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(54) **Ultrasonically excited comb**

(57) A comb for hair or fibres is disclosed which comprises a rigid comb body (10) having a spine (12) extending along a longitudinal axis and a plurality of teeth (14) projecting from the spine (12) and extending transversely to the longitudinal axis, and at least one ultrasound generator (20) connected to the spine (12). In the invention,

the or each ultrasound generator (20) comprises at least one ultrasonic transducer (22) operative to apply compression waves to the spine (12) in a direction transverse to the longitudinal axis of the spine (12) so as to cause surface waves to propagate along the spine (12) and the teeth (14) of the comb body (10).

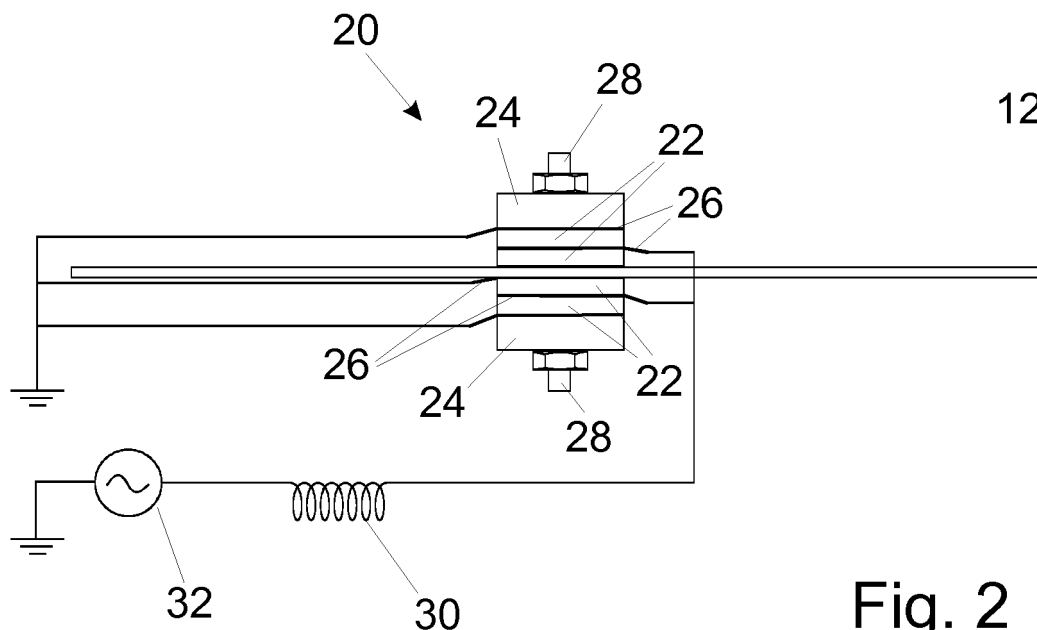


Fig. 2

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Description

Field of the invention

[0001] The present invention relates to a comb for hair or fibres that is coupled to an ultrasound generator.

Background of the invention

[0002] It has previously been proposed to couple a comb to an ultrasound generator so that ultrasonic vibrations travel along the teeth. Such a device is disclosed, for example, in US 6,575,173. The prior art does not however teach an efficient way of coupling the sound energy into the comb body.

Object of the invention

[0003] The present invention seeks therefore to provide a comb that acts as a sonotrode of an ultrasonic transducer to apply the generated ultrasound energy effectively to the hair or fibres being treated.

Summary of the invention

[0004] According to the present invention, there is provided a comb for hair or fibres comprising a rigid comb body having a spine extending along a longitudinal axis and a plurality of teeth projecting from the spine and extending transversely to the longitudinal axis, and at least one ultrasound generator connected to the spine, **characterised in that** the or each ultrasound generator comprises at least one ultrasonic transducer operative to apply compression waves to the spine in a direction transverse to the longitudinal axis of the spine so as to cause surface waves to propagate along the spine and the teeth of the comb body.

[0005] Ultrasonic vibrations can travel through a rigid sheet in a variety of modes that include both bulk waves (compression waves and shear waves) and surface waves, such as Rayleigh-Lamb waves. Whereas prior art proposals relied on ultrasound propagating as bulk waves along the length of the spine to cause the teeth to vibrate in a manner similar to the prongs of a tuning fork, the present invention relies on the ultrasound energy propagating as surface waves along the teeth. As it is only the surface of the comb that comes into contact with the hair or fibres, the invention achieves more efficient coupling of the generated ultrasonic energy.

[0006] The ultrasound generator preferably comprises a plurality of transducers arranged with an equal number of transducers on each side of the spine, the spine being clamped between the ultrasonic transducers.

[0007] In an embodiment of the invention, the comb body is made of metal and preferably serves as an electrical ground plane of the transducers.

[0008] In an embodiment of the invention, the ultrasonic transducers are excited by an a.c. HF voltage of which

the frequency is tuned to cause resonance of the ultrasonic vibrations travelling along the teeth of the comb body in at least one mode of propagation.

[0009] The excitation frequency may suitably be selected such that the length of the teeth is an integer multiple of one half of the wavelength of the ultrasonic vibrations induced in the comb body.

[0010] Advantageously the length of the spine and the separation between the teeth of the comb body may be selected to be harmonically related to one half of the wavelength of the ultrasonic vibrations induced in the comb body.

[0011] In an embodiment of the invention, the excitation frequency is selected such that resonance occurs in the ultrasonic vibrations that propagate as Lamb waves along the teeth of the comb body.

[0012] The effective coupling of the ultrasound energy together with excitation of resonance in selected modes of propagation results in heating of the comb body which is very advantageous in certain applications, as will be disclosed below.

[0013] The invention further provides a hair or fibre treatment apparatus comprising an ultrasonically excited comb as set forth above combined or integrated with a dispenser for applying a hair treatment product to be worked into the hair by the teeth of the comb, the comb having a hollow spine and hollow teeth to allow the hair treatment product to flow from the dispenser to the hair or fibre being treated.

Brief description of the drawings

[0014] The invention will now be described further, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a perspective view of a metallic comb body,

Figure 2 shows the comb body of Figure 1 sandwiched between the individual ceramic piezoelectric transducers of an ultrasound generator,

Figure 3 is a section through the comb body passing through the spine and one of the teeth and showing the elliptical motion of particles on the surface of a plate during propagation of a Lamb wave.

Figure 4 is a perspective view of a comb that includes internal passageways to allow a liquid to flow from a dispenser to the hair being combed,

Figure 5 is a section through the comb body of Figure 4, with the section plane intersecting the teeth of the comb body, and

Figure 6 is a second section through the comb body of Figure 4, in a section plane coinciding with the plane of symmetry of the comb body and normal to the section plane of Figure 5.

Detailed description of an embodiment

[0015] Figure 1 shows a comb body 10 made of a solid plate of aluminium or stainless steel, fashioned in the shape of a comb with a spine 12 and teeth 14. The spine 12 is formed with holes 16, any one or more of which may be used to couple an ultrasound generator to the comb body 10.

[0016] The ultrasound generator 20 shown in Figure 2 comprises four ceramic piezoelectric transducers 22 having electrodes 26 and arranged as a stack with two transducers 22 on each side of the spine 12. Two sound reflectors 24 are arranged at the opposite ends of the stack of transducers 22 and all the components of the generator 28 are clamped to one another and to the spine 12 by means of a bolt 28, fitted with two nuts.

[0017] The electrode 26 in electrical contact with the spine 12 and the two outer electrodes 26 of the stack of transducers 22 are connected to ground. The electrodes 26 common to the two transducers in each of the two pairs arranged on the opposite sides of the spine 12 are commonly connected to an alternating voltage supply 32 by way of an inductor 30. The four ceramic piezoelectric transducers 22 behave electrically as four capacitors connected in parallel between the inductor 30 and ground. The parallel connected capacitances of the transducers 22, in conjunction with the inductor 30, form a series resonant circuit which maximises the a.c. HF voltage acting on the transducers 22 when the frequency of the voltage supply source matches the resonance frequency of the series resonant circuit.

[0018] Some or all of the dimensions of the comb body, that is to say the length of the spine L_1 , the total height of the comb body L_1 , the distance l_2 from the ultrasound generator 20 to the teeth, the length l_1 of the teeth, as well as the thickness t_1 , separation t_2 and width t_3 of the teeth may be selected to enhance mechanical resonance of the comb at the excitation frequency of the transducers 22, to increase the amplitude of the acoustic waves propagating through the comb body.

[0019] In the invention, the waves achieving the desired effect on the hair or fibres are surface waves. Lamb waves are surface waves that travel through a body of finite thickness and the mode of propagation is explained with reference to Figure 3. In Figure 3, the arrows 42 indicate the compression forces applied by the ultrasound generator 20 along its axis 40. The region of the spine 12 placed under stress by the ultrasound generator 20 is designated 44 and the arrow 46 represents the direction of propagation of the surface waves along the teeth 14. The particles near the surfaces of the comb body move with an elliptical motion and the height of the minor axis of the ellipses decreases with distance of the particles from the surface. If the directions of movement of the particles are as indicated by the arrows in Figure 3, the wave envelope will travel from left to right, as viewed. The vibrations travel along all surfaces of the teeth so that the wave motion shown in section in Figure

3 occurs both on the interstitial surfaces of the teeth (varying the gap between the teeth) and on their lateral surfaces. The combined effect results in a form of barrel-type wave propagation (resembling peristaltic motion) along the length of the teeth.

[0020] While it is essential for the comb body to be rigid, the teeth and the spine may be hollow. Such an embodiment is shown in Figures 4, 5 and 6 in which the spine 112 has an internal passageway 135 that communicates with further passageways 137 extending along the teeth 114. An ultrasound generator 120, as described previously, is mounted on the spine 112, the end of which is coupled to a dispenser 150. The passageways 135, 137 allow a liquid, such as a dye or a treatment solution, stored in the dispenser 150 to be applied to the hair as it is being combed. The hollow teeth also serve to enhance the amplitude of vibration on the surface of the teeth.

[0021] It is an advantage of embodiments of the invention that the comb body may be heated by the ultrasonic energy and it is possible to reach thermal stability by controlling the ultrasound power. In hair dying application, the elevated temperature and increased ultrasonic efficiency improve dye penetration into hair shaft and improve dying of hair roots.

[0022] The comb also has application in control of lice and for this purpose the comb may be integrated with a dispenser of an active pharmaceutical agent, as shown in the embodiment of Figures 4 to 6.

[0023] In an embodiment of the invention, the comb dimensions facilitate ultrasound propagation with maximum of amplitude of acoustic surface waves (antinodes) at the tips of the teeth of the comb. Alternatively, the resonance frequency may be selected to maximise mechanical vibration at other positions along the length of the teeth.

[0024] The present invention sets out to provide strong ultrasound wave coupling between the teeth side walls and the hairs. Such ultrasonic vibrations have been found in practice to facilitate passage of the comb through curly and tangled hairs and to assist in applying dyes and pharmaceutical compositions to the hair.

[0025] The working elements of the comb are the teeth, or more correctly gaps between the teeth. Therefore, it is desirable to provide teeth vibrations in the direction orthogonal to the hair. Antinodes, midway along the length of the teeth may lead to tooth oscillations and rotative motion that should facilitate a tangled hair combing.

[0026] As earlier mentioned, the ultrasonic vibration of the comb results in heating, which assists in hair dying, as the colorant penetrates better into the hair.

[0027] The combination of ultrasonic vibration and heat has also been found to be helpful for parasite (lice, ticks, fleas) control and destruction of parasite eggs. In particular they assist in dislodging nits that are well known to adhere strongly to the hair shaft. Ultrasound in combination with heat can mechanically and thermally destroy nits and for such an application, the above de-

scribed barrel type teeth oscillations are very helpful.

[0028] An additional factor resulting from the use of ultrasound is that cavitations can be caused in gels, creams or liquids used for hair dying or parasite control. Such cavitations may be a powerful factor in improving these processes.

[0029] The comb body, in an embodiment of the invention is made of metal. Stainless steel is preferred for use with active chemical ingredients, and aluminium for massaging and skin processing combs. The comb body may also be made of other rigid material, including plastic or ceramic. The teeth may be solid or hollow. A hollow tooth may have an additional improvement (increased amplitude) of cross-sectional vibration in the plane orthogonal to the tooth axis.

[0030] The preferred length of the teeth is $n \cdot \lambda / 2$, λ being the wavelength. For example at an operating frequency 450 kHz, the preferred range being 100-1000 kHz, the wavelength is equal to 13 mm in stainless steel or 14 mm in aluminium. Therefore the preferred tooth lengths are 7, 14, 21 and 28 mm (in the case of aluminium); the distances between transducer axis line and tooth 12 root may be resonant ($\lambda \cdot \lambda / 2$). The width L1 of the comb may be resonant also.

[0031] The ultrasound generator shown in Figure 2, is a pre-stressed Langevin (sandwich) type generator assembled in such way that a central sonotrode/electrode is a comb-resonator. It is important to note that the generator is symmetrical about the plane of the comb body with an equal number of transducers on each side. The number of transducers in this configuration should $4n$ ($n=1, 2, 3$ etc). This configuration will provide an electrical ground electrode on the comb sonotrode.

[0032] The ultrasound excited comb operates as follows:

[0033] A high frequency (HF) power source excites the ultrasound transducers in the regular manner. A switching module (not shown) forms rectangular pulses, which are coupled to the transducer through resonant inductor 30, which acts as an autotransformer to increase HF-voltage. The inductor 30 in series with the intrinsic capacitance of the transducers 22 for an HF resonator. The HF-voltage in this resonator is a sine-wave.

[0034] Sweeping (or modulation) of the excitation frequency can be applied for compensation of thermal deviation of resonant frequency. The range of frequency sweep may be ± 2 to 7% over the operating frequency.

[0035] Though the spine has been shown as being flat and in the same plane as the teeth, it is alternatively possible to the comb body to be in the form of a rake with spine having a first section in the plane of the teeth and a section, serving as a handle, lying in a plane inclined relative to the plane of the teeth.

[0036] The ultrasonically excited comb described above, which has as acting factors ultrasound, mechanical vibration, cavitation (if liquid medium is present) and ultrasonically generated heat, offers the following advantages:

- Better penetration of the comb through tangled hair,
- Better application of dyes and chemical compositions to the hair,
- Mechanical cleaning of hairs by vibrations
- Cavitation cleaning of hairs if a liquid fraction is present,
- Vibration massage of hairs and follicles),
- Improved killing of lice, nits and fleas,
- Possibility of under-hair skin massaging, introducing anti-dandruff and anti-alpecia pharmaceuticals (sonophoresis)
- Application in perming and hair straightening,
- Can be used device, in veterinary and home care of pets.
- The device can be used in commercial or clinical applications, as well as home use, and can serve for processing or treating human hair, animal hair, and natural or artificial fibres.

Claims

1. A comb for hair or fibres comprising a rigid comb body (10) having a spine (12) extending along a longitudinal axis and a plurality of teeth (14) projecting from the spine (12) and extending transversely to the longitudinal axis, and at least one ultrasound generator (20) connected to the spine (12),
characterised in that
the or each ultrasound generator (20) comprises at least one ultrasonic transducer (22) operative to apply compression waves to the spine (12) in a direction transverse to the longitudinal axis of the spine (12) so as to cause surface waves to propagate along the spine (12) and the teeth (14) of the comb body (10).
2. A comb as claimed in claim 1, wherein the ultrasound generator (20) comprises a plurality of transducers (22) arranged with an equal number of transducers (22) on each side of the spine (12), the spine (12) being clamped between the ultrasonic transducers (22).
3. A comb as claimed in claim 2, wherein the comb body (10) is made of metal.
4. A comb as claimed in claim 3, wherein the comb body (10) serves as an electrical ground plane of the transducers (22).
5. A comb as claimed in any one of claims 1 to 5, wherein the ultrasonic transducers (22) are connected to a source (32) of a.c. voltage having an excitation frequency tuned to cause resonance of the ultrasonic vibrations travelling along the teeth (14) of the comb body (10) in at least one mode of propagation.

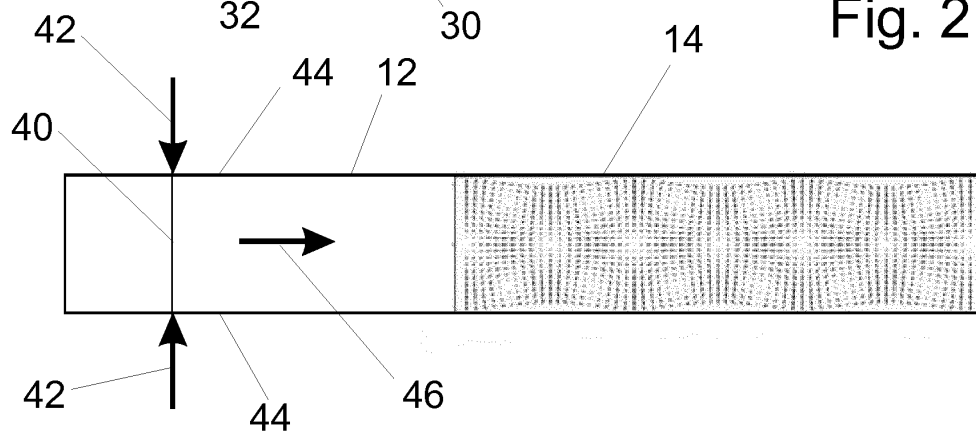
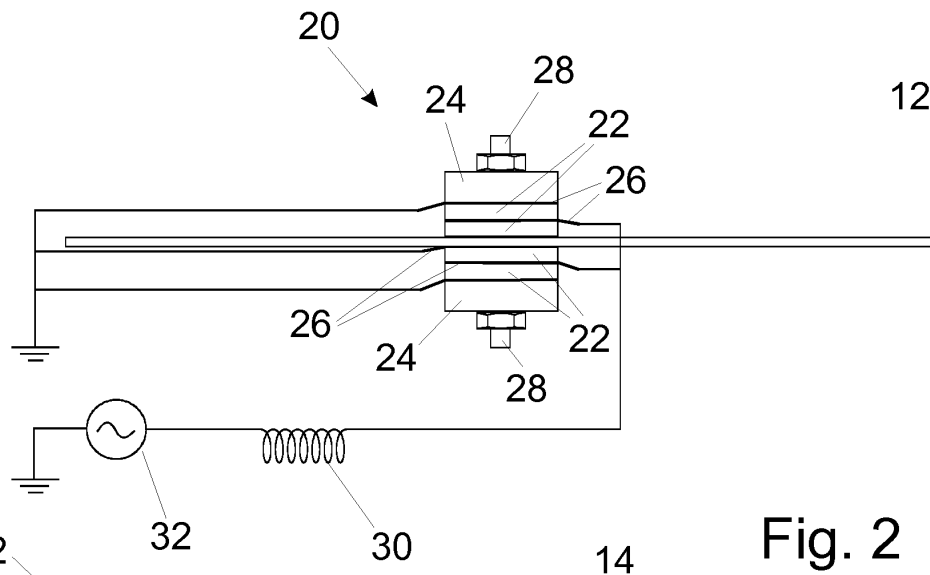
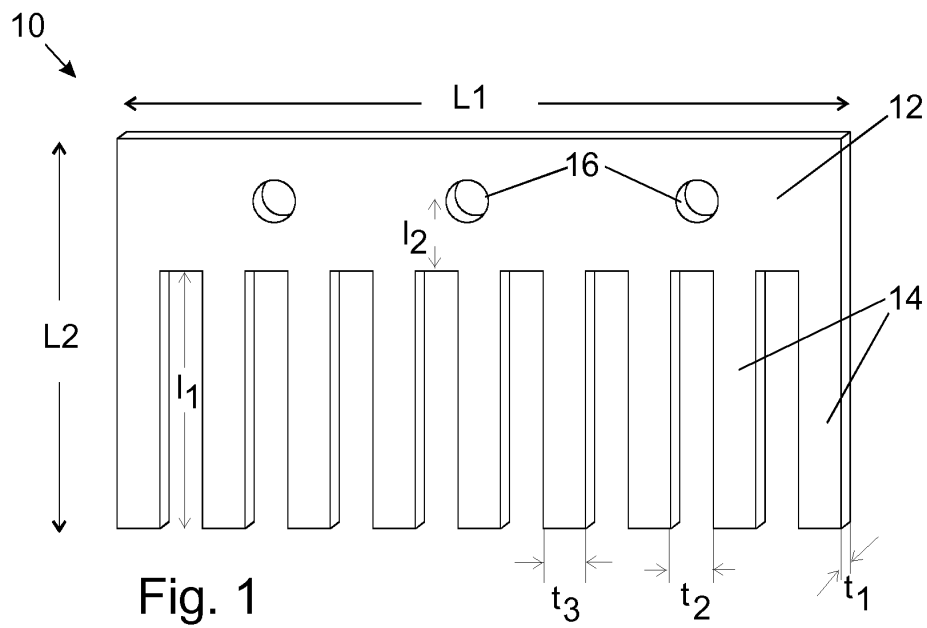
6. A comb as claimed in claim 5, wherein the excitation frequency is selected such that the length of the teeth (14) is an integer multiple of one half of the wavelength of the ultrasonic vibrations induced in the comb body (10). 5
7. A comb as claimed in claim 5 or 6, wherein the teeth (14) of the comb body are separated from one another by a distance that is an integer multiple of one half of the wavelength of the ultrasonic vibrations induced in the comb body (10). 10
8. A comb as claimed in any one of claims 1 to 7, wherein the ultrasonic vibrations produced by the ultrasound generator propagate as Lamb waves along the teeth (14) of the comb body (10). 15
9. A hair or fibre treatment apparatus comprising a comb and a dispenser (150) for applying a hair treatment product to be worked into the hair or fibre by the comb, the comb comprising 20
a rigid comb body (10) having a hollow spine (12) extending along a longitudinal axis and a plurality of hollow teeth (14) projecting from the spine and extending transversely to the longitudinal axis, the hair treatment product being able to flow from the dispenser (150) through the hollow spine (12) and teeth (14) to the hair or fibre being treated; 25
and
at least one ultrasound generator (20) connected to the spine (12), the or each ultrasound generator (20) comprising at least one ultrasonic transducer (22) operative to apply compression waves to the spine (12) in a direction transverse to the longitudinal axis of the spine (12), so as to cause surface waves to propagate along the spine (12) and the teeth (14) of the comb body (10) 30
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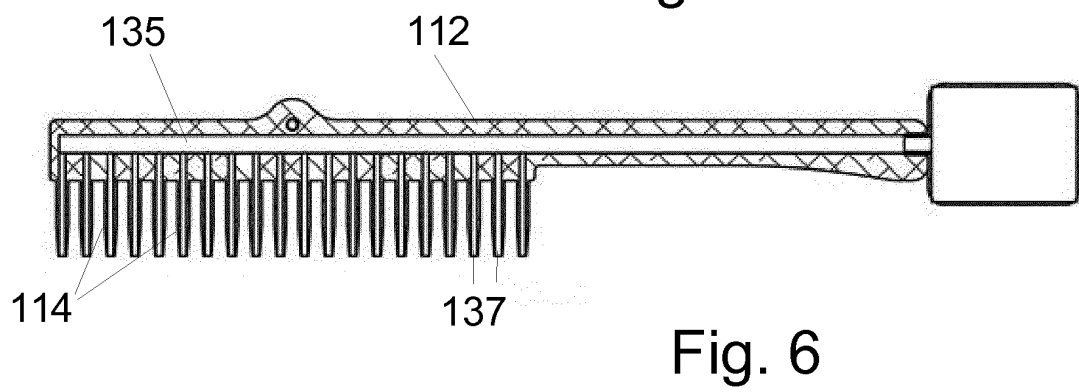
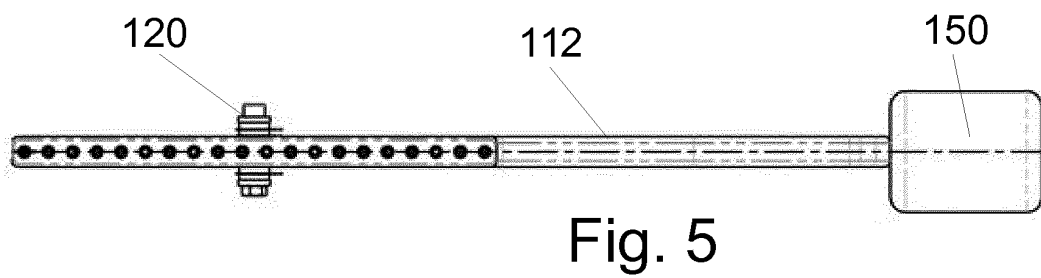
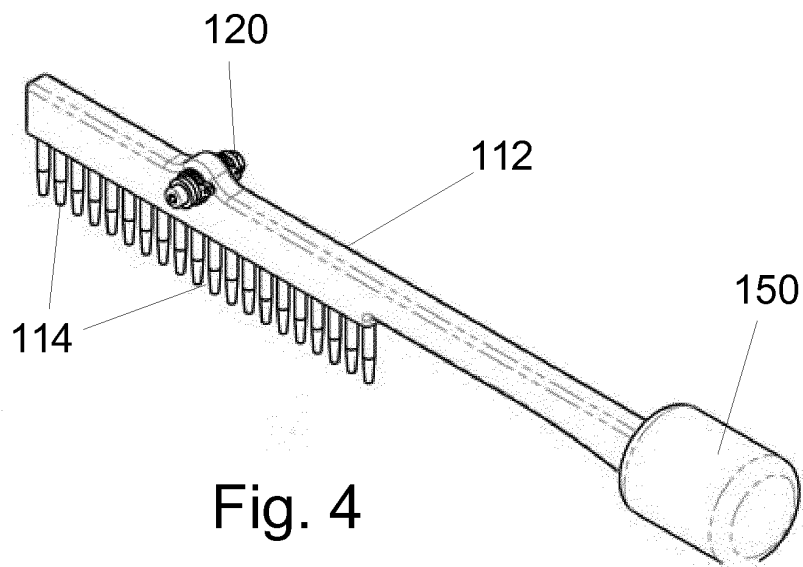
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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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