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(71) Applicant(s):
Black Swan Graphene Inc.
Suite 1410, 120 Adelaide Street West, Toronto,
M5H 1T1, Canada

(72) Inventor(s):
Michael Edwards

(74) Agent and/or Address for Service:
Patent Outsourcing Limited
1 King Street, BAKEWELL, Derbyshire, DE45 1DZ,
United Kingdom

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(56) Documents Cited:
CN 214916475 U **CN 214599368 U**
CN 214076833 U **CN 212441383 U**
CN 212237451 U **CN 211937286 U**
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(54) Title of the Invention: **Improved Homogenizer impact head**
Abstract Title: **Rolling impact head**

(57) An impact head 10 configured to be used within a homogeniser, wherein the impact head comprise a rolling impact head comprising an impact head designed to symmetrically rotate around an axis of rotation, and the impact head freely rotates. The impact head may comprise a rolling impact head and be configured to be driven by a driving means to rotate the impact head. The driving means may continuously rotate the rolling impact head. The rolling impact head may comprise a housing and a spherical impact head, an elliptical impact head or a cylindrical impact head configured to rotate within the housing. The rolling impact head may be driven by an electric motor. The impact head may comprise frictional features such as grooves, dents or dimples. Also, an impact head configured to be used within a homogeniser and comprising a stepped impact head comprising a plurality of impact heads arranged into layers.

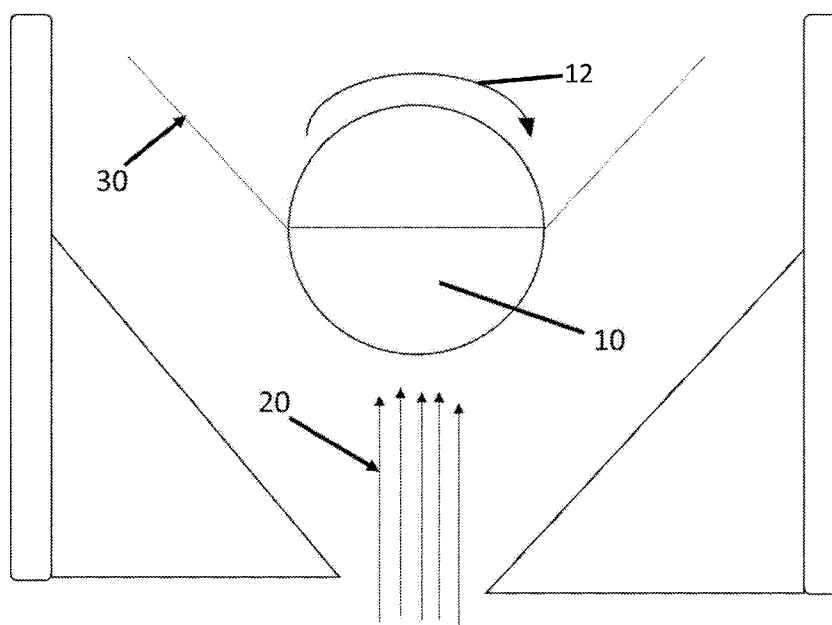


Figure 1

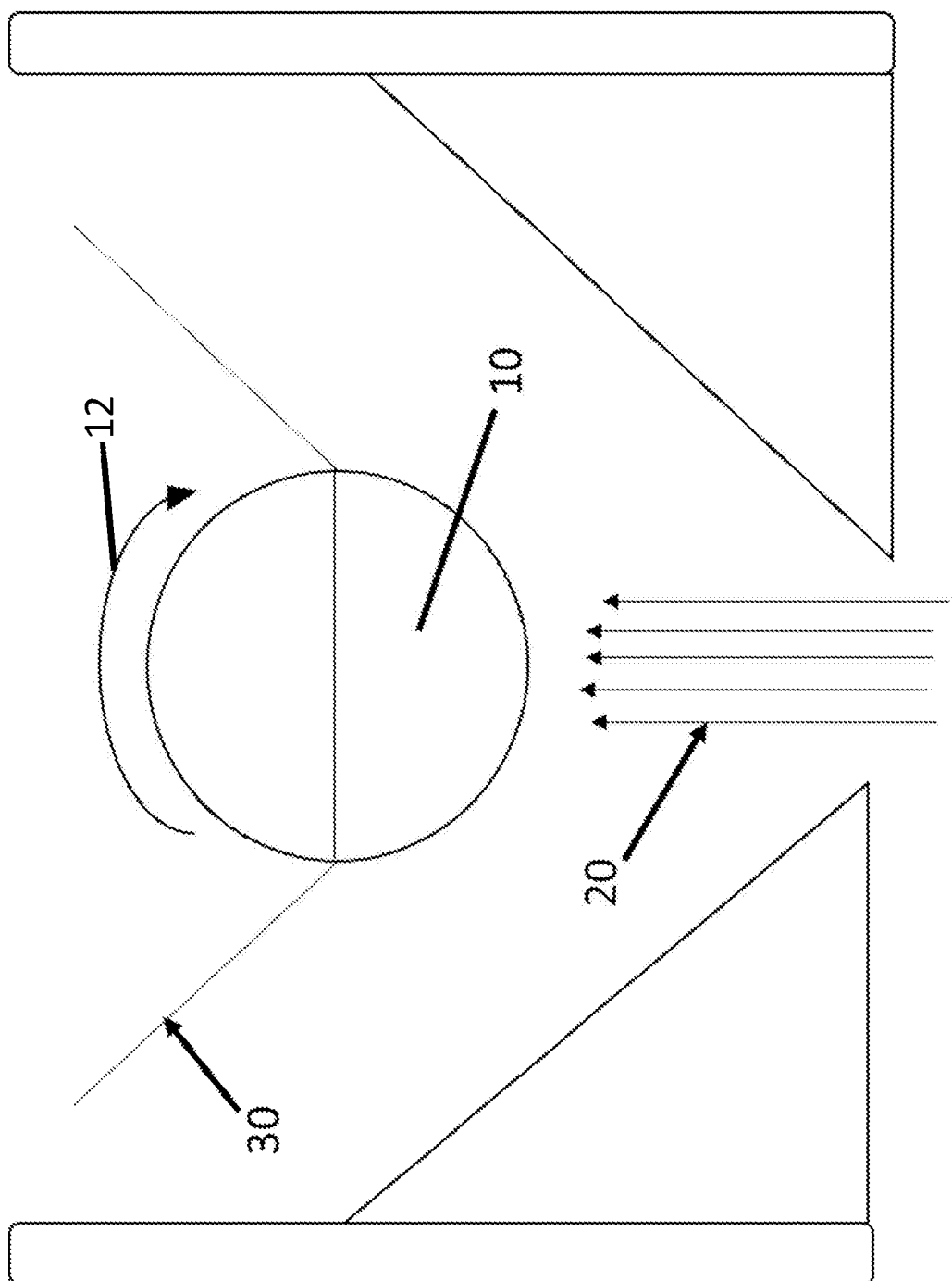


Figure 1

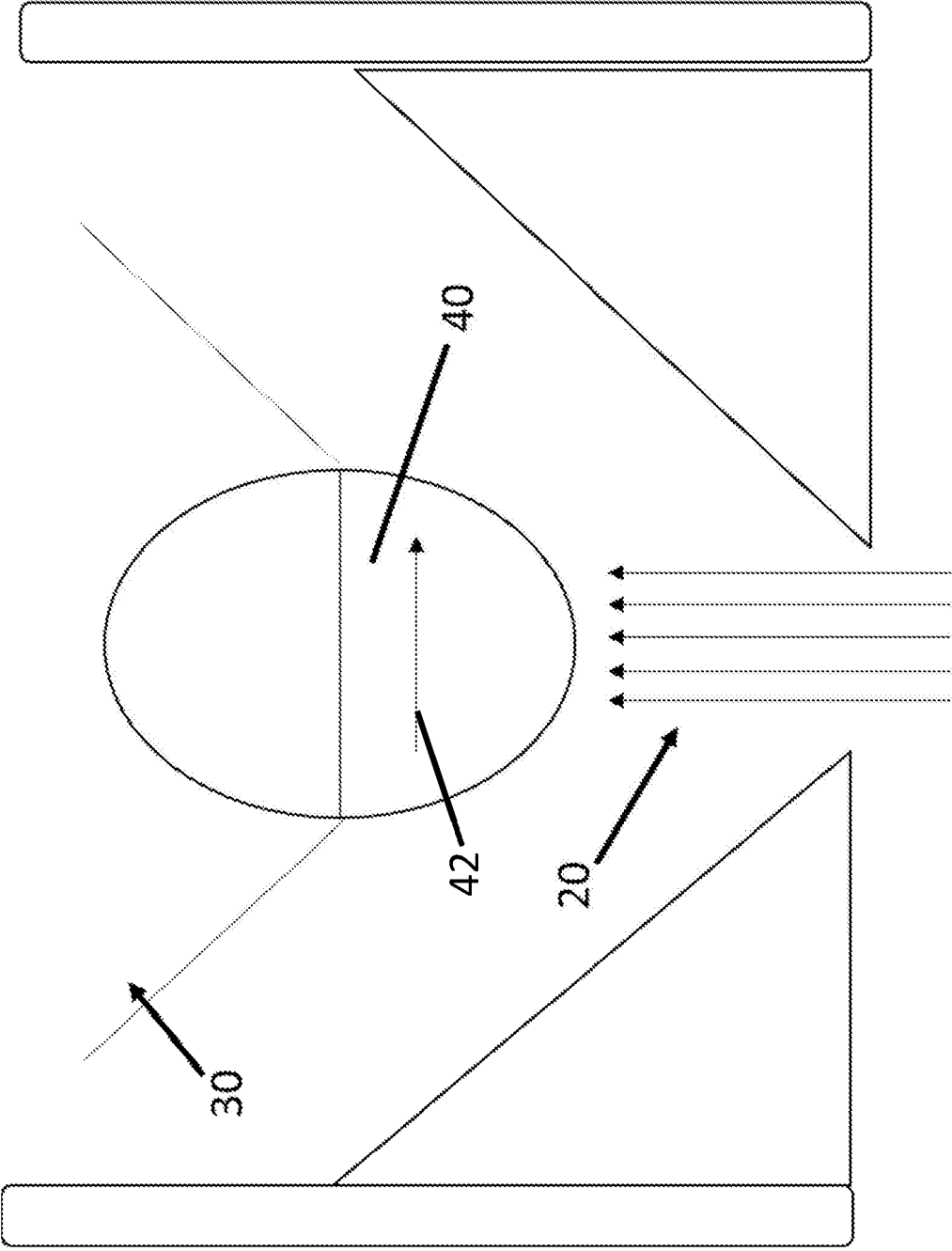


Figure 2

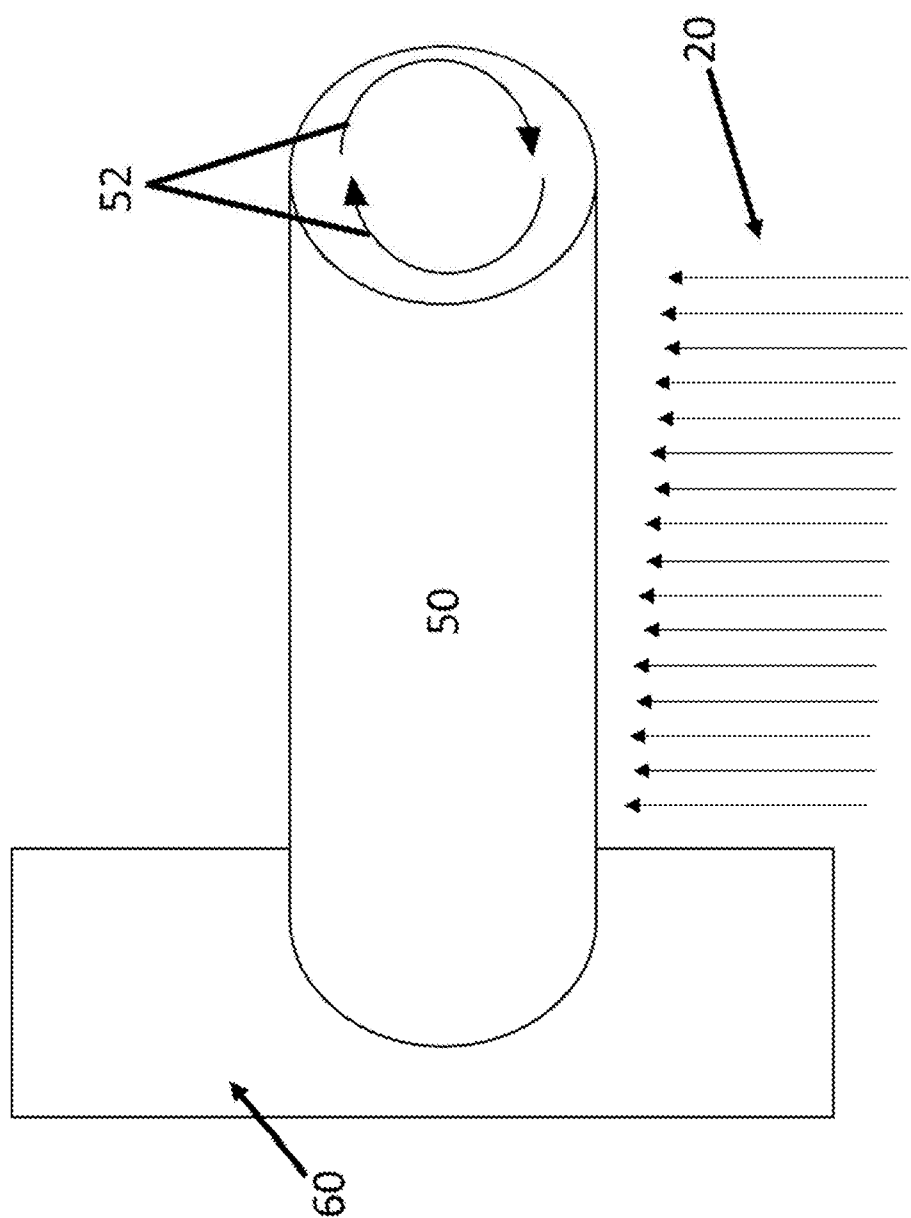


Figure 3

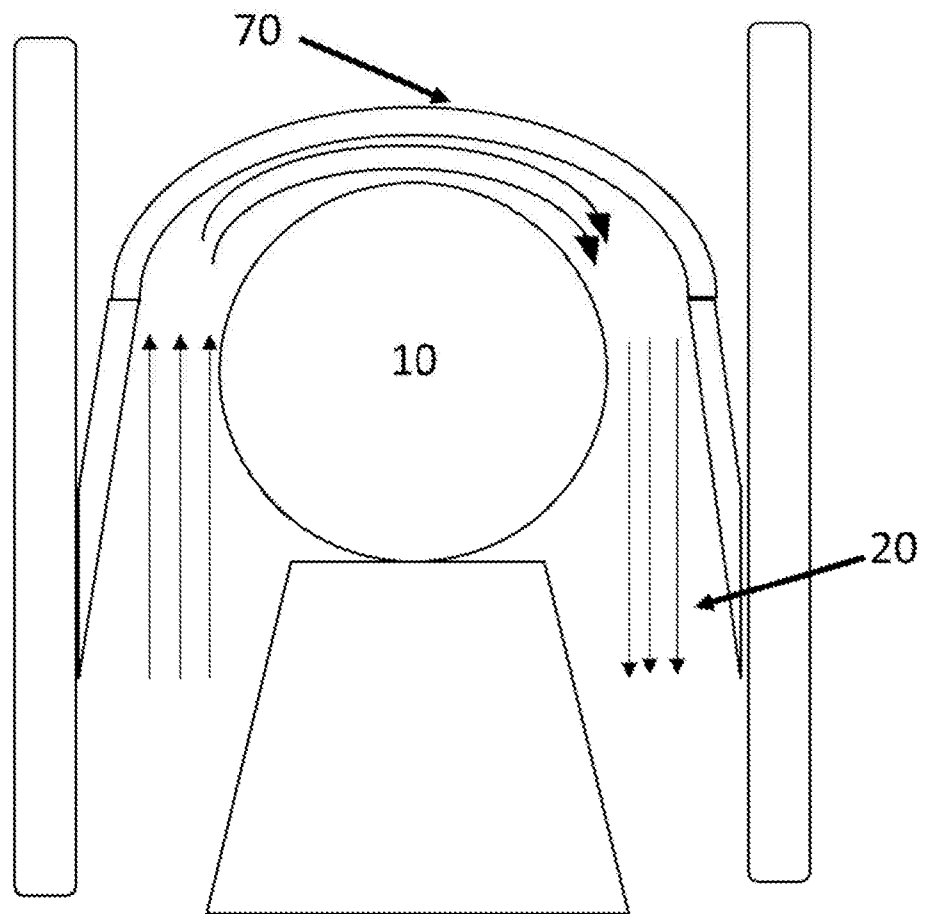


Figure 4

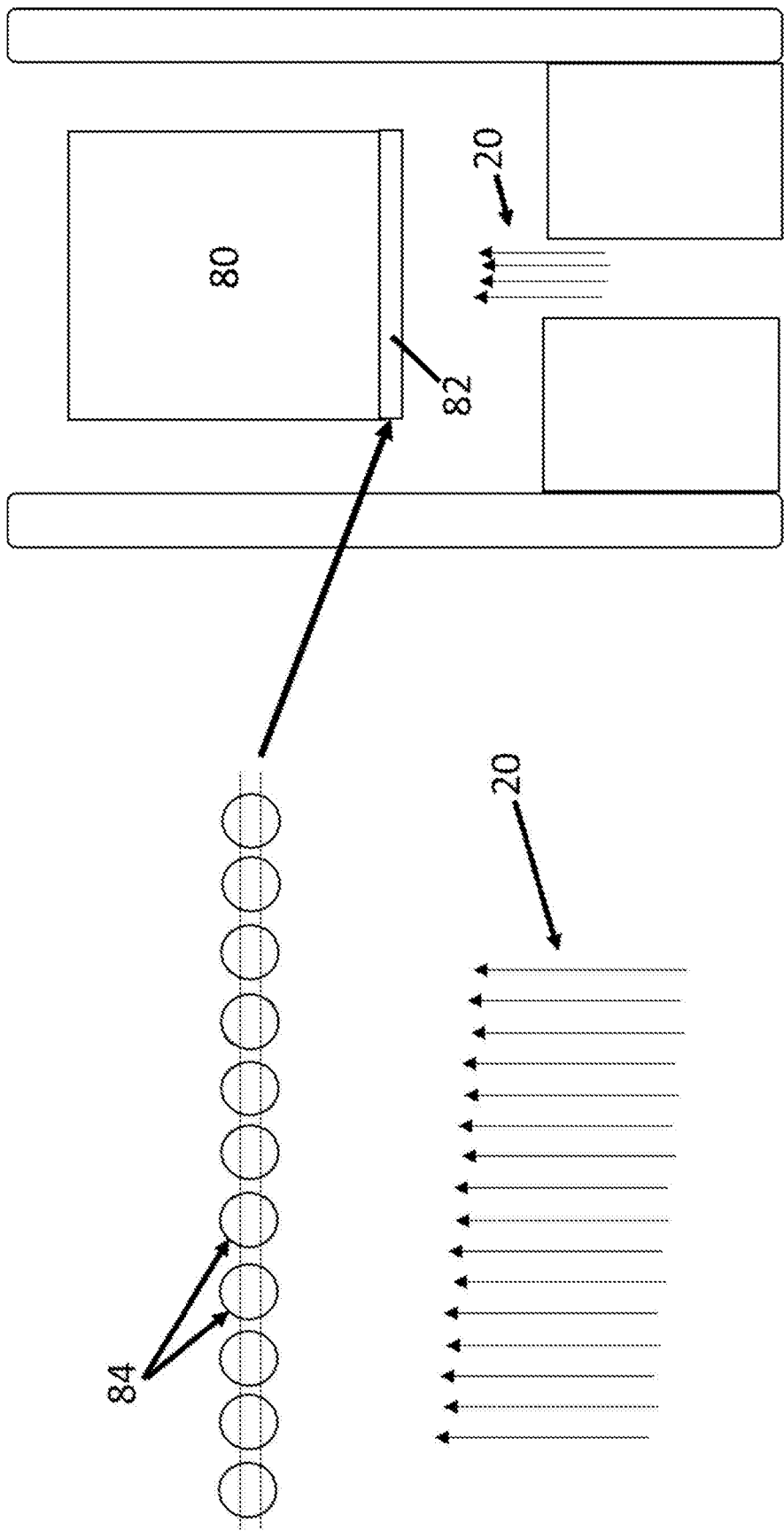


Figure 5

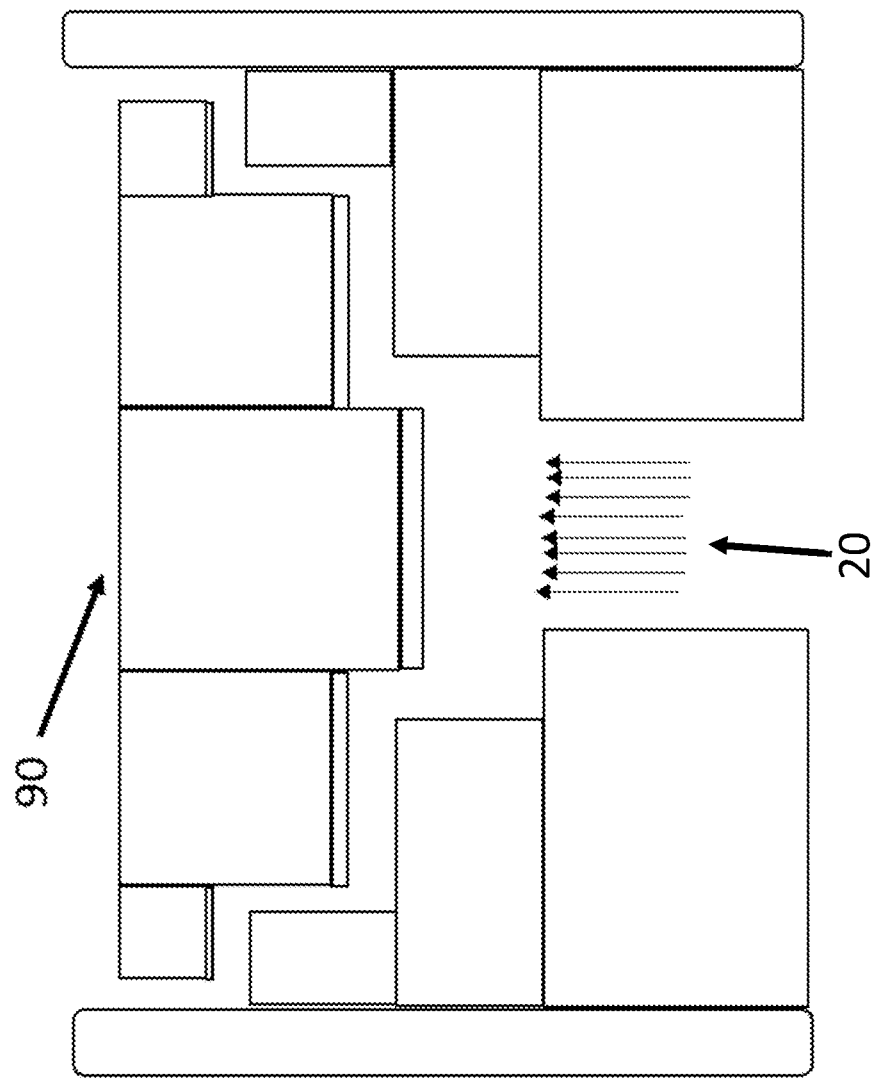


Figure 6

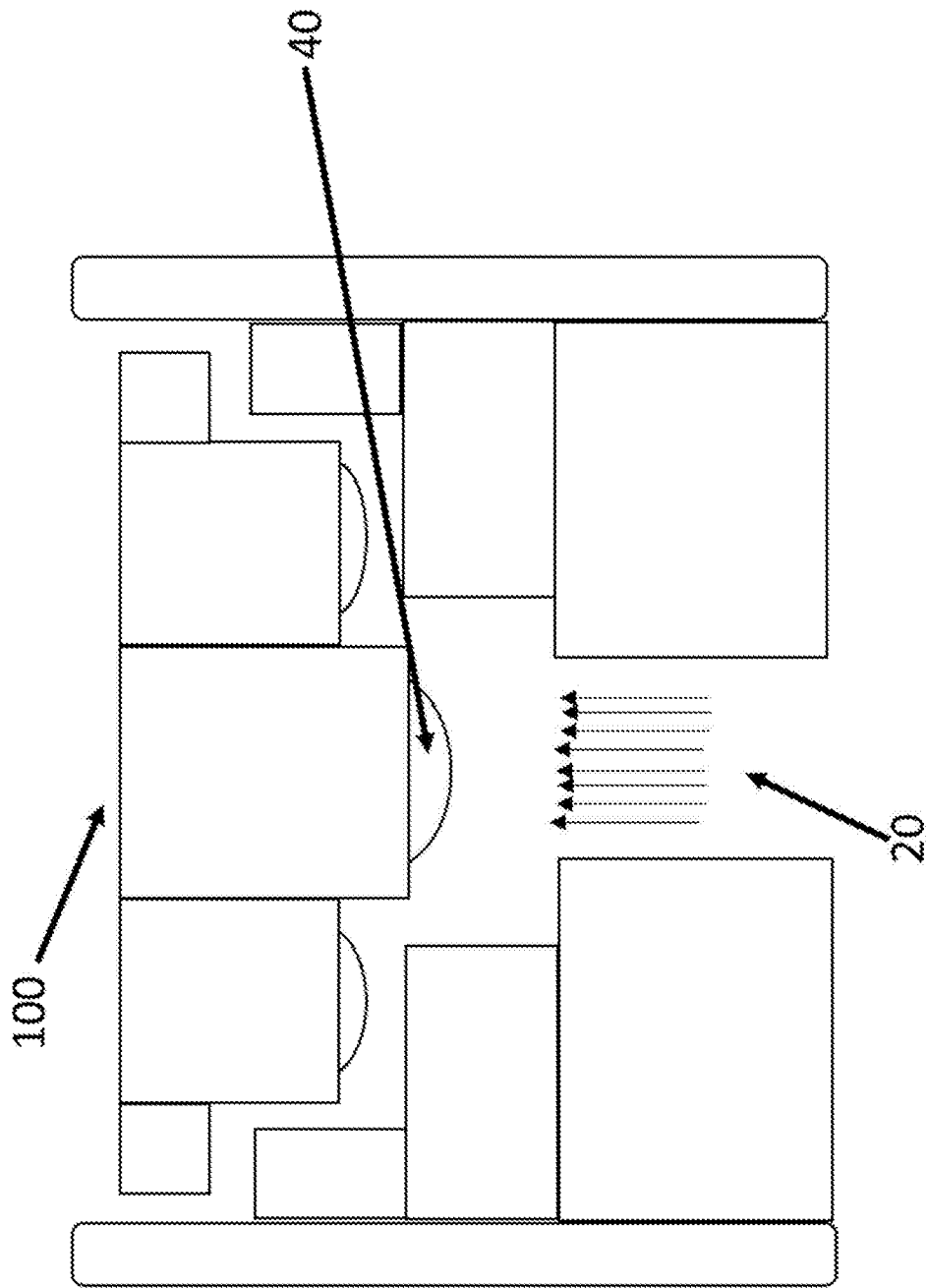


Figure 7

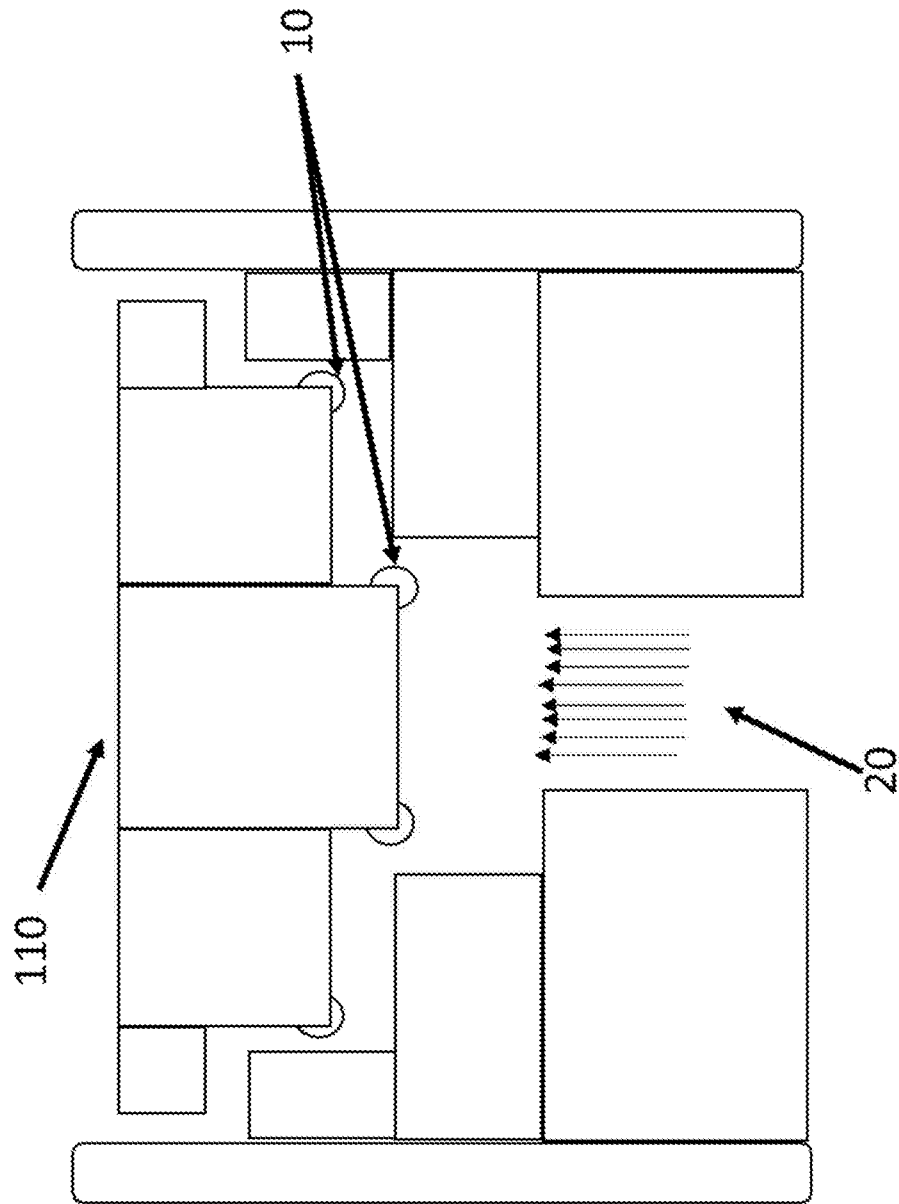


Figure 8

Improved Homogenizer impact head

Background

Graphene is a two-dimensional allotrope of carbon, consisting of sheets of a few atoms thickness in a hexagonal structure. Graphite, the widely used mineral is effectively a crystalline form of graphene, in which layers of graphene are bound together by van der Waals forces. Graphene has attracted considerable interest since its discovery as an isolatable material in 2004. The novel mechanical, thermal and electrical properties of the material suggest a number of uses. Graphene can be produced on a laboratory scale sufficient for experimental analysis, but production in commercial quantities is still a developing area. Other single layered structures such as boron nitride are expected to exhibit similarly interesting properties in the nanotechnology field.

A review of this technology has been compiled by Min Yi and Zhigang Shen and their titled 'A review on mechanical exfoliation for the scalable production of graphene', Journal of Materials Chemistry, A, 2015, 3, 11700 provides an overview of the state of the art regarding graphene production. Bottom-up techniques, such as chemical vapour deposition and epitaxial growth, can yield high-quality graphene with a small number of defects. The resultant graphene is a good candidate for electronic devices. However, these thin-film growth techniques suffer from a limited scale and complex and hence expensive production, and cannot meet the requirements of producing industrially relevant quantities of graphene.

Large-scale production of graphene at a low cost has been demonstrated using top-down techniques, whereby graphene is produced through the direct exfoliation of graphite, sometimes suspended in a liquid phase. The starting material for this is three-dimensional graphite, which is separated by mechanical and/or chemical means to reveal graphene sheets a few atoms thick.

The original technique used by the discoverers of graphene, the "Scotch Tape" method can be used to prepare high-quality and large-area graphene flakes. This technique uses adhesive tape to pull successive layers from a sample of graphite. Based on the graphene samples prepared by this method, many outstanding properties of graphene have been discovered. However, this method is extremely labour-intensive and time consuming. It is limited to laboratory research and seems unfeasible to scale up for industrial production.

The three-roll mill technique is a method to scale up the Scotch Tape method, using polyvinyl chloride (PVC) dissolved in dioctylphthalate (DOP) as the adhesive on moving rolls which can provide continuous exfoliation. Though the three-roll mill machine is a known industrial

technique, the complete removal of residual PVC and DOP to obtain graphene is not easy and brings about additional complexity.

Prof. Jonathan Coleman's group at Trinity College Dublin have developed a high-yield production of graphene by the sonication assisted liquid-phase exfoliation of graphite in 2008.

5 Starting with graphite powder dispersed in specific organic solvents, followed by sonication and centrifugation, they obtained a graphene dispersion. This method of producing graphene is capable of scaling up but one shortcoming is the extremely low graphene concentration (around 0.01 mg/mL) of the suspension produced, which is not necessarily suitable for bulk production.

10 Additionally, ultrasonic processors can only achieve the high power density required in small volumes, so it is difficult to scale up this process to achieve any economy of scale. A relevant disclosure can be found in WO2013/010211A1.

Another technique that can produce a high yield while not being as labor intensive, or energy consuming, as the methods describe above, would be the use of shear force techniques. As
15 is well known, graphite layers have a low resistance to shear force which makes graphite a useful lubricant. This has been exploited in a number of techniques which apply shear force to exfoliate graphene from graphite.

Ball milling, a common technique in the powder industry, is a method of generating shear force. A secondary effect is the collisions or vertical impacts by the balls during rolling actions
20 which can fragment graphene flakes into smaller ones, and sometimes even destroy the crystalline nature of structures.

Several improvements to the ball milling technique have been attempted, such as wet ball milling with the addition of solvents, but these techniques still require a very long processing time (around 30 hours) and produce a high number of defects even if suitable for industrial
25 scale, bulk, production. A relevant disclosure can be found in WO 2012117251 A1.

Some shear force production techniques have used an ion intercalation step prior to applying the shear force to weaken the inter-layer bonds. This reduces the energy required to exfoliate the graphite into graphene, but the resulting graphene may be contaminated with residual ions contaminating the finished product, and the process requires additional time and cost which
30 reduces the industrial application of this technique.

More recently fluid dynamics-based methods have emerged for graphite exfoliation. These are based on mixing graphite in a powder or flake form with a fluid to form a suspension, the fluid can then be subjected to turbulent or viscous forces which apply shear stress to the

suspended particles. Usually, the fluid is either a liquid of the type often used as a solvent and may include a surfactant mixture tailored to the removable from the finished product.

One method of generating the shear forces is with a high shear, for example rotary mixer. Graphene exfoliation has been demonstrated using a kitchen blender to create shear forces on graphite particles in suspension. This process has been scaled up using commercial high shear mixers comprising rotating blades passing in close proximity to an aperture screen to produce high shear. The graphite particles experience a shear force applied by the fluid due to the difference in velocity of the mixing blades and the static shear screen. A relevant disclosure can be found in WO2012/028724A1 and WO 2014/140324 A1.

A further method is the use of a high pressure homogenizer with a micro fluidizer. The micro fluidizer in this case consists of a channel with a microscale dimensions, meaning of around 75µm. Fluid is forced through the channel from an inlet to an outlet using high pressure. Because of the narrow dimension of the channel, there is a high shear force generated by viscous friction between the walls and the bulk flow which leads to delamination of the graphite. This method requires very high pressures and the starting graphite must already have been comminuted into the micron size range. A relevant disclosure can be found in WO2015/099457.

There exists a need for a graphene production process that can produce graphene using less energy, that can be scaled up to high rates of production without loss of quality of the finished product. Such a process using a preprepared graphite solution, and a homogenizer valve is disclosed within WO 2021/198794, which discloses using areas of high and low pressure within the valve to apply force to the solution, which in turn can break down the graphite in the solution other useful products such as graphene.

Another method using such a homogenize, for produce graphene, can be found in WO2018/069722, which discloses an apparatus wherein a pump is used to pump a graphite solution through a fluid conduit, at the end of the conduit the fluid flow is targeted towards the center of a symmetrical impact head, to provide the shear force. wherein the impact head is symmetrical around the axis parallel to the fluid flow. Wherein the impact head can be rotated around the axis of symmetry, so as to reduce the risk of localized wear around the area of impact, thereby extending the operational life-span of the impact head.

Further in this apparatus the impact head may be attached to an adjustable member, so that the position of the impact head by be adjusted to along its longitudinal axis, thereby changing the size of the gap between the conduit and the impact head. In these cases, the gap size is adjusted to clear any blockages that form between the conduit and the impact head. In some embodiments the impact head may be attached to a pressure drop valve. Wherein the valve

is used to provide a predetermined amount of backpressure from the conduit and other components, to improve the efficiency of the homogenizer.

In some embodiments of the apparatus the impact head is comprised of a hardened material, or at least the surface upon which the fluid impacts is covered in a layer of such a material.

5 These hardened materials are chosen so as to reduce the risk of wear to the impact head's surface, and possible to increase the amount of shear force between the fluid and the impact head. Suitable materials that could be used include material(s) selected from the group tungsten carbide, zirconia, silicon nitride, alumina, silicon carbide, cubic or wurtzite boron nitride and diamond.

10 The apparatus may also include an impact head surround, positioned around the impact head, or the outlet of the fluid conduit, which extends the region in which the fluid is constrained before exiting the apparatus, to try and further homogenize the fluid solution as it exits the apparatus, thereby improving the apparatus' efficiency and yield.

Such an apparatus is disclosed in UK patent application GB15181.5. That apparatus provides
15 a fluid conduit for impacting a suspension of particles to be de-laminated against an impact head having an impact face and an annular gap. In practice it is been found that the apparatus has a limited lifespan before maintenance is required as the annular gap can either become clogged with particulate material and/or become worn so as to provide an uneven gap through which suspension preferentially flows and, which results in the gap becoming larger, reducing
20 the homogenizers effect as the fluid pressure drops within the apparatus. Such clogging tends to occur when fresh portions of the impact head, or the surrounding annular surface are exposed, as the reduced homogenization due to the wear will leave larger particles in the solution, as well as the particles of debris from the worn areas.

The present invention seeks to overcome the problems in previous techniques to provide a
25 production method for graphene that is rapid, scalable to industrial quantities and energy efficient, via the above-mentioned homogenizer method. But such a method still has some problems as described above, this application predominantly addresses the question of wear to the homogenizer impact head. Specifically, the invention looks to provide an impact head which can reduce the amount of wear caused by regular use, while not reducing the
30 effectiveness of the homogenizer's shear force technique.

Summary

The present invention provides an impact head designed for a homogenizer, in particular a homogenizer that uses shear force technique on a mixture of suspended graphite to form graphene. In the homogenizer the mixture is injected into the apparatus at a relatively high pressure/flow rate, that then impacts upon the impact head, using the shear force of this collision to separate the graphite molecules to form graphene.

In this process the continuous use of the apparatus will eventually cause wear to the impact head, such wear can lead to the impact head deforming and becoming less effective, and eventually the wear reaches a point where the impact head must be replaced. In some homogenizer the impact head will be configured to rotate to reduce wear. In some cases, the impact head may rotate periodically, that is that when the flow has caused localized wear on the impact head, the deformation around these localized wear points will result in the force of the flow being uneven that results in the impact head rotating, resulting in an unworn portion of the impact head being exposed to the flow. Other impact heads may be configured to rotate the impact head continuously so as to reduce the overall wear by spreading the force across the entire impact head. In these devices the impact head is usually flat, or conical, to provide a relatively flat surface to maximize the generated shear force. However, by maximizing the shear force these designs also increase the risk of wearing the impact head.

In contrast, the claimed invention provides an impact with specifically chosen geometry, such as spherical impact head, said impact head may be configured to be rotated by the impacts head mounting, or be free to rotate under the force of the flow. In particular the spherical impact head comprises a ball bearing, set inside a hemispherical cowl, wherein there is a small channel between the ball bearing and the cowl so that the ball bearing can rotate within the cowl, and that any of the fluid that flows pass the ball bearing is stopped by the cowl, after which it can follow the channel and return to the flow. Wherein the flow impacts the ball bearing creating shear force on the fluid by the impact, it is also noted that the fluid may experience additional shear force when flowing through the channel between the ball bearing and the hemispherical cowl.

In other embodiments, the cowl or impact head mounting may be configured to continuously rotate the ball bearing. In this case the rotation of the ball bearing will help reduce the amount of friction/shear force acting on the ball bearing, due to the rolling friction of the ball bearing, while also spreading the impact force over the surface of the ball bearing. By doing this the overall amount of wear on the ball bearing will be reduced, as instead of localized wear point the wear will be spread over the rotating surface.

By utilizing either method above, the ball bearing impact head can be used to reduce the amount of wear on the impact head. However, it is noted that in the continuous rotation method, the rolling friction on the moving ball bearing would reduce the force on the ball bearing, but may also reduce the friction on the fluid particles in the flow, which in turn would reduce the effectiveness of the homogenizer. Another method which may help overcome this would be to pipe the fluid flow into the channel between the ball bearing and the cowl, that is to have the fluid impact the cowl with the rotating ball bearing adding additional frictional force as the fluid flows through the channel to improve the homogenization, compared to having the fluid impact a flat surface.

Therefore, there is a need to provide to provide an impact head with a geometry that will allow some rotation, to reduce the overall wear on said head and to expose different portions of the impact head to the fluid flow, while also not have so much rotation that the impact head's rotation would reduce the shear force/friction on the fluid flow, as a lower shear force would decrease the graphene yield. With these criteria, and potential problems in mind the following impact head alternatives are considered:

The first embodiment as described above would comprise a spherical impact head mounted within a housing that would allow said impact head to rotate. When using this impact head, the rolling of the spherical impact head may reduce the force applied to the impact head itself reducing the overall wear. When used frequently the force of the fluid flow may result in localized wear at/near the point of impact, on the impact head, when this occurs the worn areas may experience an uneven force which in turn may force the impact head to rotate. This induced rotation may then result in the impact moving so that an unworn portion of the impact head replaces the worn area, by exposing a new unworn portion of the impact head to the fluid flow. In doing this the life-time of the impact head can be extended as the rotations would limit the amount of localized wear, spreading the wear over the surface of the impact head.

Note that in some versions of this embodiment, the housing may be configured to mechanically rotate the impact head, this is to say the housing can be configured to rotate the impact head by a certain angle, after a predetermined amount of time, and in some cases, thereby reducing the amount of localized wear as described above. But also, the housing may be configured to continuously rotate the impact head. The continuous rotation of the impact head may reduce the overall wear, as the rotational friction acting on the rotating surface has less force than the shear/friction force on a stationary surface. However, by using the rotational motion to reduce the force felt by the impact head, it may be possible that the same motion will reduce the force acting on the fluid, within the fluid flow. If so, the reduced force may affect the overall yield of the homogenizer. This may be counteracted by adding features to the surface of the

continuously rotating impact head, such as grooves, ridges, flaps or saw-tooth shaped teeth, these surface features can provide additional surfaces to the impact head, preferable in the form of a flat surface, where these extra surfaces can provide additional shear force when the fluid comes into contact with the rotating impact head, in this case more force than that generated by a smooth, rotating spherical surface. As the additional shear force may help to improve the homogenizer's yield.

In some embodiments the spherical impact head may be replaced with a cylindrical or elliptical impact head. These other geometries may be used to restrict the impact head's rotation, specifically by limiting the degrees of freedom in which the impact head may rotate, in the case of the aforementioned geometries both will be limited to rotating around their respective elongated axis, which may be positioned parallel, or perpendicular, to the direction of the fluid flow. In particular the elliptical impact head will likely be positioned with the elongated axis parallel to the fluid flow, while the cylindrical impact head will have the elongated axis perpendicular, so that the fluid flow impacts the curve surface. In doing this the reduction in force caused by the rotational motion of the impact head may be reduced, improving the yield when compared to a freely rotating spherical head. Like the spherical impact heads, the elliptical and cylindrical heads may further comprise surface features that may provide additional surface area and/or provide flat surfaces to increase the shear force generated when the fluid impacts the impact head. Not that in the case of the cylindrical impact head the smooth cylinder may be replaced with an impact head with a shape similar to that of a drill bit, or screw thread, to provide additional shear force. It is noted that when the impact head includes these additional surface features it is preferable that the impact head is driven, that is to say periodically or continuously rotated mechanically around their elongated axis, so as to maximize the amount of shear force being generated by these additional surface features.

In some embodiments, the rotating impact head, be it spherical, elliptical, cylindrical or another rounded shape, may be embedded within a larger flat impact head. That is to say that the rotating impact head is housed within the center of a larger flat, or sloped, impact head, while still being free to rotate. In some cases, the inlet for the fluid flow may have a diameter that is smaller than, or equal to, the diameter/size of the rotating impact head, so as to target most or all of the flow towards the rotating impact head, the surrounding flat impact head may then provide a means to direct the flow after the initial impact potentially to further impact heads/surface, to further improve the yield of the homogenizer.

In other case the inlet for the fluid flow may have a diameter that is wider than the diameter/size of the rotating impact head. In this case only some of the flow is directed at the rotating impact head, with the rest being directed to the surrounding flat, or sloped, impact head. Such a flow

may be preferable as it seeks to strike a balance between the potentially lower force impacts of the rotating head, which may have a lower yield but also produces less wear on the impact head, with the potentially higher shear force impacts produced by the flat surface of the surrounding impact head, which may produce a higher yield but would be more susceptible to wear. Therefore, by using both impact head simultaneously this impact head can have increased yield compared to the rotating head alone, while having a longer life span than the flat impact head alone.

In another embodiment, the impact head may be designed to be comprised of a plurality of rotating impact heads, which may either be embedded within the surface of a larger flat impact head, or be placed adjoined to one another in order to form a relatively flat surface out of the rotating impact heads. This type of impact head will have a lower risk of wear when compared to the imbedded rotating impact head describe above, as more of the overall surface, if not all of it, is able to rotate and therefore reduce wear, while the relatively flat surface created by the plurality of impact heads improve the amount of friction/shear force being produced. It is noted that such an impact head may comprise a housing that is capable of rotating the whole impact head, and/or moving the whole impact head tangentially, so as to expose different rotating impact heads, from the plurality of rotating impact heads, to be the target of the fluid flow thereby spreading the wear between the different rotating impact heads.

In some embodiments the rotating impact head may be surrounded by a cowl, wherein there is a small channel between the cowl and the rotating impact head. In these embodiments the fluid flow may be directed through the channel to impact the cowl, once in the channel the rotating head may rotate to generate more friction with the fluid in the channel, thereby improving the efficiency of the homogenizer. In some cases, the rotating impact head may include surface features such as ridges or saw-teeth to provide additional surface area, to increase the amount of friction generated, by allowing the rotating impact head to act as a water wheel forcing the fluid through the channel. In some of these cases the cowl itself may be able to rotate in order to reduce localize wear on the cowl at the inlet to the channel. It is also noted that in the embodiments with one or more rotating impact heads embedded into a larger flat, or sloped, impact head, there may be a channel around the rotating impact head as described above.

Another way that the impact head may improve the yield of the homogenizer is to have the fluid flow undergo multiple impacts. This may be achieved by using an impact head design that has multiple impact surfaces. One example of such a geometry would be the use of a ziggurat, or stepped structure. In these structures, after the fluid flow hits the initial impact head, using a flat, or sloped impacted head, or any of the rotating impact head geometries

described above, the fluid flow is then flows over the edge of the impact head, where it may be directed to one or more pipes, or channels, which will help increase the fluids pressure/velocity as it flows down towards a second impact head, on a layer below the initial impact head. This second impact will further brake down the graphite in the fluid solution, thereby improving the efficiency of the homogenization. Note that the structure may comprise one, or more, additional layers. Each layer will comprise a plurality of impact heads, wherein the fluid flow from the layer above is directed towards the layer below, specifically the fluid will flow through a pipe or channel to target the flow towards the impact head of the next layer. Said channels, or pipes, may be shaped in order to increase the fluids pressure, or velocity, as it travels down each layer, so as to maximize the force generated when the fluid impacts an impact head, which should increase the yield of each impact. In some cases, the channels between the layers may have a relatively small or decreasing diameter to increase the fluid pressure as it flows through the channel. It should be noted that the impact heads on each layer may comprise a flat, sloped, or rotating impact head, preferably each impacted head would comprise one or more embedded rotating impact head as described above, thereby gaining the benefits of both the rotating and static impact heads, note also that in these layers the surrounding static impact head will direct the flow towards the channels to the next layer, and may be sloped to help better direct the fluid flow towards said channels.

In some cases these stepped, or layered, impact heads may utilize the rotating impact heads as described earlier on one or more layers. These impact heads may be positioned at the point of impact on each layer, so as to reduce the overall wear upon each layer of the impact head as described above. Wherein the rotating impact head may cover the entire layer of the stepped impact head, this is likely when the rotating impact head is in the form of a rotating cylinder, or be embedded within a larger, flat or sloped, impact head. Note that the stepped impact head may also utilize rotating impact heads at the edge of each layer to help increase the flow rate between layers by helping guide the flow towards the channel to the lower layer of the impact head. Note that such guiding rotating impact heads, may help increase the fluid pressure between layers, which in turn may increase the force applied to the fluid, thereby improving the homogenizing process by increasing the final yield of each of the lower layers.

Drawings

Figure 1: depicts an example impact head that utilizes a spherical rotating impact head.

Figure 2: depicts an example impact head that utilizes an elliptical rotating impact head.

Figure 3: depicts an example rotating impact head with a cowl.

5 Figure 4: depicts an example of a cylindrical impact head.

Figure 5: depicts an example impact head that utilizes a plurality of embedded rotating impact heads.

Figure 6: depicts an example impact head that utilizes a ziggurat shaped stepped impact head.

10 Figure 7: depicts an example of a stepped impact head utilizing embedded rotating impact head in the center of the flat impact heads.

Figure 8: depicts an example of a stepped impact head utilizing embedded rotating impact head in the edges of the flat impact heads.

15 Detailed Description

The claimed invention provides an impact head configured to be used within a homogenizer, such as the fluid homogenizers used to produce graphene. Wherein said impact head is configured to have a geometry that will improve the efficiency of the homogenizer. In this case, improving the efficiency of the homogenizer may mean reducing the wear on the impact head thereby giving the impact head a longer operational life time meaning the homogenizer can be operated for longer period, before the need to preform maintenance on, or replace, the impact head. Or the efficiency may be improved by improving the overall yield of the homogenizer, for example a worn impact head could result in a loss of productivity in the homogenizer, therefore an impact head that is more resilient to wear can improve the overall yield over the impact heads operational lifespan. In other cases, the impact head geometry may be configured so that the fluid within the homogenizer undergoes multiple impacts, thereby increasing the total yield of the homogenizer, per processing cycle. In some case the impact head may utilize a combination of feature to achieve both the multiple impacts and reduced wear on the impact head.

30 In some embodiments the impact head may be configured to utilize one or more rotating impact heads, to reduce the wear on the impact head. In these cases, the impact head is configured to rotate around at least one rotational axis, so as to spread the wear on the

impact head over a wider area, reducing the risk of localized wear on the impact surface of the impact head, and thereby reducing the overall effect of the wear on the impact head. In some cases, the rotating impact will be configured to be driven by an external motor, turning at a constant rate, this way the impact head ensures that the wear is spread over a large area by exposing different parts of the impact head's surface to the fluid flow within the homogenizer. In other embodiments the impact head may be free spinning, in these cases once a portion of the impact head becomes worn the uneven force created by the impact of the fluid flow on that area will cause the impact head to rotate in a manner that will expose an unworn region, or at least a less worn region of the impact head's surface to the fluid flow.

Figure 1 shows an example of a rotating impact head, specifically a spherical impact head 10. The impact head is placed in the path of the fluid flow, represented by the arrows 20, wherein the fluid will impact the curved surface of the impact head at a velocity that is sufficient to produce the force needed for a desired reaction within the fluid. Note that it is preferably that the width of the fluid flow will be less than, or at most equal to the width of the impact head, so that the entire fluid flow will impact the surface of the rotating impact head. The spherical impact head 10, is placed within a housing 30, wherein the housing 30 is configured to hold the impact head in place, within the path of the fluid flow 20, while also allowing the impact head to rotate, as indicated by arrow 12, relative to the housing 30. By doing this the impact head can rotate to expose different portions of the impact head's surface to the fluid flow 20, thereby reducing the overall wear to the impact head's surface, by spreading the force exerted onto the impact head over a larger area.

In the claimed invention there are two possible mechanisms for rotating the spherical impact head 10. The first mechanism allows the impact head to rotate freely, wherein the impact head housing 30 is configured to allow the impact head to rotate freely whenever a force is applied to the impact head. This may allow the impact head to continuously rotate under the force of the fluid flow 20, or in some case, the impact head may be positioned so that it remains stationary under normal operations, however once a part of the impact head becomes worn, the localized wear will create a force imbalance on the impact head causing the impact head to rotate in a manner that will move the worn portion away from the fluid flow 20, exposing unworn, or at least less worn portions of the impact head surface to the fluid flow 20.

The other mechanism is to have the impact head be driven by a suitable means, likely to be an electric motor, that may be housed within the same housing 30 as the impact head. Wherein the motor may be configured to either continuously rotate the impact head, or to rotate the impact head by a certain angle over a certain period of time, or at a predetermined

time. By doing so this system aims to reduce the overall wear, and potentially prevent the formation of localized wear by spreading the wear evenly across the entire surface of the impact head.

Some embodiments may use a combination of these two methods, having an impact head that is periodically driven, meaning the impact head is rotated by a specific angle at predetermined times, and then between these predetermined times the impact head may rotate freely when exposed to uneven forces. Regardless of the method used, all of these mechanisms are designed to reduce the overall wear to the impact head, by ensuring that the force applied to the impact head is spread over a wide area, by exposing areas that are not worn, or at least areas that are less worn, to the force of the fluid flow, thereby reducing the overall wear to the impact head's impact surface.

It is noted that when the impact head is rotating the force exerted on the fluid by the impact head may be reduced, as the rotational friction generated by the rotating impact head may be smaller when compared to the force generated when the impact head is static.

Additionally, when the impact head is free rolling there is the possibility that the impact head may recoil when impacted by the fluid flow 20, this may also reduce the force exerted on the fluid, which may reduce the overall efficiency of the homogenizer. Therefore, some embodiments may restrict the impact heads freedom of motion to reduce the amount of impact force lost in this way. In some cases, this may be achieved by replacing the spherical impact head 10, with an elliptical 40.

Figure 2 depicts an example of an elliptical impact head 40. The elliptical impact head 40 is designed to limit the directions in which the impact head can rotate, in the depicted example the elliptical impact head 40 is designed to rotate around its longitudinal axis, as indicated by arrow 42, the axis parallel to the fluid flow 20, as the other directions of rotation are blocked by the housing 30. Though, it is noted that the elliptical impact head 40 may be aligned differently to the depicted example. Whichever alignment is used the purpose of the impact head is the same, that is, to only allow rotations in a limited number of directions, thereby reducing the possible force lost, due to the rotating motion reducing the frictional force applied to the impacting fluid. It is also noted that these impact heads may be free rolling, motor driven, or both in the same manner as the spherical impact head 10.

Figure 3 depicts an alternative rotating impact head geometry, specifically a cylindrical impact head 50. The cylindrical impact head 50 is held in place, in the path of the fluid flow 20, by a housing, or support structure 60, wherein the cylindrical impact head 50 can only rotate around its longitudinal axis, as indicated by the arrows 52, which should be perpendicular to the direction of the fluid flow 20, so that the fluid impacts the curved surface

of the cylinder. As with the other rotating impact heads, the cylindrical head may rotate freely, or be driven by a motor, to spread the wear over the entire curved surface of the cylindrical impact head 50. However, unlike the other designs the housing, or support structure 60, of the cylindrical head 50 may be configured to move the impact head laterally, in the direction perpendicular to the direction of the fluid flow 20. That is to say when the fluid flow does not cover the entire length of the cylindrical impact head 50, the housing may be configured to move the impact head in a direction parallel to the longitudinal axis, to expose new areas of the impact surface, in this case the curved surface of the impact head to the fluid flow 20, these movements may be preformed periodically, or when a certain amount of wear is detected in the currently exposed region of the impact head. One benefit of the cylindrical impact head 50 compared to the other geometries is that the cylindrical shape will generally have a larger impact surface compared to the spherical 10, and elliptical 40 impact heads. Meaning that the cylindrical impact head 50 may have a longer operational life span than the other geometries, when using the same sized fluid flow on each. Alternatively, the cylindrical head may allow the use of a wider fluid flow, one that covers the entire length of the cylindrical impact head, which may increase the amount of fluid impact the impact head at any given time, which in turn means an increase in the amount of impacting fluid that is reacting at a given time, this may result in a homogenizer that is using the cylindrical impact head 50 having a faster rate of production, when compared to the other impact heads.

In some embodiments the curved surface of the impact head may not initially be smooth, as this smooth surface reduces friction on the impact head, and in turn reduces the force applied to the impacting fluid in the fluid flow 20. Therefore, some embodiments of the rotating impact heads may include surface features to produce more friction, such as regular grooves, dents or dimples, though these areas may become prone to wear. In the case of spherical 10 and elliptical 40 impact heads these surface features may be in the form of dimples, or dents, that give the impact head a surface similar to that of a golf ball. While the cylindrical impact head 50 may have grooves along its length giving the impact head a shape similar to a drill bit. The purpose of these surface features is to increase the amount of friction between the impact head and the impacting fluid, this will ensure that there is sufficient force for the desired reaction within the impacting fluid. Though as mentioned there may need to be a compromise, as to how many of these features are included if any, as these features will experience a greater amount of friction, meaning they may form weak point that are prone to wear, so it may be that the wear from including these features outweigh the gains made by the increased frictional force they produce.

In some embodiment wherein the homogenizer uses a rotating impact head the housing around the impact head may also include a cowl, such as the cowl 70 shown in Figure 4.

This cowl 70 may provide a channel between the impact head and the housing, through which the fluid may pass through, inside the channel the impact head may exert a crushing force to the fluid in the channel to help increase the yield of the desired reaction. This cowl 70, and any fluid between the impact head and the cowl 70, may also act as a bumper, preventing the impact head from recoiling when struck by the fluid flow 20, this may help reduce the amount of force loss when using a freely rotating impact head, once again increasing the overall yield.

Another solution to reduce the amount of force lost by using a rotating impact head is shown in Figure 5. In this example the homogenizer is using a flat impact head 80, wherein the fluid impacts a flat static surface. In traditional homogenizers the impact surface, the surface facing the fluid flow, may have a protective/hardened layer, that helps prevent wear and increases the force exerted by the impact head. Instead, the depicted impact surface 82 comprises a one or more embedded rotating impact heads 84, these impact heads may use any of the above-mentioned geometries, and may have a cowl for each of the embedded impact heads 84. The important feature of this design is that the plurality of smaller impact heads be positioned in a manner to form a near flat surface, thereby providing more frictional force when impacted, will simultaneously allowing the individual embedded impact heads to rotate, thereby reducing the wear to the impact surface. Note that these impact heads may also be designed to move laterally, in a direction perpendicular to the direction of the fluid flow 20, thereby exposing different portions of the impact surface 82 to the fluid flow 20, this may be used when the fluid flow 20 does not cover the entire impact surface 82 of the impact head 80.

An alternative to the rotating impact head geometries would be to use a layered, stepped or ziggurat shaped impact head 90, such as those depicted in figures 6 to 8. These impact heads comprise a plurality of impact heads arranged to form layers, or steps, wherein the fluid flow 20 will impact the first layer, then run off the edges of the first layer, after which the fluid falls and hits the second layer, after which the fluid may again flow to further successive layers, with the impact on each layer providing enough force to produce the desired reaction. This shape for the impact head 90 improves the overall efficiency of the homogenizer process by producing multiple impacts in a single cycle of the fluid flow 20, which may improve the yield of the process per cycle, and may remove the need for repeating cycles, meaning this impact head may remove the need to process the same fluid multiple times, to increase the yield, as this geometry produces multiple reaction impacts in a single cycle.

In some embodiment, after the impacting fluid impacts a layer of the impact head 90, the fluid may flow into one or more channels located around the edge of each layer, which then

directs the fluid toward the next layer of the impact head 90. The purpose of these channels will be to help increase the pressure, or the flow rate, of the fluid as it travels between layers, this can be achieved through the choice of shape, and/or diameter for the channels, for example, the channels may be conical wherein the end proximate the higher layer, is wider than the end facing the lower layers. These channels may help increase the velocity of the fluid between impacts, thereby increasing the amount of force exerted on the fluid at each layer of the impact head 90, which may increase the yield produced by each impact.

Figure 7 depicts an example impact head 100 that combines the features of the stepped impact head 90 and the rotating impact head as described above. In particular the plurality of impact heads that form the layers of the stepped impact head 90 includes one or more embedded rotating impact head within the impacting surface of each layer of the stepped impact head 90. It is preferable that these embedded rotating impact heads be positioned either at the point of impact or at least proximate the point of impact. In these embodiments the embedded impact heads help to reduce the wear to each of the layers of the stepped impact head 100, by spreading the wear over the surface of each embedded rotating impact head. Note that there may also be a plurality of embedded rotating impact heads, in a similar manner to the impact head in figure 5, and it is noted that these embedded rotating impact heads may use any of the shapes described above.

Figure 8 depicts another example stepped impact head 110, which utilizes one or more rotating impact heads, wherein each layer includes embedded rotating impact heads along the edge of the layer. In this example the rotating impact head are being used along the edge of the layers of the impact head 110 to act in a manner similar to a water wheel, that is to say that these impact heads will rotate as the fluid flows between layers, and in doing so these impact head may help to increase the velocity of the fluid as it flows over the edge from one layer of the impact head 110 to the next, or into channels that direct the fluid flow to the next layer of the impact head. Thereby using the rotating impact heads to increase the force exerted during the impact with the next layer. As previously mentioned, increasing the fluid velocity and in turn the force generated during an impact, the yield of said impact may be increased, thereby increasing the yield, and therefore the efficiency, of the homogenizer process. Note that in this embodiment it is preferable to have the rotating impact heads be driven so as to accelerate the fluid to a desired velocity.

Some embodiments of the stepped impact head may utilize rotating impact heads in both the center of the impact surface and the edges of the impact surface. In doing so the impact head is designed to both reduces wear on the impact surfaces, and increase the fluid velocity between layers, both of which can help improve the yield of the homogenizer, as

described above. Note that some embodiments may instead use a layered impact head wherein each of the layers are made from one or more rotating impact head, for example the impact head may comprise a pyramid structure with a spherical 10, elliptical 40 or cylindrical 50 impact head at the tip as the initial impact surface, with a plurality of cylindrical impact heads 50 forming the lower layer. It is noted that any of the rotating impact heads may be used to form the layers, but the cylindrical shape may be preferable as they provide a larger impact surface. Thereby providing the benefits of both the rotating and stepped impact heads simultaneously.

Additionally, when forming the stepped impact head from a plurality of impact heads, the space between the impact heads may form the above-mentioned channels between the different layers, the width of which can be controlled by moving the individual impact heads laterally. Further, it is noted that in some embodiments the cowls around the rotating impact head may also be used to form the channels between layers.

By using the above-mentioned geometries, the claim invention provides an improved impact head for a homogenizer. Wherein the specific shape of the impact head improves the overall efficiency of the homogenizing process, by reducing the wear on the impact head, thereby reducing down time, due to repairs and maintenance, and also increasing the operational lifespan of the impact head. Or, improvise the homogenizer, by producing multiple impacts and thereby increasing the yield of each homogenizing cycle. With some designs combining the disclosed geometries to produce all of these effects at once.

Claims:

1. An impact head configured to be used within a homogenizer, wherein the impact head has a geometry for improving the efficiency of the homogenization process, and reduce wear on the impact head, wherein the impact head comprises one of a rolling impact head or a stepped impact head;

Wherein the rolling impact head comprises an impact head design to symmetrically rotate around at least one axis of rotation, wherein the impact head freely rotates;

Wherein the stepped impact head comprises a plurality of impact heads, or surfaces, arranged into layers, the layers are configured so that the fluid flow impacts the first layer, then runs off the first layer, after which the fluid falls and impact the next layer, and then continuing to flow impacting each other layer of the impact head sequentially.

2. The impact head of claim 1, wherein the impact head comprises a rolling impact head.

3. The impact head of claims 1 and 2, wherein the impact head comprises a rolling impact head, and wherein the rolling impact head is configured to be driven by a suitable driving means, wherein the driving means rotate the rolling impact head by a predetermined angle, after a predetermined amount of time.

4. The rolling impact head of claim 3, wherein the driving means continuously rotates the rolling impact head.

5. The rolling impact head of any preceding, wherein the rolling impact head comprising a housing (30) and a spherical impact head (10).

6. The rolling impact head of claims 1 to 4, wherein the rolling impact head comprising a housing (30) and an elliptical impact head (40), wherein the elliptical impact head (40) is configured to rotate within the housing (30) in a specific direction.

7. The rolling impact head of claims 1 to 4 wherein the rolling impact head comprising a cylindrical impact head (50) and at least one of a support structure (60), or a housing, wherein the cylindrical impact head (50) is held in place by the support structure (60), or housing, and wherein the cylindrical impact head (50) is free to rotate along its longitudinal axis.

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8. The rolling impact head of claims 3 to 7, wherein the rolling impact head is driven by an electric motor.

9. The rolling impact head of any preceding claim, wherein the rolling impact head is partially surround by a cowl (70), configured to form a channel between the rolling impact head and the housing (30).

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10. The impact heads of any preceding, wherein the surface of impact head includes frictional features, such as grooves, dents or dimples.

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11. The impact head of claim 1 wherein the impact head comprises one or more flat impact heads (80), wherein the impact surface of the flat impact heads (82) comprises a plurality of embedded rolling impact heads, comprising the rolling impact heads of claims 2 to 10.

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12. The impact head of claim 1, wherein the impact head comprises a stepped impact head (90).

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13. The stepped impact head of claim 12, wherein the stepped impact head (90) further includes channels on the edge of each layer configured to direct the fluid from one layer of the impact head to the next layer of the impact head.

14. The stepped impact head of claims 12 or 13, wherein each layer of the stepped impact head (90) further includes one or more embedded rolling impact heads of claims 2 to 10, within each impact surface of the stepped impact head (90).

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15. the stepped impact head of claim 12 to 14, wherein each layer of the stepped impact head (90) further includes one or more embedded rolling impact heads of claims 2 to 10, along the edge of each layer of the impact head, configured to direct the fluid from one layer of the impact head to the next layer of the impact head, or into the channels between layer of the stepped impact head (90).

16. The stepped impact head of claims 12, wherein each layer of the impact head comprises one or more rolling impact heads of claims 2 to 10, arranged into layers.

10 17. The stepped impact head of claims 12, wherein each layer of the impact head comprises one or more of the flat impact heads (80) of claim 11.

18. The impact head of any preceding claim, wherein the impact head may move laterally in a direction perpendicular to the direction of the fluid flow (20).



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Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1-5, 8, 18	CN 214076833 U (SHENGLI OIL FIELD DELI IND CO LTD) See figure 1
X	1-4, 6-10, 18	CN 212441383 U (HUAIBEI LANGLIAN NEW BUILDING MAT CO LTD) See figure 1
X	1-4, 6-11, 18	CN 212237451 U (CHEM STONE GUANGZHOU CO LTD) See figure 2
X	1-4, 6-11, 18	CN 211937286 U (BAO YANG) See figure 1
X	1-4, 6-10, 18	CN 211515523 U (XIAN QINHAO ELECTRONIC TECH CO LTD) See figure 1
X	1-4, 6-11, 18	CN 210211004 U (JIANGSU LAIBAO DECORATION MAT CO LTD) See figure 1
X	1-4, 6-11, 18	CN 214599368 U (TANGSHAN MINGCHENG MINING IND CO LTD) See figure 2
X	1-4, 6-11, 18	CN 214916475 U (SICHUAN BAOCHENG TECH CO LTD) See figure 1

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WPI, EPODOC

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