triangular shaped abrasive particle.

Shaped ceramic abrasive particles are typically selected to have a length in a range of from 1 micron to 15000 microns, more typically 10 microns to about 10000 microns, and still more typically from 150 to 2600 microns, although other lengths may also be used.

Shaped ceramic abrasive particles are typically selected to have a width in a range of from 0.1 micron to 3500 microns, more typically 100 microns to 3000 microns, and more typically 100 microns to 2600 microns, although other lengths may also be used.

Shaped ceramic abrasive particles are typically selected to have a thickness in a range of from 0.1 micron to 1600 microns, more typically from 1 micron to 1200 microns, although other thicknesses may be used.

In some embodiments, shaped ceramic abrasive particles may have an aspect ratio (length to thickness) of at least 2, 3, 4, 5, 6, or more.

The make coat resin 14 and size coat resin 30 comprise a resinous adhesive. The resinous adhesive of the make coat resin can be the same as or different from that of the size coat resin. Examples of resinous adhesives that are suitable for these coats include phenolic resins, epoxy resins, urea-formaldehyde resins, acrylate resins, aminoplast resins, melamine resins, acrylated epoxy resins, urethane resins and combinations thereof. In addition to the resinous adhesive, the make coat resin or size coat resin, or both coats, may further comprise additives that are known in the art, such as, for example, fillers, grinding aids, wetting agents, surfactants, dyes, pigments, coupling agents, adhesion promoters, and combinations thereof. Examples of fillers include calcium carbonate, silica, talc, clay, calcium metasilicate, dolomite, aluminum sulfate and combinations thereof. A supersize coating may be applied over the size coat as well as disclosed in the Examples.

A grinding aid can be applied to the coated abrasive article. A grinding aid is defined as particulate material, the addition of which has a significant effect on the chemical and physical processes of abrading, thereby resulting in improved performance. Grinding aids encompass a wide variety of different materials and can be inorganic or organic.

The backing 12 can be any suitable material used for abrasive articles such as, paper, film, cloth, nonwovens, vulcanized fiber, plastics, and the like.

In some embodiments, a combination of shaped abrasive particles and other abrasive grains such as crushed abrasive particles or diluent particles can be used as disclosed for example in US. Patent publication US 2012/0231711 and in US patent number 5,496,386. In some embodiments, two or more shaped abrasive particles may be placed into close proximity by forming multiplexed shaped abrasive structures of duplexed, triplexed or even more shaped abrasive particles as disclosed in PCT Application No. PCT/US2015/045505 filed on August 17, 2015 entitled Coated Abrasive Articles with Multiplexed Structures of Abrasive Particles and Method of Making.

Method of Making a Coated Abrasive Article

Pending PCT Application No. PCT/US2014/069726, filed on July 2, 2015; published PCT No. PCT/US2015/10020, published on July 2, 2015, published PCT No. PCT/US2015/100018, published on July 2, 2015, and PCT Patent Application No. PCT/US2015/045505, filed on August 17, 2015 disclose a method of making abrasive articles, an apparatus for making abrasive articles, and production tooling for an abrasive particle positioning system and are herein incorporated by reference. In general, a production tool having a plurality of cavities dimensioned to hold a single shaped abrasive particle or multiple shaped abrasive particles are provided for precise positioning, rotational orientation, and transfer of the shaped abrasive particles to a coated backing thereby forming a patterned abrasive layer where the X-Y spacing and rotational orientation about the Z axis of at least 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, or 95 percent of each shaped abrasive particle in the abrasive layer can be predetermined and controlled for a specific grinding application. After the shaped abrasive particles are placed into the production tool, the production tooling and the coated backing having a make coat resin applied are brought into close proximity and the shaped abrasive particles are transferred from the cavities in the tooling and onto the backing to form a pre-determined pattern or patterned abrasive layer with the shaped abrasive particles. The make coat resin is then cured, typically a size coat resin is applied and cured, and the coated abrasive article is converted into a belt.

EXAMPLES

Objects and advantages of this disclosure are further illustrated by the following non-limiting examples. The particular materials and amounts thereof recited in these examples as well as other conditions and details, should not be construed to unduly limit this disclosure. Unless otherwise noted, all parts, percentages, ratios, etc. in the Examples and the rest of the specification are by weight.

PREPARATION OF SHAPED ABRASIVE PARTICLES

Shaped abrasive particles were prepared according to the disclosure of U.S. Patent No. 8,142,531 (Adefris et al.). The shaped abrasive particles were prepared by molding alumina sol gel in equilateral triangle-shaped polypropylene mold cavities of side length 0.068 inch (1.73 mm) and a mold depth of 0.012 inch (0.3 mm). After drying and firing, the resulting equilateral, triangular shaped abrasive particles resembled FIG. 1A except the draft angle α of a sloping sidewall was approximately 98 degrees. The fired shaped abrasive particles were about 1.3 mm (side length) x 0.27 mm thick and would pass through a 20-mesh sieve.

COMPARATIVE EXAMPLE A

The abrasive belt of Comparative Example A was obtained as 3M™ CUBITRON™ II ABRASIVE CLOTH BELT 984F, 36+ YF-WEIGHT from 3M, Saint Paul, Minnesota. In the 984F belt, the triangular shaped abrasive particles are applied to the backing by an electrostatic deposition process and therefore the first face of each shaped abrasive particle is randomly orientated with respect to the belt's longitudinal axis.

EXAMPLES 1-6 AND COMPARATIVE EXAMPLE B

Comparative Example B

Untreated polyester cloth having a weight of 300-400 grams per square meter (g/m^2), obtained under the trade designation POWERSTRAIT from Milliken & Company, Spartanburg, SC, was presized with a composition consisting of 75 parts EPON 828 epoxy resin (bisphenol A diglycidyl ether, from Resolution Performance Products, Houston, TX), 10 parts of trimethylolpropane triacrylate (obtained as SR351 from Cytec Industrial Inc., Woodland Park, NJ), 8 parts of dicyandiamide curing agent (obtained as DICYANEX 1400B from Air Products and Chemicals, Allentown, PA), 5 parts of novolac resin (obtained as RUTAPHEN 8656 from Momentive Specialty Chemicals Inc., Columbus, OH), 1 part of 2,2-dimethoxy-2-phenylacetophenone (obtained as IRGACURE 651 photoinitiator from BASF Corp., Florham Park, NJ), and 0.75 part of 2-propylimidazole (obtained as ACTIRON NXJ-60 LIQUID from Synthron, Morganton, NC).

A 10.16 cm x 114.3 cm strip of this backing was taped to a 15.2 cm x 121.9 cm x 1.9 cm thick laminated particle board. The cloth backing was coated with 229 g/m^2 of a phenolic make resin consisting of 52 parts of resole phenolic resin (obtained as GP 8339 R-23155B from Georgia Pacific Chemicals, Atlanta, GA), 45 parts of calcium metasilicate (obtained as WOLLASTOCOAT from NYCO Company, Willsboro, NY), and 2.5 parts of water using a putty knife to fill the backing weave and remove excess resin.

The shaped abrasive particles prepared according to the disclosure of U.S. Pat. No. 8,142,531 (Adefris et al.) had nominal equal side lengths of 1.30 mm and a thickness of 0.27 mm, and a sidewall angle of 98 degrees.

A production tool with an array of vertically-oriented triangular openings (wherein length = 1.698 mm, width = 0.621 mm, depth = 1.471 mm, bottom width = 0.363 mm) arranged in a rectangular array (length-wise pitch = 2.68 mm, width-wise pitch = 1.075 mm) was cut into 5 inch (12.7 cm) wide strips at a zero degree offset angle β. Sufficient bias cut tool sections to achieve a total length of 44 inches (111cm) were lined up end to end and mounted to a second 15.2 cm x 121.9 cm x 1.9 cm thick particle board. A 1.0 cm diameter hole was drilled through the thickness at the midpoint of the 15.2 cm dimension and approximately 2.54 cm from each end of both of the laminated particle boards. A base was constructed that had a 0.95-cm diameter vertical dowels at each end to engage the holes in the particle boards and thereby align the placement of first the abrasive particle filled tooling (open side up), followed by the make resin-coated backing (coated side down). Several spring clamps were attached to the particle boards to hold the construction together. The clamped assembly was removed from the dowels, flipped over (backing now coated side up and tooling open side down) and placed back onto the base using the dowels to maintain alignment. The back of the laminated particle board was repeatedly tapped lightly with a hammer to transfer the abrasive particles to the make-coated backing. Abrasive grains having a basis weight of 727 g/m^2 were thus applied. The spring clamps were removed and the top board carefully removed from the dowels so the transferred mineral was not knocked over on its side. Nominally, close to 100 percent of the shaped abrasive particles were positioned a predetermined distance from each other in the X and Y directions and had an offset angle β of zero degrees.

The tape was removed and the abrasive coated backing and it was placed in an oven at 90°C for 1.5 hours to partially cure the make resin. A size resin consisting of 43.15 parts of resole phenolic resin (obtained as GP 8339 R-23155B from Georgia Pacific Chemicals, Atlanta, GA), 9.7 parts of water, 22.75 parts of cryolite (Solvay Chemicals, Inc, Houston, Texas), 22.75 parts calcium metasilicate (obtained as WOLLASTOCOAT from NYCO Company, Willsboro, NY) and 1.65 parts red iron oxide was applied to each strip at a basis weight of 503 g/m^2, and the coated strip was placed in an oven at 90°C for 1 hour, followed by and 8 hours at 102°C .

A supersize coating consisting of 29.2 parts aqueous dispersion obtained as CMD35201 (EPI-REZ 522-C) (Rhone-Poulenc, Inc. Louisville Kentucky), 0.35 parts 2-ethyl, 4-methyl imidazole, obtained as EMI-24 (Air Products and Chemicals, Allentown, Pennsylvania), 53.3 parts 98% pure micropulverized KBF_4 (95% by weight passes through a 325-mesh screen and 100% by weight passes through a 200-mesh screen) was then applied to each strip at a basis weight of 300 g/m^2 and then the coated strips were cured at 125°C for 3 hours. After cure, the strip of coated abrasive was converted into a belt using conventional adhesive splicing practices.

EXAMPLES 1-6 AND COMPARATIVE EXAMPLES C

Examples 1-6 and Comparative Example C were made identically to Comparative Example B with the exceptions of offset angle β and coating weights, as shown in Table 1. Each basis weight in table 1 is the average weight obtained from two replicate belts.

Table 1

Example	Offset angle β degrees	Make	Particle	Size	Supersize
		Coating weight, g/m^2			
Comp. B	0	229	727	503	300
1	2	260	868	470	235
2	5	200	754	469	261
3	8	237	801	482	240
4	10	235	795	516	257
5	15	217	770	417	235
6	20	240	878	485	236
Comp. C	30	247	750	475	245

BELT TRACKING TEST

An automated tracking and grinding test was conducted on 3 inch (7.62 cm) wide x 36 inch (91.44 cm) belts to evaluate inventive and comparative coated abrasive belt constructions. The work piece was 304 stainless steel bars on which the surface to be abraded measured 0.75 inch by 0.75 inch (1.9 cm x 1.9 cm). An 8 inch (20.32 cm) diameter, 70 durometer rubber serrated contact wheel was used. The belt was run at 2750 rpm (5760 ft/minute (1756 m/minute)). The work piece was urged against the center part of the belt at a normal force of 15 pounds (6.80 kgf). The test consisted of measuring the weight loss of the work piece every 15 seconds. During the grinding process, the horizontal (tracking) forces were measured. Following each 15-second cycle, the work piece was cooled in water and tested again. The test was concluded when cut rate (grams/15 seconds) was 25% of initial cut rate, or after 40 cycles, whichever came first. The average cut for the two replicate belts in grams was then recorded for each offset angle (see FIG. 4), along with the average side force for each cycle (see FIG. 3).

As seen in FIG. 3, the side force in pounds increased as the offset angle, β, between the belt longitudinal axis and the first face increased. In general for angles less than or equal to 5 degrees, the side force was approximately the same as the electrostatically coated belt

Comparative A and nominally zero. Thus, an offset angle, β, of less than or equal to 5 degrees had the same side force load as an electrostatically coated belt but because the shaped abrasive particles are slightly rotated a non-scribing finish is obtained.

A significant shift in the side force curve occurred for the 30 degree offset angle, β, upon which no higher offset angles were attempted. Higher offset angles up to 45 degrees would result in additional increased side forces. As seen in the graph, as the shaped abrasive particles wear down from the abrading action, the side force decreases to zero and actually become negative for unknown reasons. This confirms that the significantly increased cut of the shaped abrasive particles, especially when new, caused the increase in the belt's side force when grinding.

All cited references, patents, or patent applications in the above application for letters patent are herein incorporated by reference in their entirety, or specified portion thereof, in a consistent manner. In the event of inconsistencies or contradictions between portions of the incorporated references and this application, the information in the preceding description shall control. The preceding description, given in order to enable one of ordinary skill in the art to practice the claimed disclosure, is not to be construed as limiting the scope of the disclosure, which is defined by the claims and all equivalents thereto.

What is claimed is:

1. An abrasive belt comprising:
   a backing and an abrasive layer adhered to the backing by a make coat resin and the abrasive layer comprising a plurality of shaped abrasive particles;
   a first belt side and a second belt side opposing the first belt side with the first and second belt sides generally aligned with a longitudinal axis of the grinding belt;
   at least 30% of the shaped abrasive particles in the abrasive layer having a first face and placed onto the backing such that an angle between the first face and the longitudinal axis is greater than 0 degrees and less than or equal to 20 degrees.

2. The abrasive belt of clam 1 wherein the shaped abrasive particles comprise a second face opposing the first face and a sidewall connecting the first face to the second face.

3. The abrasive belt of claim 2 wherein a perimeter of the both first face and the second face is triangular.

4. The abrasive belt of claim 3 wherein the perimeter is an equilateral triangle.

5. The abrasive belt of claims 1, 2, 3, or 4 wherein greater than 50% of the shaped abrasive particles in the abrasive layer having a first face and placed onto the backing such that an angle between the first face and the longitudinal axis is greater than 0 and less than or equal to 20 degrees.

6. The abrasive belt of claims 1, 2, 3, or 4 wherein greater than 75% of the shaped abrasive particles in the abrasive layer having a first face and placed onto the backing such that an angle between the first face and the longitudinal axis is greater than 0 and less than or equal to 20 degrees.

7. The abrasive belt of claims 1, 2, 3, 4, 5, or 6 wherein the angle is greater than 0 and less than or equal to 10 degrees.

8. The abrasive belt of claims 1, 2, 3, 4, 5, or 6 wherein the angle is greater than 0 and less than or equal to 5 degrees.

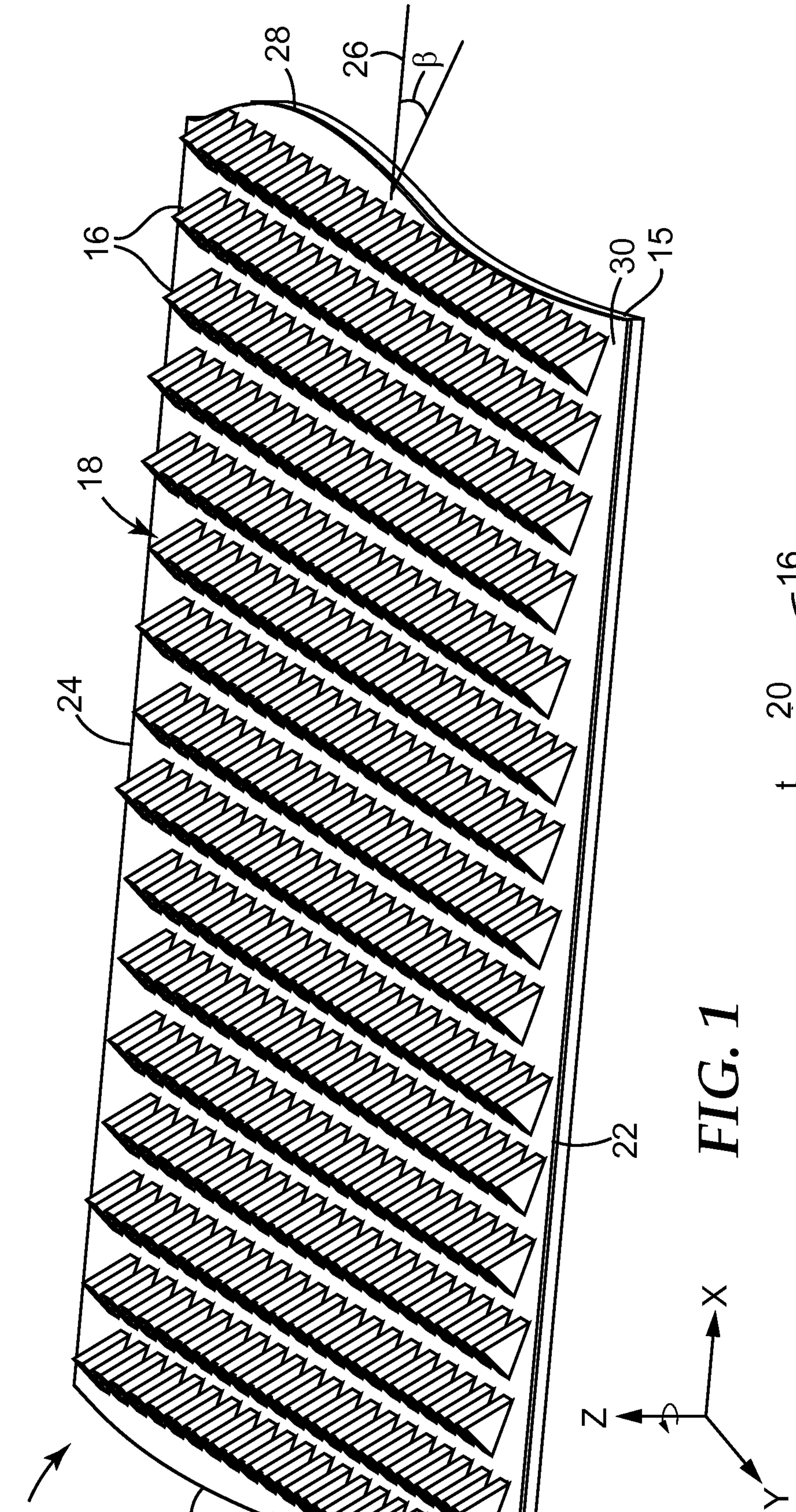

FIG. 1

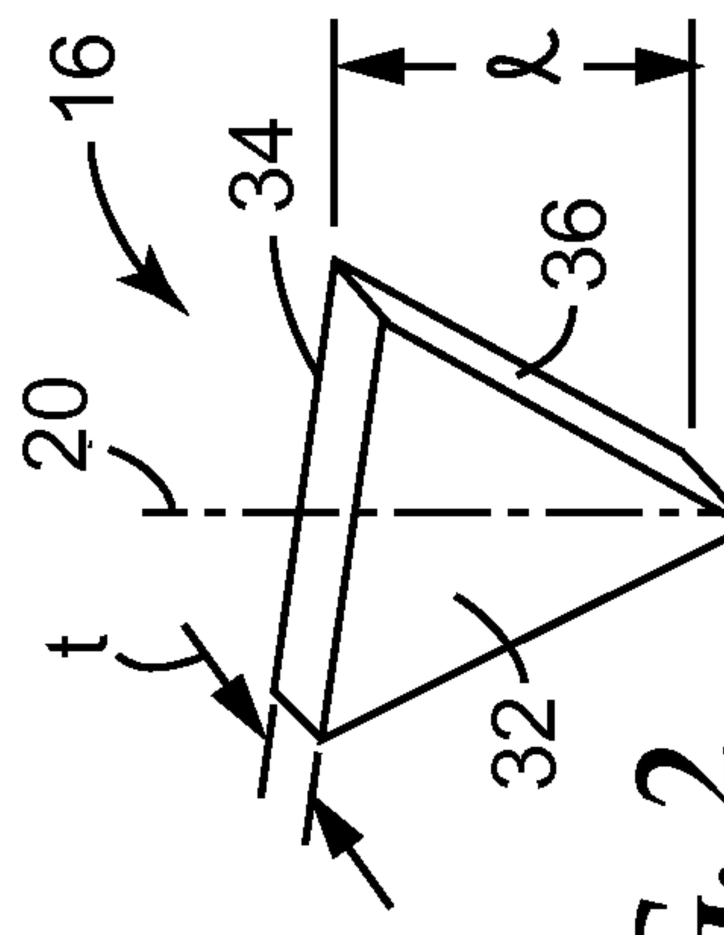

FIG. 2

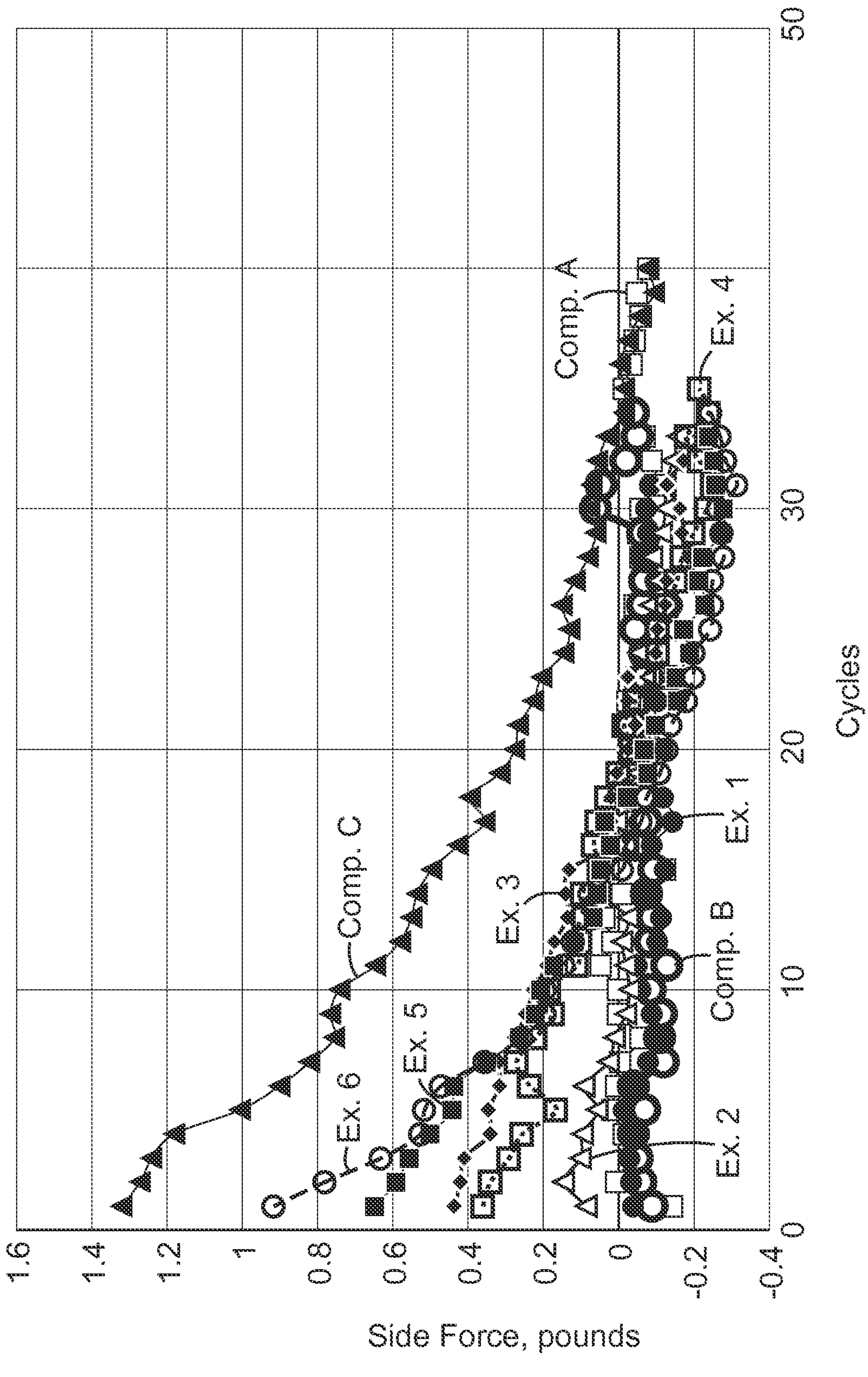
Side Force, pounds
Cycles
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
0
10
20
30
50
Comp. A
Ex. 4
Comp. C
Ex. 3
Ex. 1
Comp. B
Ex. 6
Ex. 5
Ex. 2

FIG. 3

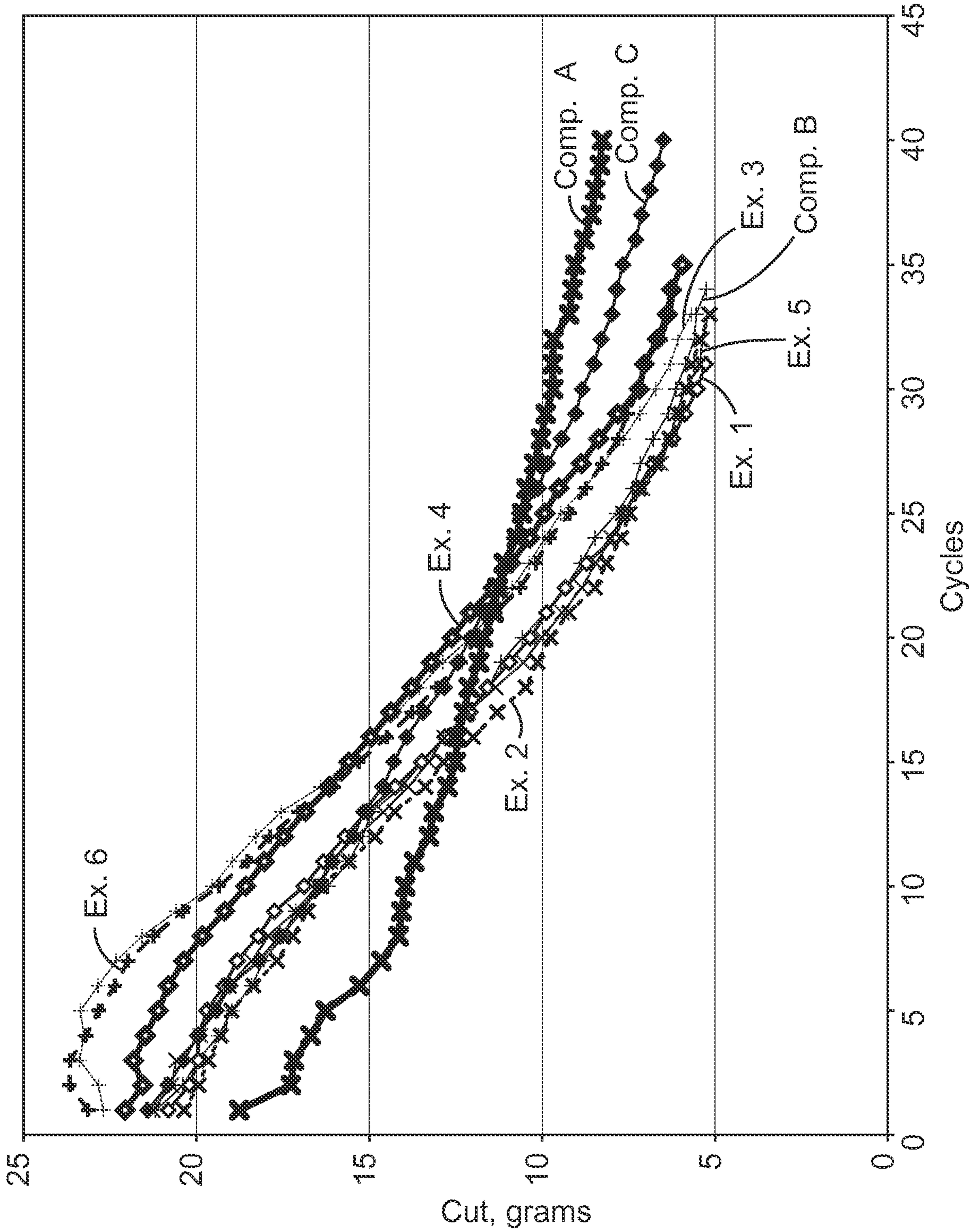
Comp. A
Comp. C
Comp. B
Ex. 3
Ex. 5
Ex. 1
Ex. 4
Ex. 2
Ex. 6
Cut, grams
Cycles
0
5
10
15
20
25
30
35
40
45

FIG. 4

FIG. 1