US 20160144484A1

(19) **United States**

(12) **Patent Application Publication**

Simon

(10) **Pub. No.: US 2016/0144484 A1**

(43) **Pub. Date: May 26, 2016**

(54) **ABRASIVE ARTICLE AND ADAPTER THEREFORE**

(71) Applicant: **3M INNOVATIVE PROPERTIES COMPANY**, St. Paul, MN (US)

(72) Inventor: **Theo Simon**, Warwickshire (GB)

(21) Appl. No.: **14/899,580**

(22) PCT Filed: **Jun. 30, 2014**

(86) PCT No.: **PCT/US2014/044823**

§ 371 (c)(1),
(2) Date: **Dec. 18, 2015**

(30) **Foreign Application Priority Data**

Jul. 2, 2013 (GB) 1311846.8

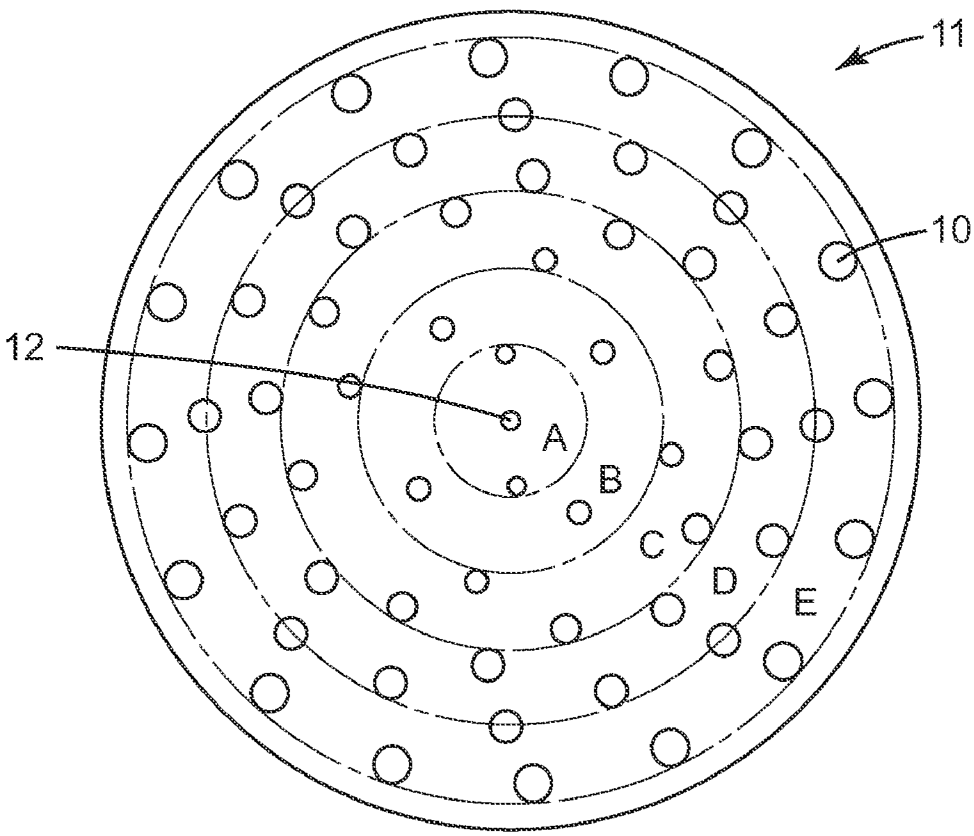
Publication Classification

(51) **Int. Cl.**
B24D 9/08 (2006.01)

(52) **U.S. Cl.**
CPC ***B24D 9/08*** (2013.01)

(57) **ABSTRACT**

An abrasive article and an adapter therefore are disclosed. The abrasive article comprises a backing and an abrasive coating on a surface of the backing, and has a centre point and a periphery and the abrasive coating forming a work surface. A plurality of holes extending through the backing and the abrasive coating are provided, through which particulate material may be extracted. The work surface is divided into at least a first inner and a second outer zone, the second zone being concentric with the first and the centre point. Each zone has at least one hole, wherein in each of the first and the second zone the sizes of the holes and their total number forms a hole density for that respective zone. The hole density of the first zone is less than the hole density of the second zone. The adapter has the mounting surface for the abrasive article adapted in a similar manner.



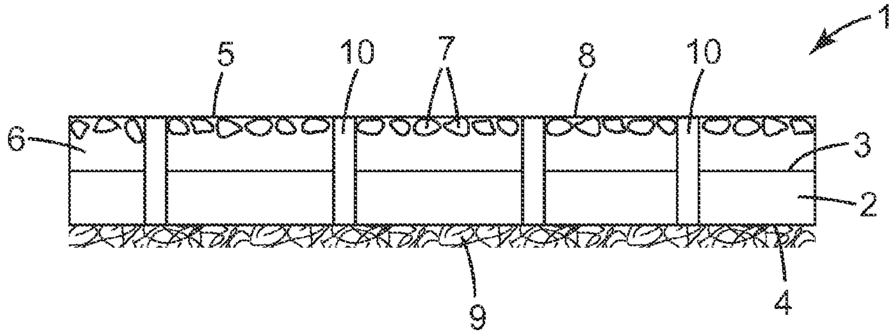


Fig. 1

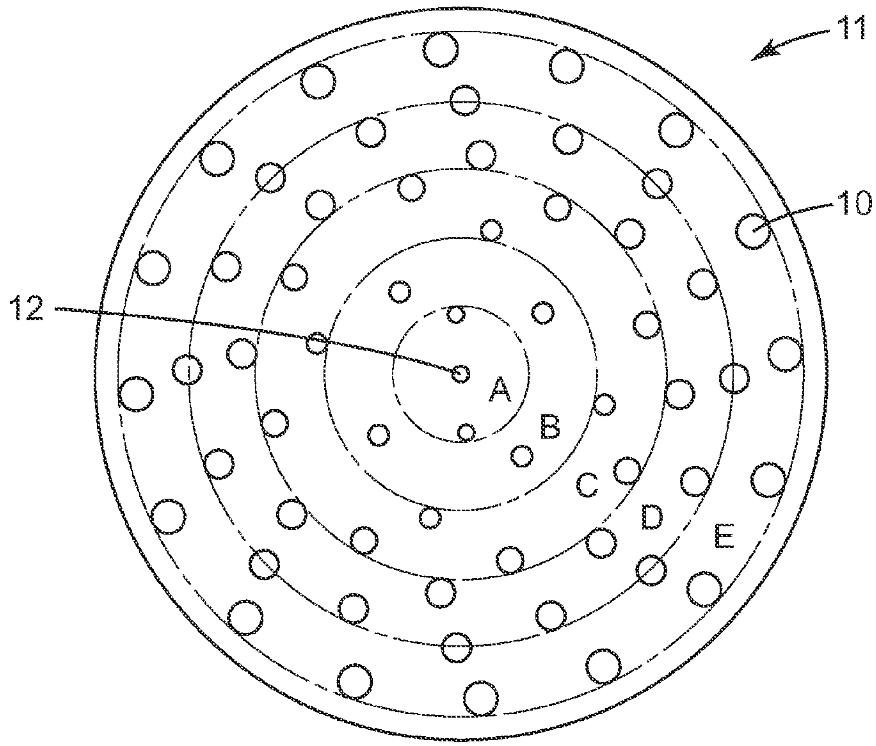


Fig. 2

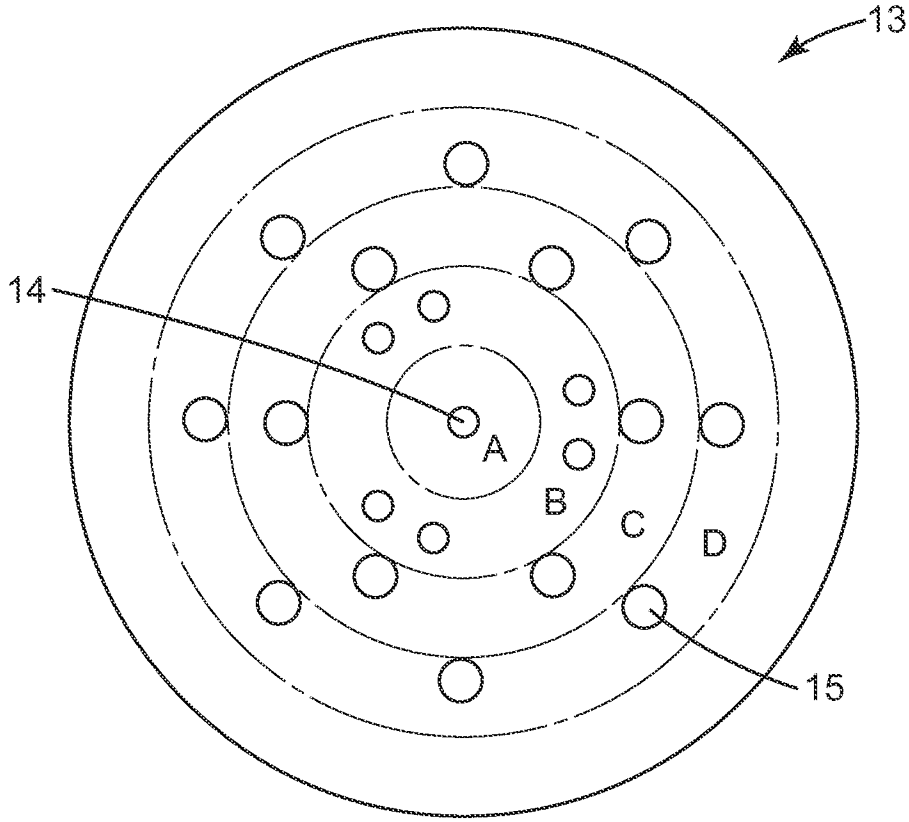


Fig. 3

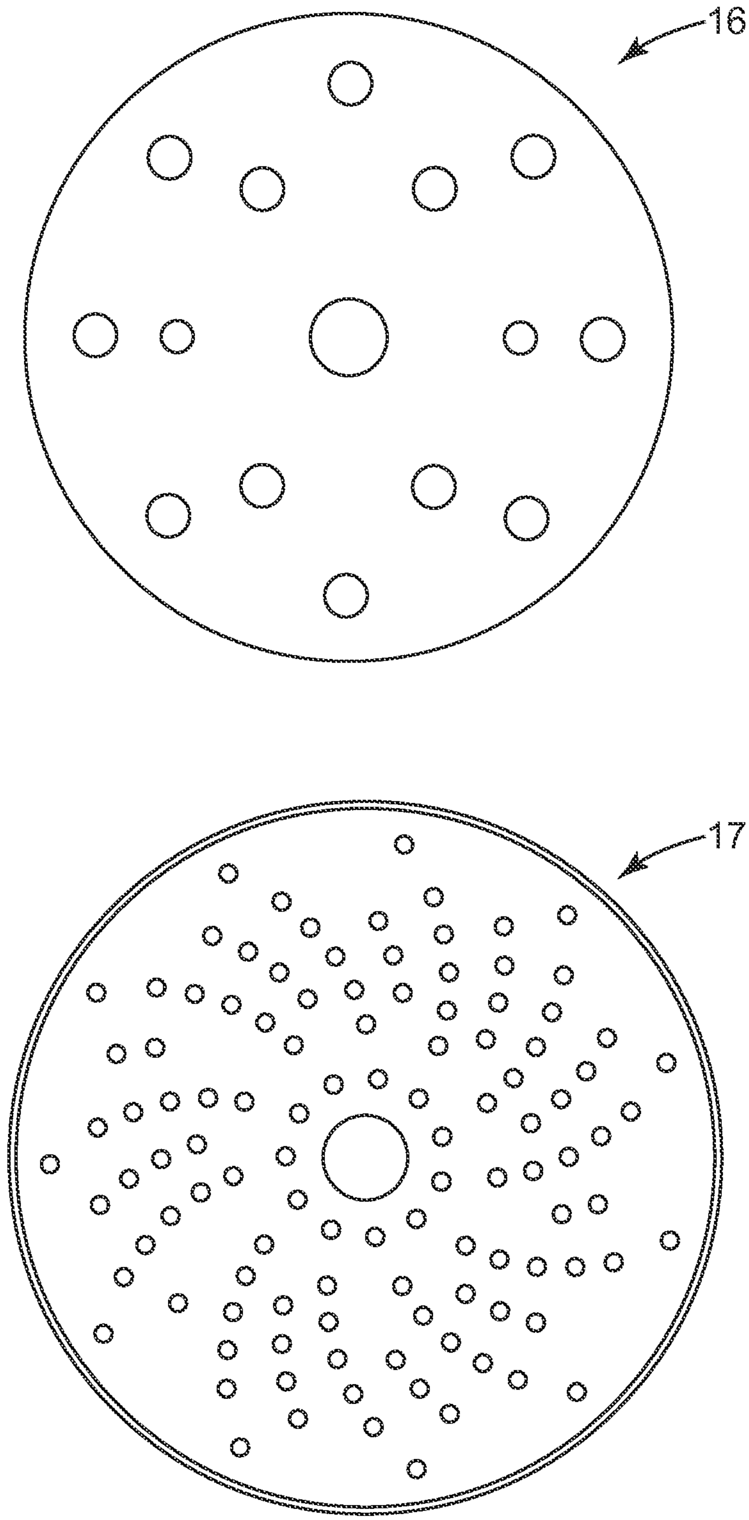


Fig. 4

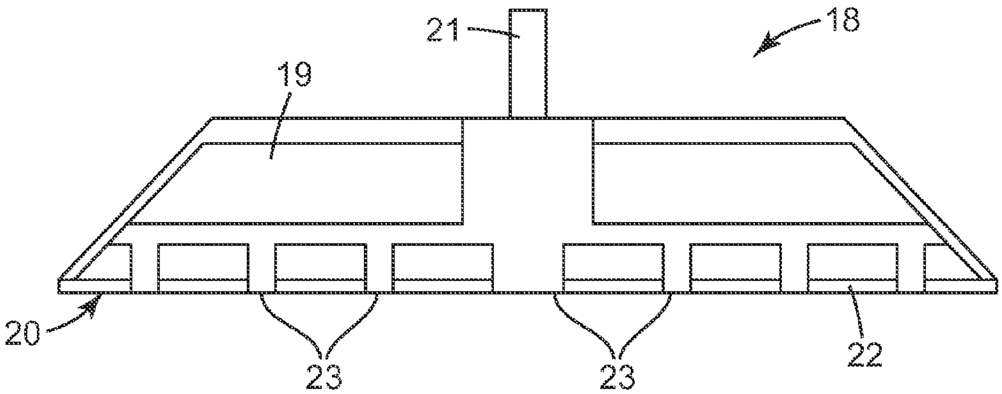


Fig. 5

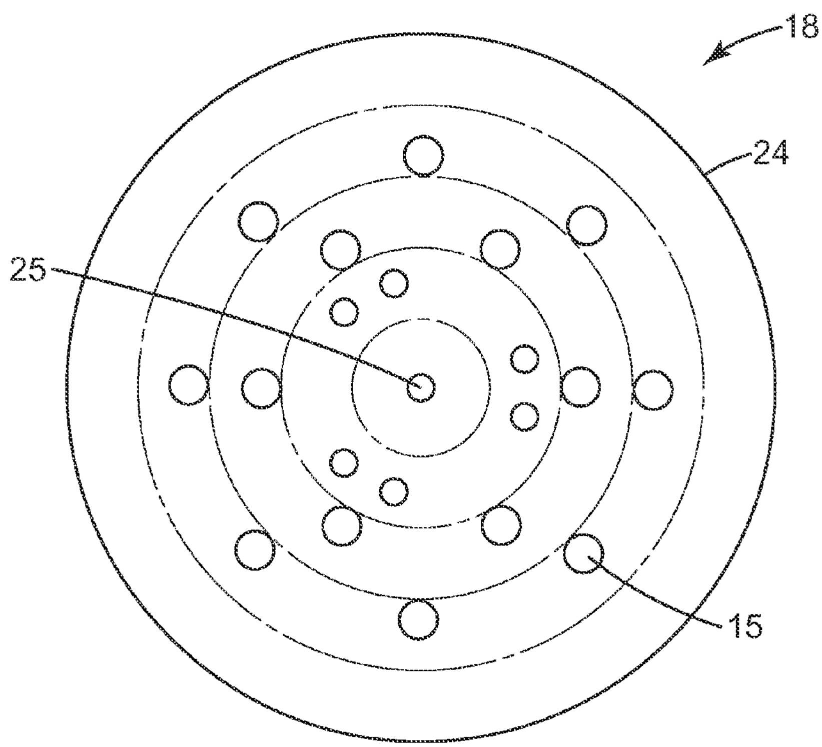


Fig. 6

ABRASIVE ARTICLE AND ADAPTER THEREFORE

[0001] The present invention relates to an abrasive article, in particular, an abrasive article comprising a backing and an abrasive coating on a surface of the backing, the article having a centre point and a periphery; and a plurality of holes through the backing and the abrasive coating, and an adapter for an abrasive article, also being provided with holes, through which particulate material may be extracted.

[0002] Many sanding and abrasive processes are carried out in a dry environment, that is, one where a workpiece is treated without the use of any lubricant. One situation where this occurs, for example, is the sanding of painted workpieces, such as the rectification of paint or lacquer surfaces on automotive vehicle parts during the repair process, or the sanding down of primers and fillers used in such a process. This generates fine particulate matter, commonly termed "dust" (such as paint debris), which, aside from needing to be removed from the workpiece, can create a hazard to the workers using abrasives, since the dust enters the atmosphere around the workpiece and can cause a potential hazard to health. One way of dealing with this is to use a dust extraction process, which may either be by extracting dust from around the workpiece (for example using a worktable with dust extraction capabilities, such as a downdraft workbench) or by extracting dust through the abrasive (for example, using a sanding tool with dust extraction capabilities). This latter option is particularly popular, due to its convenience.

[0003] Coated abrasives typically comprise a backing, such as paper or cloth, coated with an abrasive coating, formed from a resin having an abrasive grit either dispersed therein on one surface of the backing. In order to attach the abrasive article to a tool, such as an orbital sander, a layer of an attachment material, such as a hook and loop material, or a brushed nylon material, is provided on the opposite surface of the backing to the abrasive coating. This enables the abrasive article to be mounted on a back up pad, which in turn is attached to the tool. To facilitate dust extraction, holes are placed in the abrasive article, typically through the backing, abrasive coating and attachment layer, which communicate with holes provided in the back up pad, such that dust is extracted through the holes in the abrasive article and back up pad. Some designs of abrasive article use a small number of larger holes, that are typically aligned with holes provided in the back up pad, such as the fifteen hole 255P abrasive disc, available in the UK from 3M United Kingdom PLC, 3M Centre, Cain Road, Bracknell, RG12 8HT. Some designs of abrasive used fur dust extraction utilise a different structure, comprising many, small holes, which may or may not require alignment with corresponding holes in the back up pad, such as the 334U and 734U (Purple) abrasive disc, again, available from 3M United Kingdom PLC.

[0004] Previous approaches to maximise the amount of dust extracted have relied on including as many holes as possible in the abrasive article, thus maximising the surface area of the holes compared to the surface area of the abrasive. One example of this is the abrasive article discussed in EP 781 629, where a perforation comprising holes, distributed substantially uniformly over at least part of the surface of the abrasive article, in conjunction with a hook and loop attachment material, is shown to give improved dust extraction over existing abrasive articles with fewer holes. Similarly, WO2012/034785 discusses the use of many small holes for improved dust extraction, although rather than proposing a uniform distribution of holes across the surface of the abrasive article, the use of a Fibonacci sequence, or golden number, to generate a hole distribution is discussed, showing that a non-uniform arrangement also gives beneficial dust extraction results.

[0005] However, whilst the use of an increasing number of holes in the abrasive article, regardless of distribution or alignment with extraction holes in a back up pad undeniably increases the amount of dust extraction, using too many holes can lead to issues with the structural integrity of the abrasive article. Where many small holes are included, particularly towards the edge of the disc, there is a tendency for the abrasive to tear when used, due to the forces created by rotation of the back up pad. There also comes a point where too much of the overall surface area of the abrasive article is given over to holes, and the cut or overall lifetime of the abrasive article drops beyond a practical, usable or economical amount. Complex patterns of many holes may also be expensive to produce, given the wear and tear on tooling and cost of conversion of webs of abrasive material into discs and sheets with precise hole patterns. But using fewer, larger holes, whilst still ideal for many applications, does not give equivalent dust extraction, therefore in previous products there has been a trade-off between number of holes and cut to enhance both dust extraction and cut. It is desirable therefore to be able to balance both cost and performance, ensuring that the dust extraction behaviour of the product does not worsen whilst maintaining a cost-competitive manufacturing approach.

[0006] The present invention aims to address these problems by providing an abrasive article comprising a backing and an abrasive coating on a surface of the backing, the article having a centre point and a periphery and the abrasive coating forming a work surface; and a plurality of holes extending through the backing and the abrasive coating, through which particulate material may be extracted; wherein the article is divided into at least a first inner and a second outer zone, the second zone located outside the first zone and being concentric with the first and the centre point; each zone having at least one hole, wherein in each of the first and the second zone the sizes of the hole(s) and their total number forms a hole density for that respective zone; and wherein the hole density of the first zone is less than the hole density of the second zone.

[0007] By taking into consideration both the relative amounts of surface area of abrasive and surface area of holes, and the position of the holes on the abrasive article in relation to how such holes will move on a tool in use, the dust extraction capabilities of the abrasive article can be greatly improved in contrast to existing holed abrasive articles.

[0008] Preferably, in each zone, each hole has a size and position within the respective zone such that the ratio between the distance of each hole from the centre point multiplied by the total surface area of abrasive coating within the respective zone and the total surface area of the at least one hole within the respective zone is substantially constant for the first and second zones.

[0009] Preferably, the holes in each zone are distributed evenly about the centre point.

[0010] Preferably, the article is in the form of a disc.

[0011] The abrasive article may further comprise a third zone, positioned between the first and second zones, in which there are no holes. Alternatively, the abrasive article may further comprise a third zone, positioned between the first and second zones, comprising at least one hole.

[0012] Where the abrasive article is a disc, situation, preferably the holes are positioned along radii of the disc. At least one further hole may be provided outside of the at least two zones. The at least one further hole may be a centre hole, positioned at the centre point. Alternatively, the at least one further hole may be located away from the centre point. Preferably, the at least two holes in each zone form an overall asymmetric pattern across the abrasive article.

[0013] The holes have preferably a diameter in the range 1.0 mm to 25.0 mm. Preferably, the abrasive article comprises between 7 and 100 holes. More preferably, the abrasive article comprises between 7 and 30 holes.

[0014] Yet more preferably, the particulate is dust, and the abrasive article is adapted for use with dust extraction equipment.

[0015] In another aspect, the present invention also provides an adapter for an abrasive article comprising a body having a mounting surface adapted for the attachment of an abrasive article, the adapter having a centre point and a periphery; and a plurality of holes extending through the body, through which particulate material may be extracted; wherein the mounting surface is divided into at least a first inner and a second outer zone, the second zone located outside the first zone and being concentric with the first and the centre point; each zone having at least one hole, wherein in each of the first and the second zone the sizes of the holes and their total number forms a hole density for that respective zone; and wherein the hole density of the first zone is less than the hole density of the second zone.

[0016] By taking into consideration both the relative amounts of surface area of mounting surface and surface area of holes, and the position of the holes on the abrasive article in relation to how such holes will move on a tool in use, the dust extraction capabilities of the adapter can be greatly improved in contrast to existing devices. This may be with or without the optimisation of an associated abrasive article.

[0017] Preferably, in each zone, each hole has a size and position within the respective zone such that the ratio between the distance of each hole from the centre point multiplied by the total surface area of mounting surface within the respective zone and the total surface area of the at least one hole within the respective zone is substantially constant for the first and second zones.

[0018] Preferably, the at least two holes are provided in each zone, and the holes in each zone are distributed evenly about the centre point.

[0019] Preferably, the adapter is in the form of a circular back up pad.

[0020] The adapter may further comprise a third zone, positioned between the first and second zones, in which there are no holes. Alternatively, the adapter may further comprise a third zone, positioned between the first and second zones, comprising at least one hole.

[0021] Where there adapter is a circular back up pad, the holes are positioned along radii of the circular back up pad.

[0022] At least one further hole may be provided outside of the at least two zones. The at least one further hole may be a centre hole, positioned at the centre point. Alternatively, the at least one further hole is located away from the centre point. The at least two holes in each zone may form an overall asymmetric pattern across the adapter.

[0023] Preferably, the holes have a diameter in the range 1.0 mm to 25.0 mm. Preferably, the adapter comprises between 7 and 100 holes, more preferably, between 7 and 30 holes.

[0024] Preferably, the particulate is dust, and the adapter is adapted for use with dust extraction equipment.

[0025] The present invention will now be described by way of example only, and with reference to the accompanying drawings, in which:

[0026] FIG. **1** is a schematic cross-section showing the construction of an abrasive article suitable for use with any of the embodiments of the present invention;

[0027] FIG. **2** is a schematic diagram of an abrasive article in accordance with a first embodiment of the present invention;

[0028] FIG. **3** is a schematic diagram of an abrasive article in accordance with a second embodiment of the present invention;

[0029] FIG. **4** is a schematic diagram of the fifteen hole and seventy-eight hole abrasives used in comparative experiments with the first and second embodiments of the present invention;

[0030] FIG. **5** is a schematic cross-section view of an adapter for an abrasive article in accordance with a third embodiment of the present invention; and

[0031] FIG. **6** is a schematic plan view of an adapter for an abrasive article in accordance with a third embodiment of the present invention.

[0032] The present invention takes the approach of understanding that not only is a uniform level of dust extraction across the surface of an abrasive article is required for good performance, this should ideally take into account situations where the abrasive article is used on a tool providing an orbit and/or the rotation of the abrasive article in use. For example, a random orbital or dual action (DA) sander, such as the 3M Random Orbital Sander range, available from 3M as above, not only spins the abrasive article, but moves it in an elliptical orbit pattern, giving a translational motion component to the rotational motion of the abrasive article. For abrasive articles such as discs that rotate during use, the relative linear speed near the centre of the abrasive disc is significantly lower than that at the outer edge of the disc, dependent on the rotational speed of the abrasive disc.

[0033] Without wishing to be bound by theory it is thought that the increased speed at the edge of the abrasive article generates increased cut on the surface of the workpiece, as a greater area of abrasive material passes over the surface of the workpiece, creating a more aggressive cut due to the difference in speed. This generates an increased amount of particulate material being removed from the surface of the workpiece, typically dust composed of paint debris or filler, depending on the application, which requires timely removal to reduce the clogging of the surfaces of the abrasive article and the expulsion of particulate material into the surrounding atmosphere.

[0034] The present invention addresses this by dividing the work surface abrasive article, formed by the abrasive coating, into at least a first inner and a second outer zone, the second zone being concentric with the first and the centre point. Each zone has at least one hole, and in each of the first and the second zone the sizes of the holes and their total number forms a hole density for that respective zone. The hole density of the first zone is less than the hole density of the second zone. The hole density is therefore a measure of the surface area of the abrasive article dedicated to holes, and its relationship to the surface area of the abrasive article that is solely abrasive coating, i.e. not provided with holes. In each zone, each hole has a size and position within the respective zone such that the ratio between the distance of each hole from the centre point multiplied by the total surface area of abrasive coating within the respective zone and the total surface area of the at least one hole within the respective zone is substantially constant for the first and second zones. One way of doing this is to provide at least one hole in each zone, and to ensure that these holes are distributed evenly about the centre point.

[0035] This relationship effectively determines the amount of particulate matter that can be removed for each zone, such that increased extraction capability is provided for regions of the abrasive article where greater amounts of particulate matter are created, thus causing the constant K to be kept substantially constant for each zone. Overall this improves the extraction capabilities of the abrasive article, beyond both those of traditional holed abrasive articles (fewer, larger holes) and more modern so-called "multi-hole" (many, smaller holes) abrasive articles. This is due to the abrasive article in accordance with the present invention having a variable hole density, that is, the number and size of holes in each zone is different for each zone depending on the relative positions of each zone.

[0036] FIG. **1** is a schematic cross-section showing the construction of an abrasive article suitable for use with any of the embodiments of the present invention. An abrasive article **1** comprises backing **2** having a first surface **3** and a second surface **4**, and an abrasive coating **5** on the first surface **3** of the backing **2**. The abrasive coating **5** comprises a resin layer **6** having abrasive particles **7** dispersed therein, forming a work surface **8** intended to be used to sand a workpiece (not shown). An attachment layer **9**, in this example, a hook and loop attachment layer, is provided on the second surface of the backing **2**. This enables the abrasive disc to be mounted on the back up pad of a tool (not shown), the tool being provided with dust extraction capability. A plurality of holes **10** are provided, extending through the backing **2** and the abrasive coating **5**. The plurality of holes **10** also extend through the attachment layer **9**. This enables fluid communication between the work surface **8** and the tool, such that dust generated at the work surface **8** by the abrasive article **1** can be extracted away from the workpiece through the holes **10** to the tool.

[0037] The first embodiment of the present invention uses an abrasive disc intended for dust extraction as an example, although it should be understood that the same approach may be used with other shapes of abrasive article, or abrasive articles used for other types of particulate extraction, such as those used wet or damp, as well as dry. Therefore the use of an abrasive disc should not been seen as limiting the present invention, nor should the use of circular holes. FIG. **2** is a schematic diagram of an abrasive article in accordance with a first embodiment of the present invention. This shows a circular abrasive disc **11** having the structure shown in FIG. **1**, and divided into five zones (first to fifth): A (central 0-14 mm radius), B (14-28 mm radius), C (28-42 mm radius), D (42-56 mm) and E (56-70 mm), centred around a centre point **12** and concentric with each other. The abrasive disc had a diameter of 150 mm. A total of fifty-nine holes are included in the disc, distributed evenly about the centre point **12**. The position and size of the holes was determined as follows.

[0038] Such a circular abrasive disc is intended to be used on an orbital sander that causes the disc to rotate at an angular velocity ω, leading to a linear speed v (where v=ωr), and moves the disc in an orbit O. Therefore a uniform placement of holes **10** across the surface of the abrasive disc **11** does not allow for optimum dust extraction since there will be an effect on the cut and therefore the amount of dust created based upon both the rotational speed of the abrasive disc **11** and the orbit generated by the tool. A non-uniform distribution would also suffer from the same issues, hence an adjustment of the hole positions due to the effect of the disc rotation and orbit needs to be made. The amount of dust extracted will be proportional to the amount of open area, i.e. the surface area of the holes **10** provided across the abrasive disc **11**. To determine the surface area of the holes required, the following equation is used:

$$K = \left(\frac{(O+v)}{A_{hole}} A_{abrasive}\right) \qquad \text{Equation 1}$$

Where K is a constant, O is the orbit and v the linear speed as above at the point of consideration, A_{hole} is the surface area of the abrasive disc **11** occupied by holes, and $A_{abrasive}$ is the surface area of the abrasive disc **11** remaining. To determine a theoretical value of K, an ideal amount of hole area is chosen for the abrasive disc **11**. To be in line with other existing articles from a manufacturing cost perspective, the hole area was chosen to be 10% of the overall surface area of the abrasive disc **11**, and Equation 1 solved to give K, using an orbit of 2.5 mm and a rotational speed of 4000 rpm. This yielded a value of K of 199. Holes **10** were then chosen in accordance with manufacturing constraints to try to reach this theoretical value of K using Equation 1 for each zone.

[0039] Holes **10** were sized and positioned as follows and as shown in Table 1 below (all measurements are in mm). Holes were positioned at the edges of each zone, with half of the number of holes in each zone being positioned on the inner edge of the zone and half positioned on the outer edge of the zone for each of zones B, C and D, and one third of the holes in Zone E were placed on the boundary between zone D and zone E. As discussed above, the orbit O used in the calculation was 2.5 mm and the rotational speed ω was 4000 rpm. Calculated hole diameters are shown in brackets in Table 1, actual hole diameters are also shown:

TABLE 1

	Zone A	Zone B	Zone C	Zone D	Zone E
Inner Zone Radius	0	14	28	42	56
Outer Zone Radius	14	28	42	56	70
Hole Diameter 1	3.5 (2.73)	4.0 (5.72)	5.0 (5.64)	6.0 (6.01)	7.0 (6.5)
Hole Diameter 2			4.0 (4.0)	6.0 (6.0)	6.0 (6.5)
Hole Diameter 3					6.0 (5.36)
No. Holes 1	3	4	8	8	8
No. Holes 2			4	8	8
No. Holes 3					8
Total Hole Area	28.87	50.27	207.35	452.39	841.95
Total Abrasive Area	586.89	1796.99	2871.42	3857.88	4699.82
K	119	419	244	200	164

Total number of holes: 59

[0040] The ratio of the surface area of the abrasive disc **11** occupied by holes to the surface area of the abrasive disc **11** remaining was 0.098 (9.8%). Holes **10** were placed in each zone so as to be evenly distributed around the centre point **12** of the abrasive disc **11**. It can be seen that the manufacturing constraints on hole size and position led to a discrepancy in K values for some zones in practice, despite the Equation being solved for the required surface area (hole diameters in accordance with Equation 1 are given in brackets in Table 1, actual hole diameters are also shown). Testing of the abrasive disc **11** was carried out to determine if this resulted in a detrimental effect on performance.

[0041] Comparative tests between an abrasive disc **11** in accordance with the first embodiment of the present invention, an abrasive disc 150 mm in diameter and having fifteen holes, and an abrasive disc 150 mm in diameter having seventy-eight holes were carried out. All three abrasive discs were made from 255P abrasive material, available from 3M as above, and in a P500 grade. The fifteen hole disc had a ratio of the surface area of the abrasive disc occupied by holes to the surface area of the abrasive disc remaining of 0.062 (6.2%), and the seventy-eight hole disc 0.05 (5%). Each disc comprised a centre hole with the remaining holes distributed evenly across the surface of the abrasive disc, as illustrated in FIG. **4** below.

[0042] All tests were carried out on a Fanuc Robotics robot using a 150 mm National Detroit Air Powered Sander, available from National Detroit, 1590 Northrock Court, Rockford, Ill. 61103, US. A 600×600 mm primer panel was painted with a Standox VOC System filler, available from Standox, Wedgwood Way, Stevenage, Hertfordshire, SG1 4QN to a thickness of approximately 100 μm, weighed, and the weight recorded. Before sanding, the surface of the primer panel was wiped down with a clean tack cloth, which was then disposed of To begin the test, the robot sanded the surface of the primer panel at a medium pressure (5.5 lbs/2.5 kg) in alternating north-south and east-west direction for fifteen seconds. The primer panel was then weighed a second time, and the weight recorded. This was repeated for a further forty-five second period and a one-hundred and eighty second period, with the panel being weighed after each sanding session. After the forty-five second period the panel was cleaned with a second tack cloth of known initial weight, the second tack cloth was then weighed, and placed in an airtight bag. The second tack cloth was subsequently weighed to determine the amount of dust left on the panel. By measuring the weight of the primer panel the total amount of material removed in grams gives the amount of cut, and by measuring the weight of the tack cloth the additional weight of dust in grams indicates the efficiency of the dust extraction process.

[0043] Six of each abrasive disc were tested, with all abrasive discs being grade P500. Both the fifteen and seventy-eight hole abrasive discs had their holes aligned with the holes in the back up pad, whereas it was not possible to align the holes in the fifty-nine hole abrasive disc in accordance with the first embodiment of the present invention. Results of the tests are shown in Table 2 below:

TABLE 2

	Dust Remaining after 60 s (g)	Cumulative Cut After 15 s (g)	Cumulative Cut After 60 s (g)	Cumulative Cut After 240 s (g)
15 holes	0.043 g	85.2	85.1	84.6
59 holes	0.037 g	99.0	100.5	102.8
78 holes	0.043 g	100.0	100.0	100.0

[0044] The fifty-nine hole disc showed an improvement in both dust extraction, with less dust remaining on the surface of the panel after testing than both the fifteen hole and seventy-eight hole abrasive discs, and cut. Despite having a smaller overall surface area and fewer aligned holes of the abrasive article dedicated to holes to enable dust extraction than the seventy-eight hole disc, the fifty-nine hole abrasive article in accordance with the present invention gives the better performance.

[0045] FIG. **3** is a schematic diagram of an abrasive article in accordance with a second embodiment of the present invention. This shows an abrasive disc **13** having a centre point **14**, and divided into four zones A, B, C, and D, similar to the first embodiment described above. The abrasive disc had a diameter of 150 mm. Twenty-one holes **15** were provided using the same methodology as above, in each zone as shown in Table 3 below. Initially Equation 1 was solved to give a desired surface area of 0.066 (6.6%, so as to be the same as an existing **15** hole abrasive disc) and a theoretical value of K of 316. The orbit O was 2.5 mm and the speed ω 4000 rpm, again all measurements are in mm. Using twenty-one holes in four zones, the ratio of the surface area of the abrasive disc **13** occupied by holes **15** to the surface area of the abrasive disc **13** remaining was 0.068 (6.8%). Hole diameters in accordance with Equation 1 are given in brackets in Table 3, actual hole diameters are also shown:

TABLE 3

	Zone A	Zone B	Zone C	Zone D
Inner Zone Radius	0	18	34	52
Outer Zone Radius	18	34	52	70
Hole Diameter 1	7.0 (5.49)	7.0 (4.89)	8.5 (8.16)	10.0 (9.65)
No. Holes 1	1	6	6	8
Total Hole Area	38.48	230.91	340.47	628.32
Total Abrasive Area	979.39	2382.90	4522.72	6270.62
O	0.0025	0.0025	0.0025	0.0025
ω	4000	4000	4000	4000
K	192	147	289	293

Total number of holes: 21

[0046] All tests were carried out on a Fanuc Robotics robot, using an Elite orbital sander, available from 3M as above, having a theoretical free rotational speed of 12000 rpm and 4000 rpm under loading, and an orbit of 2.5 mm. A back up pad having fifty-one holes was used. A wooden panel (pine) measuring approximately 200×400 mm was weighed, and the weight recorded. This was then placed on a painted metal panel approximately 600×600 mm in size for sanding. Before sanding, the surface of the wooden panel and the painted panel it rested on was wiped down with a tack cloth, which was then discarded. To begin the test, the robot sanded the surface of the wooden panel at a medium pressure (5.5 lbs/2.5 kg) in alternating north-south and east-west direction for two minutes. The wooden panel was then weighed a second time, and the weight recorded. This was repeated for a further minute period and a one minute period. After a total of five minutes of sanding the wooden panel was cleaned using a second tack cloth of known initial weight, the painted metal panel was also wiped clean with the same tack cloth and then the tack cloth placed in an airtight bag for subsequent weighing. The tack cloth was weighed to determine the amount of dust left on the panels. By measuring the weight of the wooden panel the total amount of material removed in grams gives the amount of cut, and the measurement of the weight of the tack cloth gives the additional weight of dust in grams remaining in the working area, which is indicative of the efficiency of the dust extraction process.

[0047] This was used to compare an abrasive disc **13** in accordance with the second embodiment of the present invention and a fifteen hole disc. However, the back up pad used was a 51 hole back up pad, against which the holes in both the fifteen hole abrasive disc and the twenty-one hole abrasive disc in accordance with the present invention could be aligned. Again, the ratio of the surface area of the abrasive disc occupied by holes to the surface area of the abrasive disc remaining was 0.066 (6.6%) for the fifteen hole disc. Both abrasive discs were formed from 236U abrasive material, available from 3M as above, and in a P320 grade. Five discs of each type were tested. Results of the comparative testing are shown in Table 4 below:

TABLE 4

	Cumulative Cut After 5 mins (g)	Dust Remaining After 5 mins (g)
15 holes	4.08	0.0493
21 holes	3.92	0.0427

[0048] Again, the abrasive disc **13** in accordance with the present invention removed more dust during use than a fifteen hole abrasive disc. FIG. **4** is a schematic diagram of the fifteen hole **16** and seventy-eight hole **17** abrasives used in comparative experiments with the first and second embodiments of the present invention. This illustrates that the present invention offers similar or improved performance when compared with traditional hole patterns and multihole abrasive discs, as the ratio between the surface area of abrasive coating within the zone and the surface area of the holes is optimised for the hole size and distribution.

[0049] The level of accuracy of the constant K will also be influenced by the method used to form the holes in the abrasive article. For example, if there is a limit on the hole size achievable, either in terms of absolute size (minimum radius) or engineering tolerance, then there may be some variability in K. Therefore where Equation 1 is best satisfied by a hole size that is not practicable, a more reasonable hole size may be used. Methods to create the holes in the abrasive article include mechanical punching and cutting using a laser. In addition, it may be desirable to adjust the size of the hole in the abrasive article to form a complete system with the back up pad. For example, if it is convenient to create a 7 mm hole in the abrasive article, but the back up pad is provided with an alignable 5 mm hole, the overall dust extraction is influenced by the 5 mm hole. This will also affect the level of accuracy of the constant K, for example, if Equation 1 predicts an ideal hole size of 4.89 mm as in the second embodiment described above, the use of a back up pad with a 5 mm hole has a considerable effect on K, as this may be effectively substituted into the calculations. This gives a K value closer to that predicted by Equation 1.

[0050] In the examples described above, circular abrasive articles intended for use in situations where dust extraction is necessary. However, other shapes of abrasive article may be formed, such as sheets, for example rectangular sheets, where the sheets also have a centre point and a periphery, as the above equation may be re-written to be in terms of distance, d, of the zone from the centre, rather than rotational speed:

$$K = \left(\frac{(d + O)}{A_{hole}} A_{abrasive} \right) \quad \text{Equation 2}$$

[0051] In the same manner as described in relation to the circular abrasive discs in the first and second embodiments of the present invention, in this situation the article is divided into at least two zones, being concentric with each other and the centre point. Each zone has at least one hole, preferably two holes distributed evenly about the centre point. Each hole has a size and position such that the ratio between the distance of the zone from the centre point multiplied by the surface area of abrasive coating within the zone and the surface area of the holes within the zone is approximately constant for each zone. Thus, in the example above, the abrasive article is an abrasive disc, such that the holes are positioned along radii of the disc. The orbit may be a linear translation in the case of a tool used with an abrasive sheet, such that the constant O represents the amplitude of the translational motion. In situations where the abrasive article is used with a tool that does not provide an orbit or other translational motion, the constant O may be omitted.

[0052] Furthermore, the holes used need not necessarily be circular, but shaped so as to be suitable for their intended use, for example, triangular, square, rectangular, or other polygonal or curved shape. In the above examples, twenty-one and fifty-nine holes were used. However, the equations 1 and 2 may be used to position any number of holes as required. Preferably this may be between 7 and 100 holes, more preferably between 7 and 30 holes. The sizes of the holes used in the above examples is within the range of 3.5 mm to 10 mm in diameter, but may preferably be between 1.0 mm and 25.0 mm in diameter if desired.

[0053] The use of a hook and loop layer as the attachment layer is particularly suitable, since this is permeable to the passage of both air (hence allowing extraction by means of a vacuum) and dust (of a typical particulate size found in sanding) with little or no clogging during normal use. Other materials offering similar advantages include brushed nylon. In the above examples, the abrasive coating comprises a resin material having abrasive particles dispersed therein. However, the abrasive coating may comprise other materials, such as grinding aids, other layers, such as a supersize layer, or may be formed from an adhesive material or a slurry. Other layers, such as a tie-coat or other strengthening or reinforcing layer may be provided between the backing and the abrasive coating. Microreplication techniques may be used to form the abrasive coating if desired, or the coating may comprise and adhesive and various abrasive grains or particles. Suitable backing materials include paper and textiles (both treated and untreated), foams, and other materials generally used in the manufacture of coated abrasive articles.

[0054] In the above examples, the particulate is dust, and the abrasive article is adapted for use with dust extraction equipment. Such equipment either comprises vacuum extraction means or self-generated vacuum extraction means, or may just rely on centripetal forces to move dust and air through the holes and away from the surface of the workpiece. However, other types of particulate extraction may be carried out. One situation where this is the case is where an abrasive is used wet or damp or with a polish, and the motion of the tool causes swarf, paint or other particulate debris to move within a liquid carrier, hence through the holes of the abrasive article.

[0055] It may be desirable to include further zones in the abrasive article. For example, the abrasive article may comprise a third zone, positioned between the first and second zones, in which there are no holes. Alternatively, the abrasive article may comprise a third zone, positioned between the first and second zones, comprising at least one hole.

[0056] In the above embodiments, the holes **10**, **15** are distributed evenly around the centre point **12**. However, this need not be the case. The holes may be distributed in any fashion, whether this forms a regular array or pattern or not, since as long as the above Equation 1 and Equation 2 are satisfied the dust extraction performance of the abrasive article is optimised.

[0057] In the above embodiments, at least one further hole may provided outside of the at least two zones. This may be, for example, a centre hole, positioned at the centre point. Often this is required to align with holes provided on a standard back up pad or other tool attachment means, such as a block for an abrasive sheet. Alternatively, or additionally, the at least one further hole may be positioned elsewhere on the abrasive article, such as away from the centre point. The at least two holes in each zone may form an overall asymmetric pattern across the surface of the abrasive article. This may be desirable from an aesthetic point of view, or for ease of manufacture. Alternatively the least two holes in each zone may form an overall symmetric pattern across the surface of the abrasive article. For example, the arrangement of holes shown in both the first and second embodiments of the present invention are approximately spiral, or having arms distributed in a spiral arrangement, this should not be seen as limiting, as any arrangement of holes within each zone satisfying the above equations 1 and 2 will fall within the scope of the appended claims.

[0058] In the above examples, Equations 1 and 2 are applied to abrasive articles, such as abrasive discs and sheets. However, the equations may also be applied to the accessories used with such abrasive articles, as follows. Although the accessories do not themselves generate dust or other particulate matter at a workpiece, they drive the behaviour of the abrasive article, hence similar considerations apply. FIG. **5** is a schematic cross-section view of an adapter for an abrasive article in accordance with a third embodiment of the present invention. This is used to mount an abrasive article, such as an abrasive disc, onto a tool, such as a sander. In this example, the adapter is a circular back up pad, but it may alternatively or additionally be an interface pad (which is placed between an abrasive article and a back up pad to provide a cushioning effect in use) or other adapter such as a hand block. The back up pad **18** comprises a body **19**, a mounting surface **20**, adapted for the attachment of an abrasive article such as an abrasive disc **11**, **13**, as shown in FIGS. **2** and **3**, and a tool attachment means **21**, for attaching to a tool (not shown). The mounting surface **20** comprises a hook material **22** suitable for engagement with the hook and loop or brushed nylon layer **9** provided on the abrasive disc **11**, **13**, such that the abrasive disc **11**, **13** is attached firmly to the back up pad **18** during use. The back up pad **18** is provided with a plurality of holes **23**, extending through the mounting surface **20** and through at least a portion of the body **19**, through which particular matter is extracted. This enables fluid connection between dust extraction means (not shown) and the surface of a workpiece (also not shown) during use. Thus, dust or other particulate matter generated at the surface of the workpiece during use is removed via the holes **23** in the back up pad.

[0059] FIG. **6** is a schematic plan view of an adapter for an abrasive article in accordance with a third embodiment of the present invention. The back up pad **18** has a periphery **24** and a centre point **25**, and is divided into a series of zones, A, B, C, D, as with the abrasive articles described above. Each zone comprises at least two holes, distributed evenly about the centre point **15**. The plurality of holes **23** are arranged as follows. Since the back up pad **18** will be subject to the same rotational and/or translational or orbital movement as the abrasive article, Equations 1 and 2 can be modified to apply to the back up pad **18**. For a circular back up pad:

$$\left(K = \left(\frac{O + v}{A_{hole}} A_{attachment}\right)\right) \quad \text{Equation 3}$$

[0060] Where K is a constant, O is the orbit and v the linear speed as above, A_{hole} is the surface area of the back up pad **18** occupied by holes, and $A_{attachment}$ is the surface area of the back up pad remaining. In this situation, holes are positioned along the radii of the circular back up pad. For a non-circular back up pad, for example, a sheet holder:

$$K = \left(\frac{(d + O)}{A_{hole}} A_{attachment}\right) \quad \text{Equation 4}$$

[0061] Where K is a constant, O is the orbit and d the distance of the holes from the centre point **25**, A_{hole} is the surface area of the back up pad **18** occupied by holes, and $A_{attachment}$ is the surface area of the back up pad remaining.

[0062] Thus, as in the first and second embodiments discussed above, the mounting surface is divided into at least a first inner and a second outer zone, the second zone being concentric with the first and the centre point. Each zone has at least one hole, wherein in each of the first and the second zone the sizes of the holes and their total number forms a hole density for that respective zone, and the hole density of the first zone is less than the hole density of the second zone.

[0063] For a circular back up pad, in each zone, each hole has a size and position within the respective zone such that the ratio between the distance of each hole from the centre point multiplied by the total surface area of mounting surface within the respective zone and the total surface area of the at least two holes within the respective zone is substantially constant for the first and second zones. As above, K is calculated for a particular desired hole area. This may be desired to be a match for a particular abrasive article, for example, with the holes **23** positioned on both the back up pad **18** and an abrasive disc **11**, **13** or other abrasive article such that the holes **10**, **15**, in the abrasive disc **11**, **13**, or other abrasive article align completely with the holes **23** in the back up pad. Alternatively, the holes **23** may be positioned such that there is no or only partial alignment, or the holes **23** in the back up pad **18** may be greater or lesser in diameter than corresponding holes **10**, **15** in the abrasive disc **11**, **13** or other abrasive article. In addition or alternatively, if Equations 3 and 4 are also applied to an interface pad, the holes in the interface pad may be adjusted similarly to align or not as desired with both the holes **23** in the back up pad and in any abrasive article mounted on the interface pad.

[0064] In the above example, at least two holes are provided in each zone, and the holes in each zone are distributed evenly about the centre point, although only one hole is necessary. However, the holes may be distributed in an uneven or non-regular pattern, as with the abrasive article described above. For example, holes may be distributed in an overall asymmetric pattern across the adapter. This may be the case regardless of whether the adapter is used with or without an abrasive article in accordance with an embodiment of the present invention, or whether the abrasive article has an even or uneven distribution of holes. The adapter may comprise a third zone, positioned between the first and second zones, in which there are no holes. Alternatively, the adapter may further comprise a third zone, positioned between the first and second zones, comprising at least one hole. This allows for further freedom in design of the adapter and optimisation of the adapter/abrasive article combination as a whole. To aid in this, at least one further hole may be provided outside of the at least two zones. This one further hole may be a centre hole, positioned at the centre point, or it may be located away from the centre point. Preferably, the holes have a diameter in the range 1.0 mm to 25.0 mm. Preferably, the adapter comprises between 7 and 100 holes, more preferably between 7 and 30 holes. Preferably, the particulate is dust, and the adapter is adapted for use with dust extraction equipment.

1. An abrasive article comprising a backing and an abrasive coating on a surface of the backing, the article having a centre point and a periphery and the abrasive coating forming a work surface;
- and a plurality of holes extending through the backing and the abrasive coating, through which particulate material may be extracted;
- wherein the work surface is divided into at least a first inner and a second outer zone, the second zone being concentric with the first and the centre point;
- each zone having at least one hole, wherein in each of the first and the second zone the sizes of the holes and their total number forms a hole density for that respective zone;
- and wherein the hole density of the first zone is less than the hole density of the second zone.

2. Abrasive article according to claim **1**, wherein in each zone, each hole has a size and position within the respective zone such that the ratio between the distance of each hole from the centre point multiplied by the total surface area of abrasive coating within the respective zone and the total surface area of the at least one hole within the respective zone is substantially constant for the first and second zones.

3. Abrasive article according to claim **1**, wherein the at least two holes are provided in each zone, and the holes in each zone are distributed evenly about the centre point.

4. Abrasive article according to claim **1**, wherein the article is in the form of a disc.

5. Abrasive article according to claim **1**, further comprising a third zone, positioned between the first and second zones, in which there are no holes.

6. Abrasive article according to claim **1**, further comprising a third zone, positioned between the first and second zones, comprising at least one hole.

7. Abrasive article according to claim **4**, wherein the holes are positioned along radii of the disc.

8. Abrasive article according to claim **1**, wherein at least one further hole is provided outside of the at least two zones.

9. Abrasive article according to claim **8**, wherein the at least one further hole is a centre hole, positioned at the centre point.

10. Abrasive article according to claim **8**, wherein the at least one further hole is located away from the centre point.

11. Abrasive article according to claim **1**, wherein the at least two holes in each zone form an overall asymmetric pattern across the abrasive article.

12. Abrasive article according to claim **1**, wherein the holes have a diameter in the range 1.0 mm to 25.0 mm.

13. Abrasive article according to claim **1**, comprising between 7 and 100 holes.

14. Abrasive article according to claim **1**, comprising between 7 and 30 holes.

15. Abrasive article according to claim **1**, wherein the particulate is dust, and the abrasive article is adapted for use with dust extraction equipment.

16. An adapter for an abrasive article comprising a body having a mounting surface adapted for the attachment of an abrasive article, the adapter having a centre point and a periphery;
- and a plurality of holes extending through the body, through which particulate material may be extracted;
- wherein the mounting surface is divided into at least a first inner and a second outer zone, the second zone being concentric with the first and the centre point;
- each zone having at least one hole, wherein in each of the first and the second zone the sizes of the holes and their total number forms a hole density for that respective zone;
- and wherein the hole density of the first zone is less than the hole density of the second zone.

17. Adapter according to claim **16**, wherein in each zone, each hole has a size and position within the respective zone such that the ratio between the distance of each hole from the centre point multiplied by the total surface area of mounting surface within the respective zone and the total surface area of the at least one hole within the respective zone is substantially constant for the first and second zones.

18. Adapter according to claim **16**, wherein the at least two holes are provided in each zone, and the holes in each zone are distributed evenly about the centre point.

19. Adapter according to claim **16**, wherein the adapter is in the form of a circular back up pad.

20. Adapter according to claim **16**, further comprising a third zone, positioned between the first and second zones, in which there are no holes.

21. Adapter according to claim **16**, further comprising a third zone, positioned between the first and second zones, comprising at least one hole.

22. Adapter according to claim **19**, wherein the holes are positioned along radii of the circular back up pad.

23. Adapter according to claim **16**, wherein at least one further hole is provided outside of the at least two zones.

24. Adapter according to claim **23**, wherein the at least one further hole is a centre hole, positioned at the centre point.

25. Adapter according to claim **23**, wherein the at least one further hole is located away from the centre point.

26. Adapter according to claim **16**, wherein the at least two holes in each zone form an overall asymmetric pattern across the adapter.

27. Adapter according to claim **16**, wherein the holes have a diameter in the range 1.0 mm to 25.0 mm.

28. Adapter according to claim **16**, comprising between 7 and 100 holes.

29. Adapter according to claim **16**, comprising between 7 and 30 holes.

30. Adapter according to claim **16**, wherein the particulate is dust, and the adapter is adapted for use with dust extraction equipment.

* * * * *