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(54) **PROCESS AND APPARATUS FOR THE TREATMENT OF THE ROUGHNESS OF A ROAD SURFACE**

VERFAHREN UND VORRICHTUNG ZUR BEHANDLUNG DER RAUHIGKEIT EINER STRASSENOBERFLÄCHE

PROCÉDÉ ET APPAREIL DE TRAITEMENT DE LA RUGOSITÉ D'UNE SURFACE DE ROUTE

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WO-A1-2004/067847
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EP 3 690 140 B1

Description

[0001] The present invention relates to a process and an apparatus for the treatment of the roughness (in particular of the macro-roughness) of a road surface, in particular of an asphalt road surfacing.

[0002] The roughness depends upon the asperities present upon the rolling surface of a pavement (road surface). These asperities can be classified into micro-roughness and macro-roughness. The macro-roughness depends upon the entirety of the intergranular surface asperities; the micro-roughness is instead linked to the roughness of the individual stone elements of which the mixture is composed.

[0003] The measurement and characterization of the roughness is performed by means of the analysis and measurement of the surface profile of the pavement.

Background

[0004] The present invention lies in the construction of road surfaces sector. More particularly, the invention is relevant with regard to the problems of the control and/or reduction of noise due to the rolling of the tyres of vehicles transiting upon the road surface.

[0005] It is well known that the emission of noise on the part of the tyres depends strongly upon the type of road surface upon which the vehicle moves. It is for this purpose that standards (for example ISO10844) are provided for that regulate these aspects and also for the purposes of the type-approval of tyres.

[0006] Therefore, an aspect of particular importance is that of being able to construct a road surface that can reduce the noise emitted by certain types of tyres, and it is a strongly felt problem.

[0007] WO2004/067847 discloses a method for repairing defects due to the wear of a road surface, in particular permanent deformations and losses in roughness.

[0008] US2008/193214 discloses an apparatus for road reconstruction and, in particular, a method for the depositing of road surface reconditioning material.

[0009] The purpose of the present invention is, therefore, to resolve the problems left open by the prior art in providing a process as defined in claim 1.

[0010] A further object of the present invention is an apparatus as defined in claim 6.

[0011] Further characteristics of the present invention are defined in the corresponding dependent claims.

[0012] The present invention involves numerous and evident advantages over the known art that, together with the characteristics and usage of the present invention, will become clear from the following detailed description of preferred embodiments thereof, given purely by way of non-limiting examples.

Brief description of the figures

[0013] Reference will be made to the drawings shown in the attached figures, wherein:

- Figure 1A schematically illustrates a profile of a road surface prior to the application of a process according to the present invention;
- Figure 1B schematically illustrates a profile of a road surface after the first step of a process according to the present invention;
- Figure 1C schematically illustrates a profile of a road surface and a plane on which to perform the second stage (smoothing) of a process according to the present invention;
- Figure 1D schematically illustrates a profile of a road surface at the termination of a process according to the present invention (after the smoothing);
- Figure 2 shows a diagram of the Helmholtz Resonator Model;
- Figure 3 illustrates a progression of the profile of the road surface after treatment with a process according to the present invention;
- Figure 4 is a graph that shows the values of the mean profile depth (MPD) before, during and after treatment with a process according to the present invention, with three different types of asphalt;
- Figure 5 illustrates a progression of the MPD value along a section of road surface following treatment with a process according to the present invention;
- Figure 6 shows values of the coefficient of absorption (or CA) measured on a road surface after treatment with a process according to the present invention as a function of varying the frequency band;
- Figure 7 shows examples of means for increasing the mean profile depth (MPD) in a treatment apparatus according to the present invention; and
- Figure 8 shows, by way of example, means for reducing the mean profile depth (MPD) in a treatment apparatus according to the present invention.

Detailed description of possible embodiments of the invention

[0014] The present invention will hereinafter be described with reference to the above indicated figures.

[0015] The term mean profile depth, or MPD, refers to the average depth of the road surface calculated as the arithmetic mean of the individual depths of such a surface. A road surface, which is the object of the treatment according to the present invention, is characterized by a mean profile depth (MPD) of a predetermined value.

[0016] The term coefficient of absorption, or CA, refers to the ability of a material to absorb sound energy and wherein the value is between 0 and 1.00, where zero represents an absolute lack of absorption (complete reflection) and 1.00 represents the total absorption of incident sound.

[0017] Overall, the Figures from 1A to 1D schematically illustrate the steps of a treatment process of a road surface S according to the present invention; these steps

are:

- increasing the mean profile depth MPD of the surface S in generating new cavities V and/or in accentuating pre-existing cavities V on the surface S; and
- reducing the mean profile depth MPD of the surface S in order to return it to approximately the predetermined value in performing the smoothing of said surface S such as to reduce the asperities that emerge from the surface S.

[0018] These cavities V function according to the Helmholtz Resonator model illustrated in Figure 2, resulting in an increase in the acoustic coefficient of absorption CA of the surface S. The system described by this model is equivalent to that comprising an oscillating mass (air within the neck D), an elastic element (air within the cavity V) and a damping element (the friction of the air against the walls of the neck D). Such a system behaves as a set of Helmholtz resonators insofar as it is the holes that are producing a sound absorption effect based upon the principle of Helmholtz. Such a resonator is able to dissipate acoustic energy as heat by the effect of viscous friction, which is generated due to the oscillations of the air contained within the neck D and of the friction of the air with the walls of the neck D itself.

[0019] With initial reference to Figure 1A, this shows schematically a formation of the road surface before applying the method according to the present invention. As is known, the laying of asphalt results in an irregular alternation of ridges and valleys upon the surface profile of the road surface S; the valleys correspond to the profile view of the cavities V within the road surface S.

[0020] According to the present invention, the first part of the methodology consists in increasing the mean profile depth MPD of the surface S and this can be implemented by accentuating the pre-existing cavities V upon the surface S and/or in generating new cavities T.

[0021] According to a preferred embodiment of the invention, such a result can be obtained in directing a jet of fluid J at high pressure and thereby generating cavities V, and/or in accentuating pre-existing cavities V within the texture of the surface S. Such cavities V have the function of absorbing the acoustic waves according to the Helmholtz Resonator model explained above.

[0022] As can in fact be appreciated from Figure 1B, the pre-existing cavities V show a greater depth, therefore a greater MPD value, due to the jet of fluid J. The dotted line indicates the initial profile of each cavity V, i.e., the profile shown in Figure 1A.

[0023] Preferably, the jet of fluid J is at a pressure of between about 1,500 bar and 3,500 bar. More preferably a pressure of about 2500 bar is used.

[0024] According to a most preferred embodiment, the fluid used is water; in this case, this first step of the process will be called *jet water."* It is however to be understood that such an indication should not be considered in a limiting sense.

[0025] In Figure 1C, the dotted line P indicates the plane on which the second step of the treatment is performed, i.e., the smoothing. This process renders the surface S completely planar, making it contemporaneously possible to maintain the cavities V obtained by means of the first treatment, for example the *jet water.*

[0026] The result of this step of the process is appreciable in Figure 1D: having cut away part of the surface asperities of the surface S, the mean profile depth MPD has been accordingly reduced. In this way, one part of the acoustic waves will be absorbed by the cavities V of the surface S and the other part will be reflected by the "flat" part (the cut part).

[0027] This effect produces acoustic absorption at high frequencies and reflection of the lower frequencies. From the graph of Figure 3, the measurement can be observed of a progression of the profile of the surface S along a section X of road surface, similarly to that exemplified in Figures 1A to 1D.

[0028] A graph is shown in Figure 4 that instead reports the MPD values: three curves A, B and C are shown here that vary depending upon the type of asphalt; for each type of asphalt, prior to being treated, the respective MPD value is measured subsequent to the first step (for example, after the *water jet)* and at the end of the second step of smoothing (i.e., at the end of the complete treatment process); the dotted line represents the limiting MPD value imposed by the ISO 10844 standard.

[0029] In Figure 5 it is possible to appreciate the progression of the MPD value measured along a section X of road surface traveled by a vehicle for a road surface treated with a process according to the present invention; it can be seen how the MPD value falls entirely within the range of values accepted by the aforementioned ISO standard (between 0.3 and 0.7 mm).

[0030] In Figure 6, instead, the CA values are shown measured as a function of varying the frequency band of the stress exerted by the tyre, for a vehicle that travels along a road surface treated with a process according to the present invention; these also are falling within the limits of acceptability (<8%) according to the aforementioned ISO standard.

[0031] A process according to the present invention, as described heretofore in the possible embodiments thereof, may also envisage that both the increase and the reduction in the mean profile depth (MPD) are between 60% and 120% of the initial predetermined value.

[0032] More particularly, the process described, according to the present invention, can provide for both the increase and the reduction in the mean profile depth (MPD) being approximately 100% of the initial predetermined value.

[0033] A further object of the present invention is that of describing an apparatus for the treatment of a road surface S having a mean profile depth MPD of a predetermined value. Such an apparatus is able to perform a treatment process as described thus far and comprises:

- means for increasing the mean profile depth MPD of the surface S generating new cavities V and/or accentuating pre-existing cavities V upon the surface S;
- means for reducing the mean profile depth MPD of the surface S, adapted to direct a fluid jet at high pressure fluid towards said surface in order to return it to approximately the predetermined value in performing the smoothing of said surface S such as to reduce the asperities that emerge from the surface S.

[0034] Figure 7 shows an exemplary design of a possible embodiment of the means for increasing the depth MPD for an apparatus according to the present invention. The means to increase the MPD may be a means of the type conventionally used within the industry. In the example shown in Figure 7, the means for increasing the MPD are implemented in the form of a lance 10 for delivering high pressure fluid onto the asphalt in order to generate new cavities V and/or to accentuate pre-existing cavities V upon the surface S.

[0035] In a preferred embodiment according to a treatment apparatus of the present invention, the means for increasing the MPD comprise a movement mechanism 11 which allows the lance 10 for high pressure fluid to slide along at least one axis on a plane parallel to the surface S of the road surface to be treated.

[0036] In an even more preferred embodiment according to a treatment apparatus of the present invention, the means for increasing the MPD comprise a movement mechanism 11 which allows the lance 10 for high pressure fluid to be independently, and possibly also contemporaneously, moved along two axes orthogonal therebetween on a plane parallel to the surface S of the road surface to be treated. Moreover, such a movement mechanism 11, according to the latter two embodiments, may provide for an ergonomic seat 12 in order to accommodate the operator assigned to the maneuvering and operation of the lance for high pressure fluid in such a way as to facilitate the performance of tasks.

[0037] Figure 8 shows an exemplary design of a possible embodiment of the means for reducing the MPD for an apparatus according to the present invention. In the example shown in Figure 8, such means for reducing the MPD can be a sanding machine 13 of the type conventionally used within the industry.

[0038] In a further embodiment, a treatment apparatus according to the present invention comprises within a single system the means to increase the MPD and the means to reduce the MPD.

[0039] In a further preferred embodiment, a treatment apparatus according to the present invention comprises within a single system the means to increase the MPD illustrated in Figure 7 and the means to reduce the MPD illustrated in Figure 8. Purely by way of example, a treatment apparatus according to that described heretofore can be implemented in the form of a vehicle (such as, for example, a car or a truck), which, at the front, provides for means to increase the MPD, for example in the form a lance 10 for high pressure fluid, and, at the rear, means for reducing the MPD and for performing smoothing processes, for example in the form of a sanding machine 13.

[0040] The present invention has heretofore been described with reference to the preferred embodiments thereof. It is intended that each of the technical characteristics implemented in the preferred embodiments described herein, purely by way of example.

Claims

1. Process for the treatment of the ruggedness of a road surface (S) having a mean profile depth (MPD) of predetermined value to increase the absorption coefficient of the road surface (S), comprising the following steps:

   - increasing the mean profile depth (MPD) of said surface (S) by generating new cavities (V) and/or by emphasizing already existing cavities (V) on the surface (S);
   - reducing the mean profile depth (MPD) of said surface (S), in order to restore it to about the predetermined value, by performing smoothing of said surface (S) such as to reduce the bumps which emerge from said surface (S),

   wherein said cavities (V), operating as Helmholtz resonators, determine an increase of the coefficient of sound absorption (CA) of the surface (S),
   wherein said step of increasing the mean profile depth (MPD) comprises directing a fluid jet (J) at high pressure towards said surface (S),
   wherein said mean profile depth (MPD) is defined as the arithmetic mean of single depth values of said road surface (S).

2. Process according to claim 1, wherein said increase and said reduction of the mean profile depth (MPD) are comprised among 60% and 120% of the initial predetermined value.

3. Process according to claim 2, wherein said increase and said reduction of the mean profile depth (MPD) are about 100% of the initial predetermined value.

4. Process according to anyone of the claims 1 to 3, wherein said fluid jet is at pressure of about 1.500 to 3.500 bar, preferably about 1.500 bar.

5. Process according to anyone of the claims 1 to 4, wherein said fluid is water.

6. Apparatus for the treatment according to any of the claims 1 to 5, of the ruggedness of a road surface (S) having a mean profile depth (MPD) of predeter-

mined value, comprising:

- means for increasing the mean profile depth (MPD) of said surface (S) by generating new cavities (V) and/or by emphasizing already existing cavities (V) on the surface (S);
- means for reducing the mean profile depth (MPD) of said surface (S), adapted to direct a fluid jet (J) at high pressure towards said surface (S) in order to restore it to about the predetermined value, by performing smoothing of said surface (S) such as to reduce the bumps which emerge from said surface (S).

7. Apparatus according to claim 6, wherein said means for increasing the mean profile depth (MPD) comprises a fluid spear (10) at high pressure.

8. Apparatus according to claim 7, wherein said spear (10) is suitable for producing a fluid jet at pressure of about 1.500 to 3.500 bar, preferably about 1.500 bar.

9. Apparatus according to one of claims from 6 to 8, wherein said means for reducing the mean profile depth (MPD) comprises a smoothing machine (13).

Patentansprüche

1. Verfahren zur Behandlung der Robustheit einer Straßenoberfläche (S) mit einer mittleren Profiltiefe (MPD) von vorgegebenem Wert zur Erhöhung des Absorptionskoeffizienten der Straßenoberfläche (S), umfassend folgende Schritte:

- Erhöhen der mittleren Profiltiefe (MPD) der Oberfläche (S) durch Erzeugen neuer Hohlräume (V) und/oder durch Hervorheben bereits vorhandener Hohlräume (V) auf der Oberfläche (S);
- Reduzieren der mittleren Profiltiefe (MPD) der Oberfläche (S), um sie auf etwa den vorbestimmten Wert wiederherzustellen, indem eine Glättung der Oberfläche (S) durchgeführt wird, um die Erhebungen zu reduzieren, die aus der Oberfläche (S) austreten,

wobei die Hohlräume (V), die als Helmholtzresonatoren arbeiten, eine Erhöhung des Schallabsorptionskoeffizienten (CA) der Oberfläche (S) bestimmen,
wobei der Schritt des Erhöhens der mittleren Profiltiefe (MPD) das Richten eines Fluidstrahls (J) mit hohem Druck auf die Oberfläche (S) umfasst,
wobei die mittlere Profiltiefe (MPD) als das arithmetische Mittel einzelner Tiefenwerte der Straßenoberfläche (S) definiert ist.

2. Verfahren nach Anspruch 1, wobei die Zunahme und die Abnahme der mittleren Profiltiefe (MPD) zwischen 60 % und 120 % des anfänglichen vorbestimmten Werts betragen.

3. Verfahren nach Anspruch 2, wobei die Zunahme und die Abnahme der mittleren Profiltiefe (MPD) etwa 100 % des anfänglichen vorbestimmten Werts betragen.

4. Verfahren nach einem der Ansprüche 1 bis 3, wobei der Fluidstrahl unter einem Druck von etwa 1,500 bis 3,500 bar, vorzugsweise etwa 1,500 bar steht.

5. Verfahren nach einem der Ansprüche 1 bis 4, wobei das Fluid Wasser ist.

6. Vorrichtung zur Behandlung nach einem der Ansprüche 1 bis 5 der Robustheit einer Straßenoberfläche (S) mit einer mittleren Profiltiefe (MPD) mit einem vorbestimmten Wert, umfassend:

- Mittel zum Erhöhen der mittleren Profiltiefe (MPD) der Oberfläche (S) durch Erzeugen neuer Hohlräume (V) und/oder durch Hervorheben bereits vorhandener Hohlräume (V) auf der Oberfläche (S);
- Mittel zum Reduzieren der mittleren Profiltiefe (MPD) der Oberfläche (S), die dazu ausgelegt sind, einen Fluidstrahl (J) mit hohem Druck auf die Oberfläche (S) zu richten, um ihn auf etwa den vorbestimmten Wert zurückzuführen, indem eine Glättung der Oberfläche (S) durchgeführt wird, um die Erhebungen zu reduzieren, die aus der Oberfläche (S) austreten.

7. Vorrichtung nach Anspruch 6, wobei das Mittel zum Erhöhen der mittleren Profiltiefe (MPD) eine Fluidstange (10) bei hohem Druck umfasst.

8. Vorrichtung nach Anspruch 7, wobei die Stange (10) zum Erzeugen eines Fluidstrahls bei einem Druck von etwa 1,500 bis 3,500 bar, vorzugsweise etwa 1,500 bar, geeignet ist.

9. Vorrichtung nach einem der Ansprüche 6 bis 8, wobei die Mittel zum Reduzieren der mittleren Profiltiefe (MPD) eine Glättungsmaschine (13) umfassen.

Revendications

1. Procédé de traitement de la rugosité de la surface d'une route (S) présentant une profondeur moyenne de profil (MPD) de valeur prédéterminée pour augmenter le coefficient d'absorption de la surface de la route (S), comprenant les étapes suivantes :

- l'augmentation de la profondeur moyenne de profil (MPD) de ladite surface (S) en générant de nouvelles cavités (V) et/ou en amplifiant des cavités (V) déjà existantes sur la surface (S) ;
- la réduction de la profondeur moyenne de profil (MPD) de ladite surface (S), afin de la restaurer à environ la valeur prédéterminée, en effectuant un lissage de ladite surface (S) de manière à réduire les bosses qui se dégagent de ladite surface (S),

dans lequel lesdites cavités (V), fonctionnant comme des résonateurs de Helmholtz, déterminent une augmentation du coefficient d'absorption acoustique (CA) de la surface (S),
dans lequel ladite étape d'augmentation de la profondeur moyenne de profil (MPD) comprend la direction d'un jet de fluide (J) à haute pression vers ladite surface (S),
dans lequel ladite profondeur moyenne de profil (MPD) est définie comme la moyenne arithmétique de valeurs de profondeur uniques de ladite surface de route (S).

2. Procédé selon la revendication 1, dans lequel ladite augmentation et ladite réduction de la profondeur moyenne de profil (MPD) sont comprises entre 60 % et 120 % de la valeur initiale prédéterminée.

3. Procédé selon la revendication 2, dans lequel ladite augmentation et ladite réduction de la profondeur moyenne de profil (MPD) sont d'environ 100 % de la valeur initiale prédéterminée.

4. Procédé selon l'une quelconque des revendications 1 à 3, dans lequel ledit jet de fluide est à une pression d'environ 1,500 à 3,500 bar, de préférence d'environ 1,500 bar.

5. Procédé selon l'une quelconque des revendications 1 à 4, dans lequel ledit fluide est de l'eau.

6. Appareil pour le traitement selon l'une quelconque des revendications 1 à 5, de la rugosité de la surface d'une route (S) ayant une profondeur moyenne de profil (MPD) de valeur prédéterminée, comprenant :

- un moyen pour augmenter la profondeur moyenne de profil (MPD) de ladite surface (S) en générant de nouvelles cavités (V) et/ou en amplifiant des cavités (V) déjà existantes sur la surface (S) ;
- un moyen pour réduire la profondeur moyenne de profil (MPD) de ladite surface (S), adapté pour diriger un jet de fluide (J) à haute pression vers ladite surface (S) afin de la restaurer à environ la valeur prédéterminée, en effectuant un lissage de ladite surface (S) de manière à réduire les bosses qui se dégagent de ladite surface (S).

7. Appareil selon la revendication 6, dans lequel ledit moyen pour augmenter la profondeur moyenne de profil (MPD) comprend une lance de fluide (10) à haute pression.

8. Appareil selon la revendication 7, dans lequel ladite lance (10) est appropriée pour produire un jet de fluide à une pression d'environ 1,500 à 3,500 bar, de préférence d'environ 1,500 bar.

9. Appareil selon l'une des revendications 6 à 8, dans lequel ledit moyen pour réduire la profondeur moyenne de profil (MPD) comprend une machine de lissage (13).

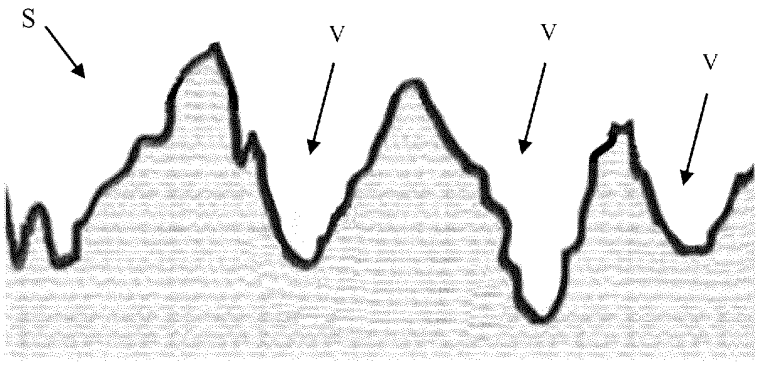


FIG. 1A

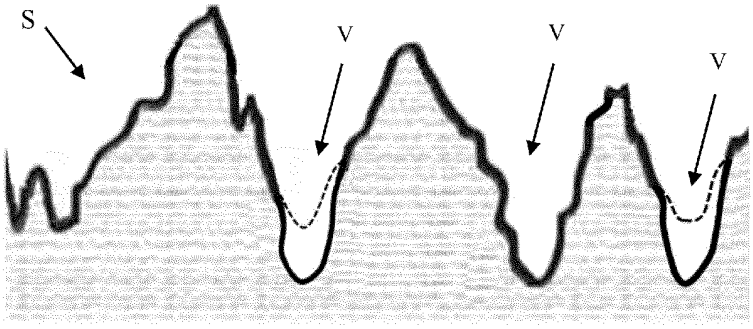


FIG. 1B

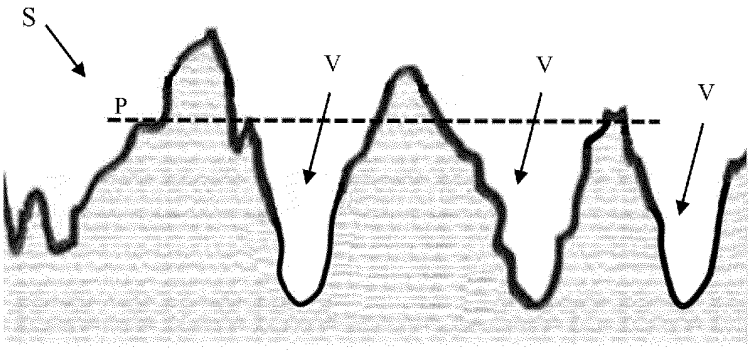


FIG. 1C

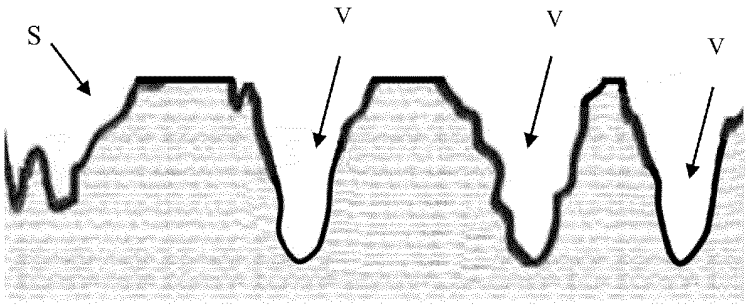
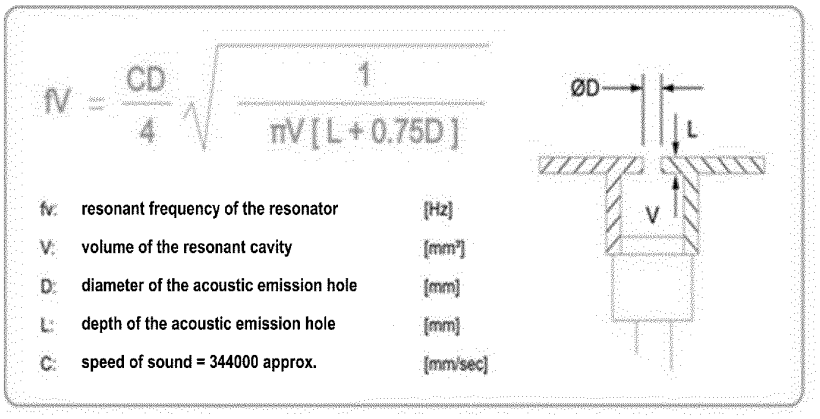


FIG. 1D

$$fV = \frac{CD}{4}\sqrt{\frac{1}{\pi V\,[\,L + 0.75D\,]}}$$

fv:	resonant frequency of the resonator	[Hz]
V:	volume of the resonant cavity	[mm³]
D:	diameter of the acoustic emission hole	[mm]
L:	depth of the acoustic emission hole	[mm]
C:	speed of sound = 344000 approx.	[mm/sec]



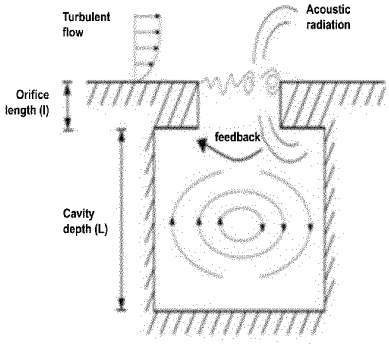
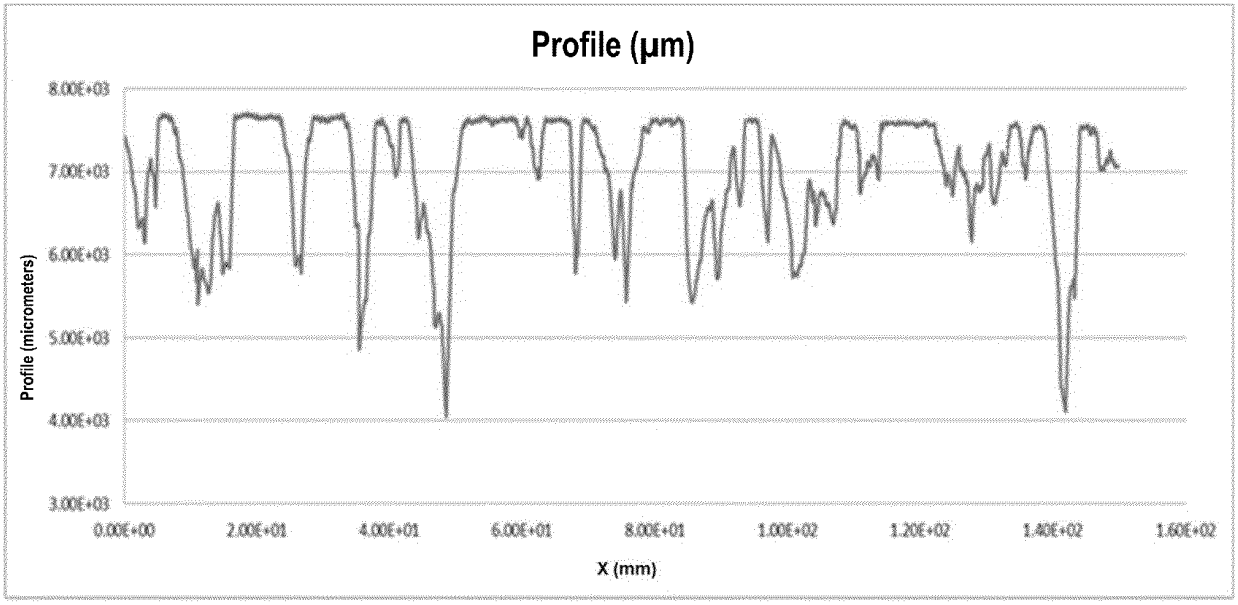


FIG. 2


Profile (µm)
Profile (micrometers)
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7.00E+03
6.00E+03
5.00E+03
4.00E+03
3.00E+03
0.00E+00
2.00E+01
4.00E+01
6.00E+01
8.00E+01
1.00E+02
1.20E+02
1.40E+02
1.60E+02
X (mm)

FIG. 3

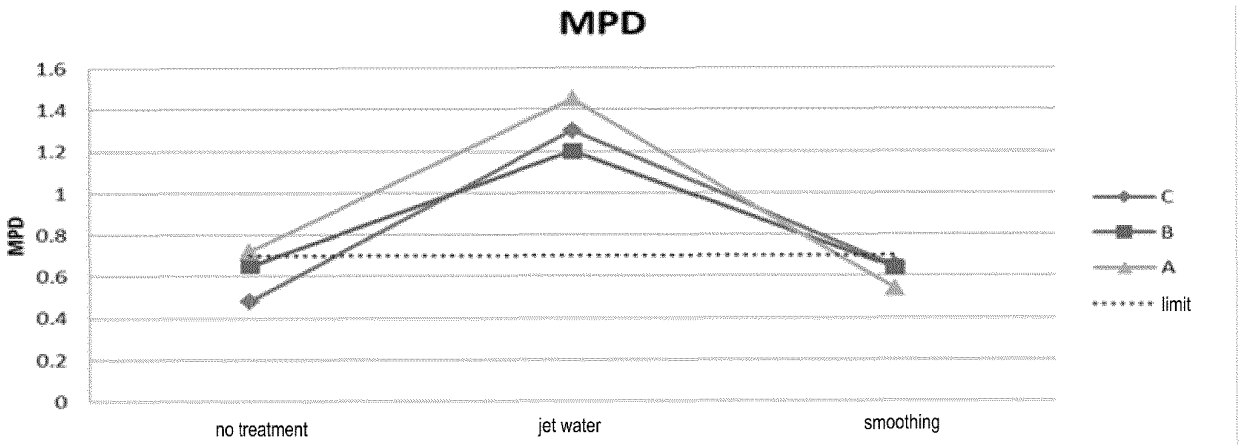
MPD
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
MPD
no treatment
jet water
smoothing
C
B
A
limit

FIG. 4

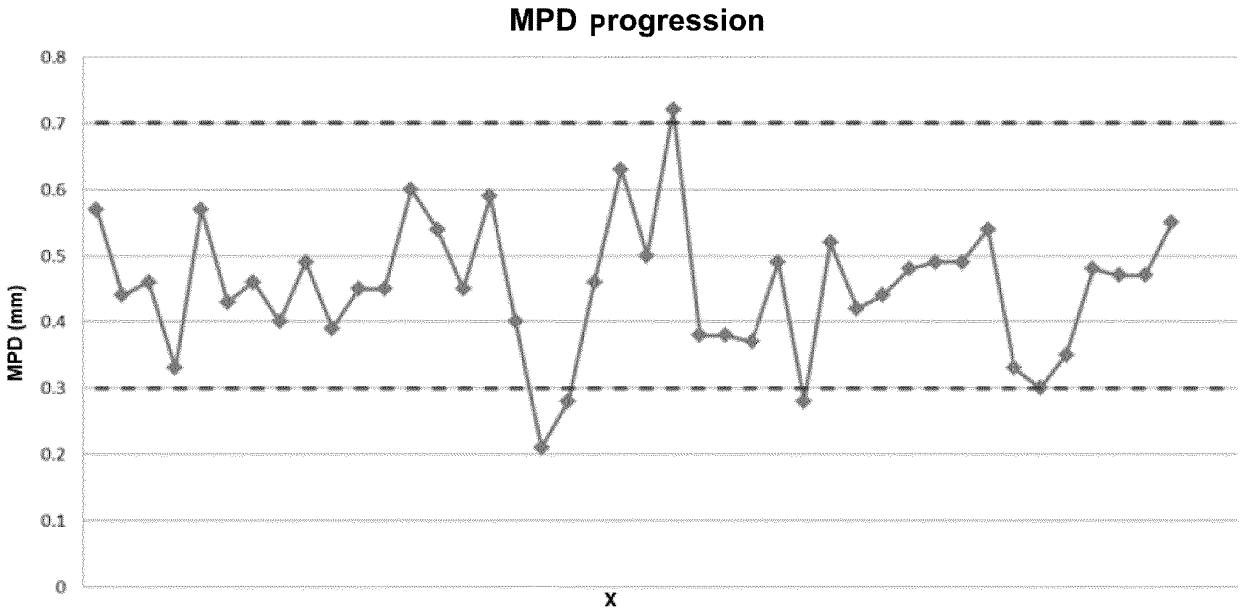

FIG. 5

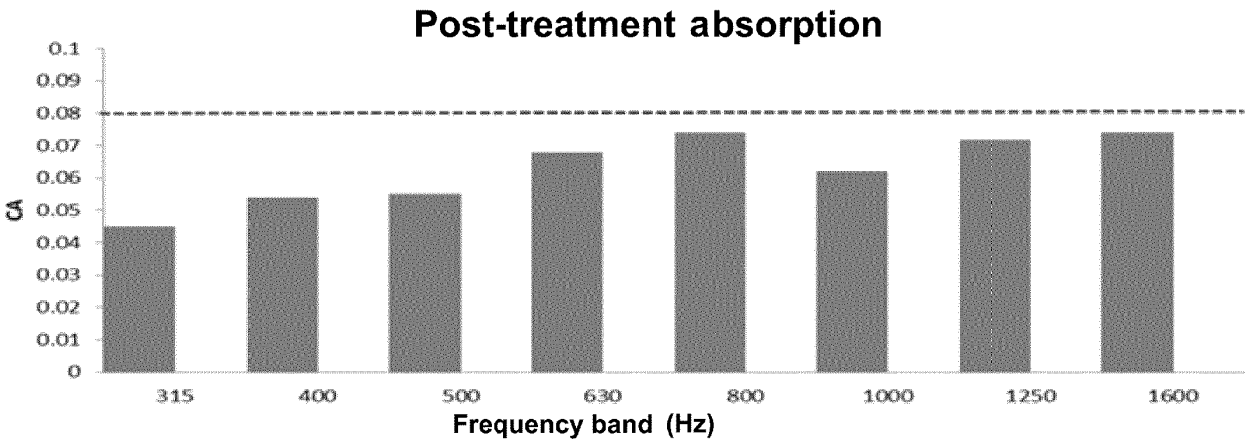
Post-treatment absorption
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
αs
315
400
500
630
800
1000
1250
1600
Frequency band (Hz)

FIG. 6

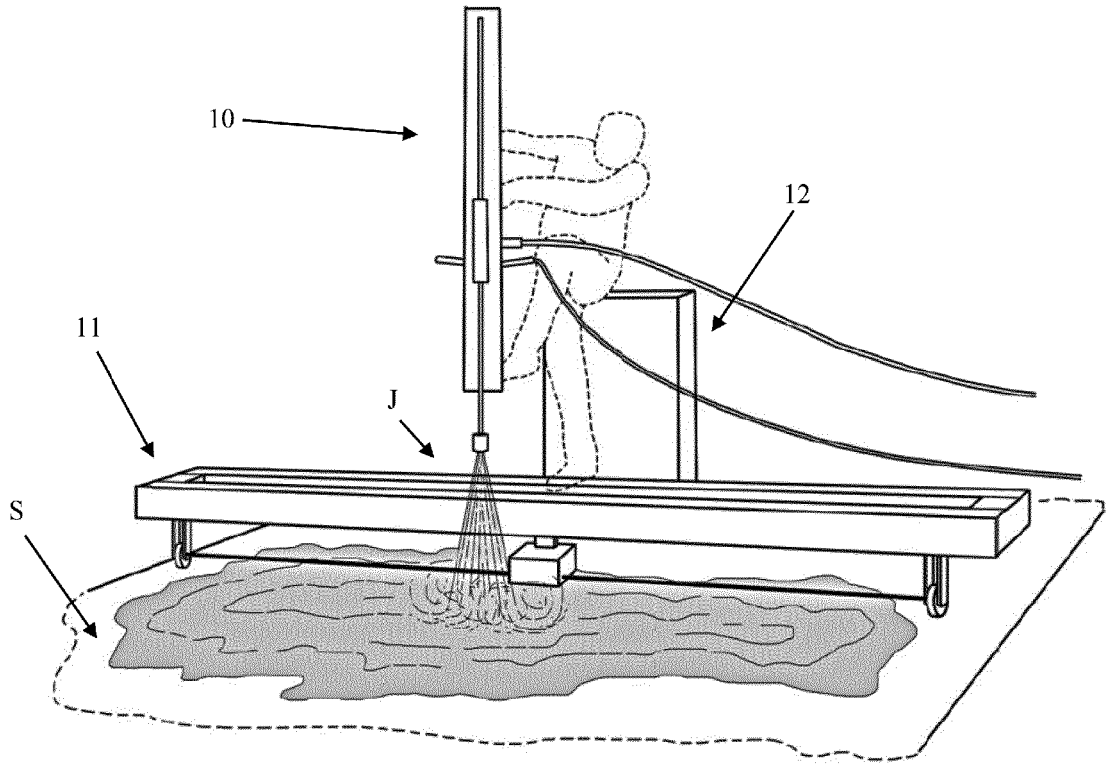

FIG. 7

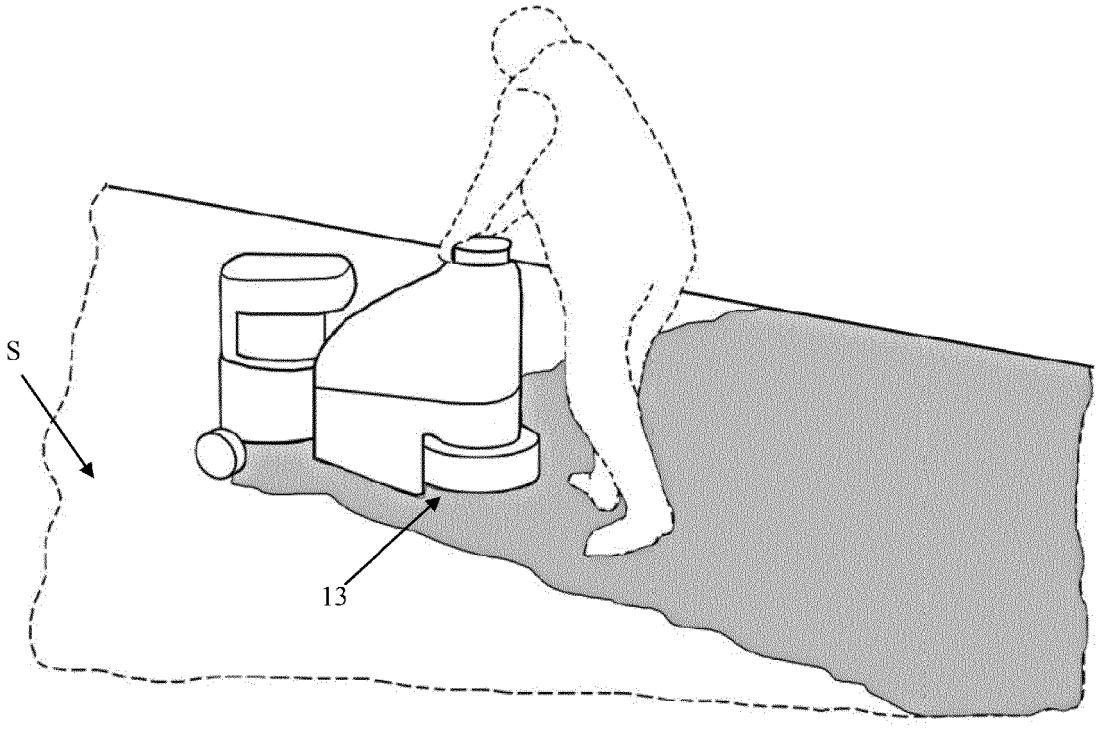

FIG. 8

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- WO 2004067847 A **[0007]**
- US 2008193214 A **[0008]**