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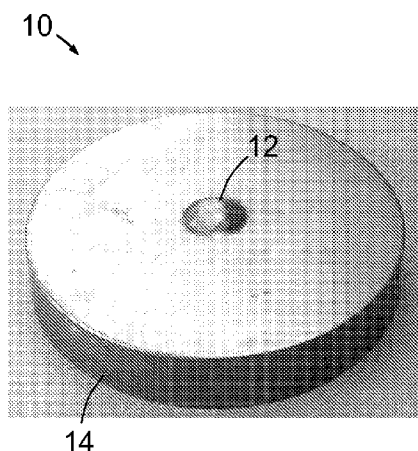


Figure 2A

(57) Abstract: A method of manufacturing a metal object with one or more desired structural characteristics, comprising producing tensile prestresses (76; 84) in the object (10; 20; 70; 78) by selectively producing localized plastic deformation (12; 22; 74; 82) in the object (10; 20; 70; 78) such that the object (10; 20; 70; 78) has the desired structural characteristics.

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METHOD OF MANUFACTURING METAL OBJECTS WITH DESIRED STRUCTURAL CHARACTERISTICS

Field of the invention

5 The invention relates to a method of manufacturing metal objects (including structural members, component parts and musical instruments, and in particular of sheet- or cast-metal objects) with one or more desired structural characteristics, of particular but by no means exclusive application in the design of such objects, and in modifying the resonant properties of metal objects (such as to tune the overtones of a percussion
10 instrument to the harmonic series).

Background of the invention

One existing technique for modifying structural properties of a metal object may be seen in the field of tuned percussion instruments. It is known to tune such instruments
15 by manufacturing the struck part to have a geometry adapted so as to tune the modal frequencies.

For example, it is known to manufacture a gong with a central boss and a stiffening rim. Mode shapes calculated by finite element analysis (FEA) for ring and meridial modes of an unconstrained gong are shown in figures 1A, 1B and 1C. These modes are
20 described by two wave numbers: the first describes the number of meridial lines, the second the number of nodal rings. Thus, figure 1A shows the results of FEA of a flat gong model geometry of the background art, figure 1B the results of FEA of a meridial (2,0) mode shape of the gong and figure 1C the results of FEA of a symmetric (0,1)
25 mode shape of the gong.

The Indonesian Gamelan, for example, has been shown to have a second ring mode tuned to twice the frequency of the fundamental, owing to the addition of the mass of a central boss. These ring modes have been shown to dominate the acoustical spectra of
30 the early part of the gong sound and so largely influence the pitch of the gong (N. Fletcher and T. Rossing, *The Physics of Musical Instruments*, Springer-Verlag, 1991, Chapter 20).

Tuned gongs have occasionally been manufactured in Western countries. These have
35 either been individual gongs where attention has been paid to the overtone tuning (see N. Fletcher, *Designing and Making a Ceremonial Dinner Gong*, Acoustics Australia, 32 (2004) 65-68), sets of gongs closely imitating existing Indonesian gongs, or gongs

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made by musicians with materials readily at hand for which little information on their design or acoustic properties is available. The gong designed by N. Fletcher (*op. cit.*) used a variety of manufacturing procedures that would not be amenable to mass production and produced modal frequencies at the ratios of 1: 1.72 : 2 : 2.35 : 3 one
5 second after striking. The mode shapes that produced these frequencies are not disclosed by Fletcher.

Summary of the Invention

According to a first broad aspect of the invention, therefore, there is provided a method
10 of manufacturing a metal object with one or more desired structural characteristics, comprising:

producing tensile prestresses in the object by selectively producing localized plastic deformation in the object such that the object has the desired structural characteristics.

15

Prestresses are residual stresses that are deliberately added to a manufactured object.

The method may comprise determining the desired structural characteristics of the object before producing the tensile prestresses.

20

In another embodiment, the method comprises modifying an existing object (such as following one or more preliminary manufacturing steps) by producing the tensile prestresses in the object.

25 In one embodiment, the desired structural characteristics comprise desired resonance characteristics.

In another embodiment, the desired structural characteristics comprise desired stiffness.

30

In one embodiment, the prestressing of the object increases critical buckling load of the object (such as a column, beam or other structural member).

Thus, the present invention allows design improvements to be made according to the
35 expected use of the object and the expected loads, etc, to which the object will be subjected. The performance improvement may include the tuning the frequencies of modes of vibration or vibrational modes (such as of a structural member, mechanical

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component or percussion instrument), decreasing strain under certain loads (i.e. increasing stiffness) or increasing the magnitude of a load under which the object will buckle.

- 5 It should also be appreciated that the method of this aspect can be employed in mass production techniques. In such cases, the step of determining the desired structural characteristics may be done once before the production of a large number of individual objects. It should be further appreciated that, in some manufacturing techniques, the modification of the object's structural properties may be largely integrated into the manufacturing process, such that the object is essentially manufactured with the desired one or more structural properties.

The selectively plastically deforming typically comprises creating prestresses in specific directions and regions of the object.

- 15 It will be appreciated by the skilled person that the desired structural characteristics will typically be expressed as an ideal set of desired structural characteristics or a target set of desired structural characteristics, and a tolerance that recognizes that it may be difficult to achieve the ideal or target but that a result approximating that ideal or target will nonetheless be valuable. Consequently, desired structural characteristics will commonly comprise a range of structural characteristics that approximate the ideal or target structural characteristics. The tolerance will depend on the application. If the object is a machine part and the purpose of applying the method to the machine part is to reduce wear from vibration in use, an acceptable tolerance may be calculated by balancing the expected extension in the part's life against the cost (in, for example, time) of employing a lesser tolerance. If the object is a percussion instrument (such as a gong) and the purpose of applying the method to the percussion instrument is to improve sound quality, an acceptable tolerance may be calculated according to whether further perceptible improvement could be obtained in sound quality by further reduction in the tolerance.

In one embodiment, the method comprises creating a plurality of discrete deformations.

In one embodiment, the object comprises sheet metal.

- 35 In one embodiment, the method comprises tuning vibrational modes of the object.

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In one embodiment, the prestressing of the object increases stiffness of at least a portion of the object.

5 In one embodiment, the object is a percussion musical instrument (such as a metal gong).

In a particular embodiment, the object is a percussion musical instrument with at least the first three modes tuned to the harmonic series.

10 It should be understood that, in this specification, reference to the first, say, three modes refers to the lowest frequency mode, the second lowest frequency mode and the third lowest frequency mode. References to other numbers of modes should be construed similarly.

15 In one embodiment, the object is a metal gong, such as formed from a sheet of metal. The gong may have a substantially polygonal principal vibratory surface and a rim formed by folding and fastening a peripheral portion of said sheet of metal.

20 In one embodiment, the object is a percussion musical instrument tuned by selectively plastically deforming said instrument so as to form three or more eccentric deformations in the principal vibratory surface of said instrument.

25 Although controlling modal frequencies of the object has clear application in the manufacture of a percussion musical instrument, this ability is expected to find application in many areas, especially in controlling unwanted and damaging noise or vibration.

30 Thus, in one embodiment, the object is a (for example, stamped) metal bracket or housing, such as an engine mount or housing, and the desired structural characteristics are selected to tune modal frequencies of the mount or housing.

In one specific embodiment, the method includes tuning the modal frequencies of the metal mount or housing to differ from a rotational frequency of the engine (to prevent or reduce structural resonances that may cause increased noise and decreased lifespan).

35 In other embodiment, the object is a metal mount or housing, and the method comprises determining desired structural characteristics of the object so as to prevent

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or reduce structural resonances (such as arising from excitation by interactions with wind, water, a suspension system, road or railway). Such embodiments are expected to particular application in road vehicles, railway vehicles, watercraft, aircraft and spacecraft.

5

Existing transport systems generally balance improved structural stability of vehicles due to higher stiffness with increasing weight due to added effective thickness.

Increased stiffness provided by prestress according to the present invention may improve the stability of road and rail transport vehicles, and watercraft, aircraft and

10 spacecraft without adding extra weight to the vehicle.

Loudspeakers also require high stiffness with low mass. Increased stiffness through prestress provided by prestress according to the present invention will increase the range of accurate frequency responses that a loudspeaker can produce without

15 increasing mass that would reduce the dynamic responsiveness.

One of the most common failure modes of metal components is buckling under compression. Creating tension in the surface along the axial direction of a column, beam or other structural member by forming prestress (such as by forming dimples)

20 according to the present invention may increase the critical buckling loads of that column. This would have broad general application in the design of road and rail transport vehicles, watercraft aircraft and spacecraft, and for the housings of plants and machinery.

25 There are a number of limitations that may limit the application of tensile prestresses according to the present invention. For example, geometric constraints may limit the formation of prestresses in the regions of the object that interact effectively with the stresses created by the specific load cases. Also, whenever a tensile prestress is created in a region of an object, a compressive prestress is also created somewhere in

30 the object or assemblage in equilibrium, so the present invention may not be preferred in cases in which it is not possible to shift the compressive field to a region of the object that does not interact with the load case. In some cases, this may involve modification of the object, such as to add a structure to (or modify an existing structure of) the object that, in response to the deformation of the object, will assume this compressive

35 prestress.

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A geometric limitation for object design is that metal flows from the object surface into localized regions of high yield in order to create tensile prestresses. Furthermore, discontinuities in the surface shape may limit metal flow. Finally, regions of localized high yield relative to the surface thickness must be able to be formed in the object. This
5 may not always be possible in very thick objects.

According to a second broad aspect of the invention, there is provided a metal object with structural properties modified according to the method described above.

10 It should be noted that any of the various features of each of the above aspects of the invention can be combined as suitable and desired.

Brief Description of the Drawing

In order that the invention may be more clearly ascertained, embodiments will now be
15 described, by way of example, with reference to the accompanying drawing, in which:

Figures 1A, 1B and 1C are schematic illustrations from FEA of, respectively, the geometry of a background art gong, the meridial (2,0) mode shape of the background art gong and the symmetric (0,1) mode shape of the background art gong;

20 Figure 2A is a photograph of a spun rim gong according to an embodiment of the present invention, with one (central) dimple;

Figure 2B is a photograph of a folded rim gong according to another embodiment of the present invention, with four (eccentric) dimples;

25 Figure 3A is a graph plotting modal frequencies of the gong of figure 2A as a function of dimple height (h) (and of a comparable gong without dimple from finite element analysis);

Figure 3B is a graph plotting modal frequencies of the gong of figure 2B as a function of dimple heights (h) (and of a comparable gong without dimples from finite element analysis);

30 Figure 4 is schematic view of an exemplary piece of metal of suitable shape for folding to form a gong;

Figure 5 is schematic view of the residual stress and deformation after the stamping and spring-back of a gong with a central dimple according to an embodiment of the present invention, calculated by explicit FEA (with a maximum
35 residual stress of about 3 MPa);

Figure 6 is a plot of the frequency of the 0,1 mode as a function of diameter for a central dimple as shown in Figure 5 according to an embodiment of the

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present invention, calculated by linear modal FEA with inclusion of stress fields calculated by explicit FEA;

Figure 7A is diagrammatic representation of the equilibrium of residual stresses after dimple formation in a gong with rim and central dimple according to an embodiment of the present invention (with only x-components of radial stresses shown for clarity);

Figure 7B is diagrammatic representation of the equilibrium of residual stresses after dimple formation in a gong with rim and four eccentric dimples according to an embodiment of the present invention (with orthogonal-components of stresses shown); and

Figure 8 is a flow diagram of a method of manufacturing a metal object with one or more desired structural characteristics according to an embodiment of the present invention.

Detailed Description

Figure 2A is a photograph of a metal gong 10 according to an embodiment of the present invention. Gong 10 has a single, central dimple 12 and spun rim 14. Figure 2B is a photograph of a metal gong 20 according to another embodiment of the present invention. Gong 20 has four, eccentric dimples 22 and a folded rim 24. Gongs 10 and 20 have diameters of ≈ 250 mm, rim depths ≈ 40 mm and were formed from mild steel of 1.2 mm thickness.

The overtone tuning for gongs is generally improved by adding a rim, as this increases the frequencies of meridial modes.

Modal frequencies of sheet metal components, such as a metal gong, are very sensitive to the presence of residual stresses created by sheet metal forming processes. This effect is described below for the example of gongs 10 and 20. In this specification, the "mode sequence" and "frequency sequence" of a gong refer to lists of modes and frequencies respectively in order of ascending modal frequency. Also, references to frequencies "being tuned", and similar expressions, refer to modal frequencies that it is desired be modified to substantially adopt particular values (hence, conform to desired resonance characteristics, that is, to target resonance characteristics to within an acceptable tolerance). For example, a tuned gong has a number of modal frequencies that been substantially "tuned" to particular frequencies or ratios of frequencies with desirable musical attributes. Furthermore, herein modal frequencies are described as

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substantially in an harmonic series when a frequency series substantially conforms to the ratios 1, 2, 3, etc. with respect to and including the lowest frequency mode.

5 The modal frequencies of gongs 10 and 20 were measured as the height of respective dimples 12 and 14 were increased. Also, FEA calculations were conducted of essentially identical gongs but lacking dimples.

10 The results are plotted in figures 3A and 3B. Figure 3A is a graph plotting the modal frequencies of gong 10 of figure 2A as a function of dimple height (h) with, at the extreme left of the plot, the FEA results for a comparable gong without dimple. Figure 3B is a graph plotting modal frequencies of gong 20 of figure 2B as a function of dimple heights (h) with, at the extreme left of the plot, the FEA results for a comparable gong without dimples.

15 It is evident from figure 3A that modal FEA did not predict the frequency of the 2,0 mode for gong prototypes with rims produced by metal spinning. This is likely to be due to compressive residual stresses introduced to the surface of the gong by the spinning process. Figure 3A also shows that stamping a small dimple 12 in the surface of gong 10 after the rim had been spun increased the frequency of certain modes by up to 50%.
20 However, the frequency of the 2,0 mode was largely unaffected, so gong 10 could not be tuned harmonically.

25 Folded rim gong 20 of figure 2B was created so that residual stress formation due to the rim could be better controlled. Tension was added to the outer regions of the surface of gong 20 by this design, as determined by the difference between the FEA and prototype 0,2 modal frequencies (without dimples) shown in figure 3B. The position of dimples 22 relative to the maxima of stresses created by various vibratory modes affected the degree of influence the residual stresses due to dimple formation have on the modal frequencies. Figure 3A shows that the axisymmetric 0,1 modal frequency was
30 increased more by central dimple 12 than the 2,0 mode. However Figure 3B shows that the 2,0 mode increased more than the 0,1 mode with multiple, eccentric dimples 22. Modal FEA demonstrated that the geometric changes alone due to the dimple formation had very little effect on the modal frequencies.

35 A gong according to another embodiment of the present invention can be manufactured in the following manner, so that at least the first three modes are substantially tuned to a harmonic series.

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The gong is constructed from sheet metal of constant thickness in the following four steps.

- 5 1) Referring to figure 4, sheet metal is cut out in a shape 40 that leaves flaps 42 suitable for folding under the gong's striking surface and fixing to form a rim. The size of the metal shape may be determined by first making a test gong according to these four steps and determining the fundamental frequency of the test gong. In accordance with the physics of plate vibrations (see N. Fletcher and T. Rossing, *Op. cit.*, Chapter 3),
10 the size of subsequent gongs can then be calculated by scaling the original geometry by the inverse square root of the desired frequency ratio. The exact shape of a rim of given depth does not greatly effect the tuning of the gong. The top surface of the gong comprises a polygon with eight or more sides so that the 2,0 mode is not split into two modes of different frequencies, one with longer meridial nodal lines between the
15 corners of the polygon and the other with shorter meridial nodal lines between the centers of the edges of the polygon. The sheet metal thickness may be increased or decreased for substantially larger or smaller gongs in approximate proportion to the gong shown in Figure 2B. Figure 4 shows an example of a flat metal shape that may be folded to form a gong.
20
- 2) The rim is formed by folding and fastening together overlapping edges of the metal flaps that form the rim. Fastening is preferentially done by spot welding.
- 3) At least three (and advantageously four or eight) equally spaced dimples are formed
25 at approximately one half of the maximum gong radius from the centre of the gong. The depth of these dimples should be such that the frequency ratios of all the modes to be tuned with respect to the first mode are increased to more than the harmonic ratio equal to the order of the mode. For example, the 3rd mode is raised in frequency to greater than three times the frequency of the first mode.
30
- 4) The frequencies of the modes other than the first mode are then reduced by plastically deforming the gong surface symmetrically about the centre by striking the centre with a flat hammer (or other similar forming device) without forming a dimple. Most of the deformation will elastically relax thereby reducing radial components of the
35 residual stress field and bring the modes into harmonic relationships as shown in Figure 3B.

– 10 –

Steps 3) and 4) may be repeated, including the addition of extra dimples as required, to achieve the desired tuning.

Plastic deformations other than dimples can be used to induce residual stress equilibriums in which certain component surfaces are placed in tension. The mechanism by which residual stress equilibriums are formed in the specific case of dimples will be explained in detail below by way of example.

Residual stress formation is due to transport of material from the surrounding surface into the dimple during stamping. After the release of the stamp the dimple does not elastically spring back fully, resulting in tension across the surface that is counterbalanced by tensile residual stresses in the dimple and compressive residual stresses around the edge of the surface. Figure 5 is schematic view of the residual stress and deformation after the stamping and spring-back of a gong with a central dimple according to an embodiment of the present invention, calculated by explicit FEA (with a maximum residual stress of about 3 MPa). Figure 6 is a plot of the percentage change Δ in the frequency of the 0,1 mode as a function of dimple diameter d for equal height dimples according to an embodiment of the present invention, calculated by linear modal FEA with stress fields calculated using the explicit FEA analysis shown in Figure 5; this plot shows that smaller diameter dimples create higher residual stresses and higher frequencies.

Figure 7A is diagrammatic representation of the equilibrium of residual stresses after dimple formation in a gong 70 with rim 72 and central dimple 74 according to an embodiment of the present invention (with only x-components of radial stresses shown for clarity, such as at 76). Figure 7B is diagrammatic representation of the equilibrium of residual stresses after dimple formation in a gong 78 with rim 80 and four eccentric dimples 82 according to an embodiment of the present invention (with orthogonal-components of stresses shown, such as at 84).

The increase in the frequency of axisymmetric modes of the gong by a central dimple was due to prestresses with predominantly radial tension, whereas the increase in the frequency of modes with meridional nodes by eccentric dimples was due to increased tension predominantly in the circumferential direction (hoop stresses).

Any plastic deformation that creates an equilibrium (as shown, for example, in figures 7A and 7B) could be used to improve the performance of a sheet metal component

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according to the present invention. Other examples that generate tension in the surrounding surface may include raised surfaces or raised “X”, “T”, or “L” shapes. Broadly, the geometric constraints on the shape of the deformation required to create tension in the surrounding surface are that:

- 5 i) their formation causes metal to be transported into the deformation from the surrounding surface, and so places the surface in tension,
- ii) once formed there is a section of the dimple surface along the direction of the required surface tension to provide tensile strength against elastic spring-back, and,
- 10 iii) the dimple height is sufficient for the dimple surface along the direction of the required surface tension to provide tensile strength against elastic spring-back.

The geometric constraints on the remainder of the component are that there is sufficient material surrounding the surface to be placed in tension, or that the component is rigidly
15 fixed around this surface, to provide an opposing force to the surface tension, and that the surface in the direction to be tensioned is approximately flat. In the first example the material surrounding the surface under tension will be compressed as in the example of harmonic gongs provided in this specification. Where the surface is rigidly fixed to another structure, the other structure will bear the loads required to resist the
20 tensile stress.

Surface tension can be created along specific directions in the surface by the placement of a series of plastic deformations along that direction (according to either Cartesian or polar coordinate systems), or by the design of the deformation such that it only provides
25 tensile strength in certain directions. An example of the first method is provided in the example of tuning a harmonic gong provided in this specification (where dimples were placed around a fixed radius), and an example of the second method is to use a linear deformation (so little tensile strength is provided in the direction normal to the line of the deformation).

30 Surface tension created in this fashion can be modified by plastically deforming the entire surface such that spring-back adds compression (as in the known method of autofrettage of pressure vessels). This may be used to remove tension in just one direction, as described in the final tuning step of the harmonic gongs described in this
35 specification, where radial tension was removed leaving largely hoop stresses in the surface.

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Metals with high tensile yield stresses (the stress at which the metal begins to plastically deform) can support greater prestresses. The use of higher tensile strength alloys will expand the range of improvements possible in the structural characteristics of the designed component.

5

Figure 8 is a flow diagram 90 of a method of manufacturing a metal object with one or more desired structural characteristics according to an embodiment of the present invention.

10 At step 92, a blank of the object (cf. figure 4) is formed. At step 94, the object itself is created in preliminary form ('preliminary' because tensile prestresses have not yet been added).

15 At step 96, the desired structural characteristics of the object—and the tensile prestresses that will provide those structural characteristics—are determined, such as with FEA. At step 98, local plastic deformation of the object is conducted to produce the necessary tensile prestresses to give the object the desired structural characteristics. The method then ends.

20 It will be appreciated by the skilled person that, although the application of the invention to gongs has been described in detail above, the present invention will find wide application in, for example, diverse areas of engineering. Prestress may be advantageously added to structural members and many mechanical components. These may include, however, beam, columns, fuselages, window- or door-frames
25 (especially of vehicles, vessels and aircraft), mounts and housings. In some cases this may be done, as in the gong example, to improve resonant characteristics, but in others to modify resonant characteristics so as to avoid or reduce the possibility of resonant behaviour (such as to decrease wear).

30 Generally, it is envisaged that prestress would be added to structural members to increase, but in some applications prestress might be used with the principal aim of modifying resonant characteristics (even if some modification of stiffness also occurs).

35 In these and other applications, existing and desired structural characteristics of the object can be determined according to known techniques, as would be apparent to those skilled in the art, including FEA, the recording of FFT spectra or stress-strain testing.

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Modifications within the scope of the invention may be readily effected by those skilled in the art. It is to be understood, therefore, that this invention is not limited to the particular embodiments described by way of example hereinabove.

5

In the claims that follow and in the preceding description of the invention, except where the context requires otherwise owing to express language or necessary implication, the word “comprise” or variations such as “comprises” or “comprising” is used in an inclusive sense, that is, to specify the presence of the stated features but not to
10 preclude the presence or addition of further features in various embodiments of the invention.

Further, any reference herein to prior art is not intended to imply that such prior art forms or formed a part of the common general knowledge in any country.

15

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CLAIMS:

1. A method of manufacturing a metal object with one or more desired structural characteristics, comprising:
5 producing tensile prestresses in the object by selectively producing localized plastic deformation in the object such that the object has the desired structural characteristics.
2. A method as claimed in claim 1, comprising determining the desired structural
10 characteristics of the object before producing the tensile prestresses.
3. A method as claimed in claim 1, comprising modifying an existing object by producing the tensile prestresses.
- 15 4. A method as claimed in claim 1, wherein said desired structural characteristics comprise desired resonance characteristics.
5. A method as claimed in claim 1, wherein said desired structural characteristics
20 comprise desired stiffness.
6. A method as claimed in claim 1, wherein the prestressing of said object increases critical buckling load of the object.
7. A method as claimed in claim 1, wherein the object is a column, beam or other
25 structural member.
8. A method as claimed in claim 1, wherein the prestressing of said object increases stiffness of at least a portion of the object.
- 30 9. A method as claimed in claim 1, comprises tuning frequencies of modes of vibration of said object.
10. A method as claimed in claim 9, wherein said object is a percussion or other
35 musical instrument.
11. A method as claimed in claim 9, wherein the object is a percussion musical instrument with at least the first three modes tuned to the harmonic series.

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12. A method as claimed in claim 1, wherein the object is a percussion musical instrument tuned by selectively plastically deforming said instrument so as to form three or more eccentric deformations in the principal vibratory surface of said instrument.
- 5
13. A method as claimed in claim 1, comprising creating a plurality of discrete deformations.
14. A method as claimed in claim 1, wherein said object comprises sheet metal.
- 10
15. A method as claimed in claim 1, wherein the object is a metal gong.
16. A method as claimed in claim 15, wherein said gong has a substantially polygonal principal vibratory surface and a rim formed by folding and fastening a peripheral
- 15
- portion of said sheet of metal.
17. A method as claimed in claim 1, wherein the object is a metal bracket or mount, and the desired structural characteristics are selected to tune modal frequencies of the metal bracket.
- 20
18. A method as claimed in claim 17, comprising tuning the modal frequencies of the metal bracket or mount to differ from a rotational frequency of an engine or other mechanism supported or to be supported by the bracket or mount.
- 25
19. A method as claimed in claim 1, wherein the object is a metal mount or housing, and the method comprises determining desired structural characteristics of the object so as to prevent or reduce structural resonances.
20. A method as claimed in claim 1, wherein the object is a loudspeaker.
- 30
21. A metal object with structural properties modified according to the method of any one of the preceding claims.
22. A metal object as claimed in claim 21, wherein said object is a structural member,
- 35
- mechanical component or musical instrument.

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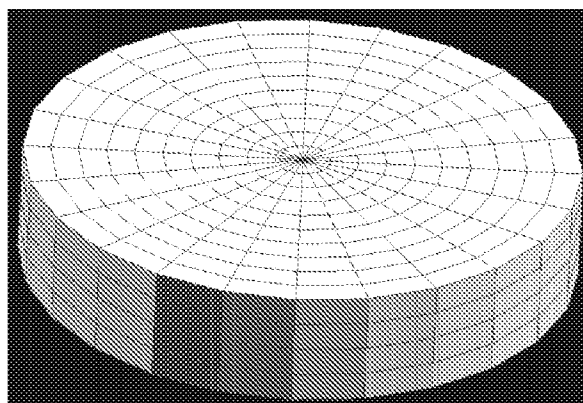


Figure 1A

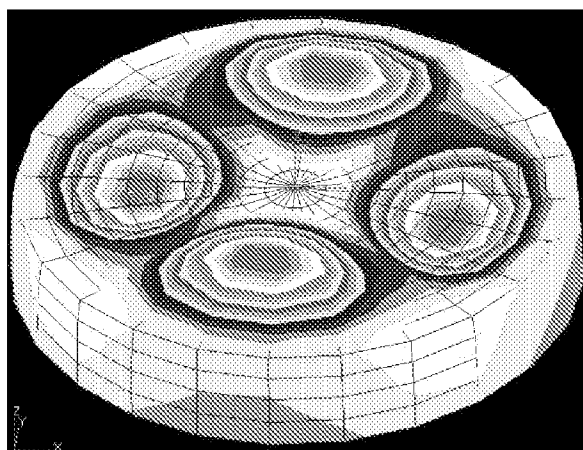


Figure 1B

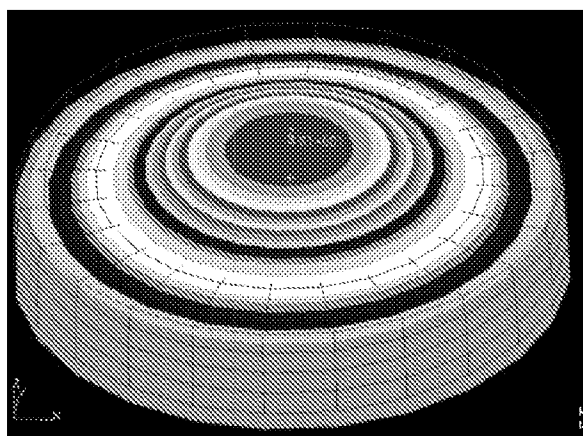


Figure 1C

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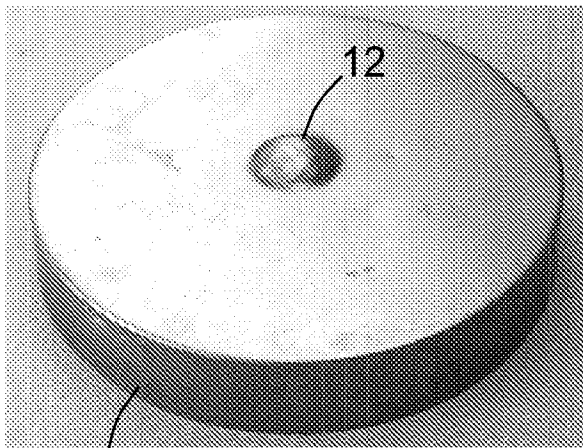


Figure 2A

20

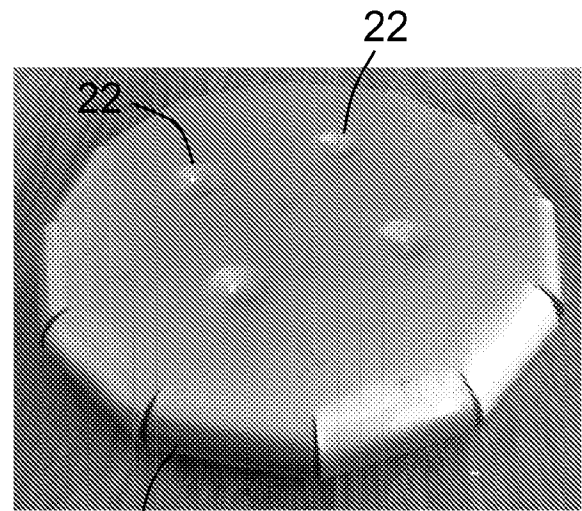


Figure 2B

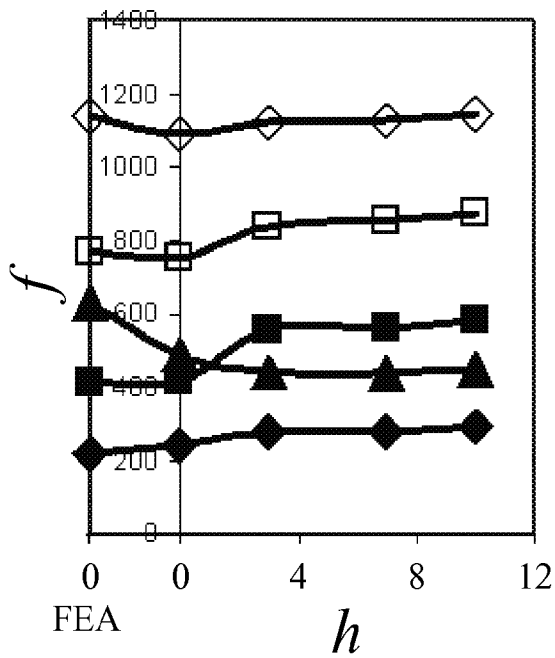


Figure 3A

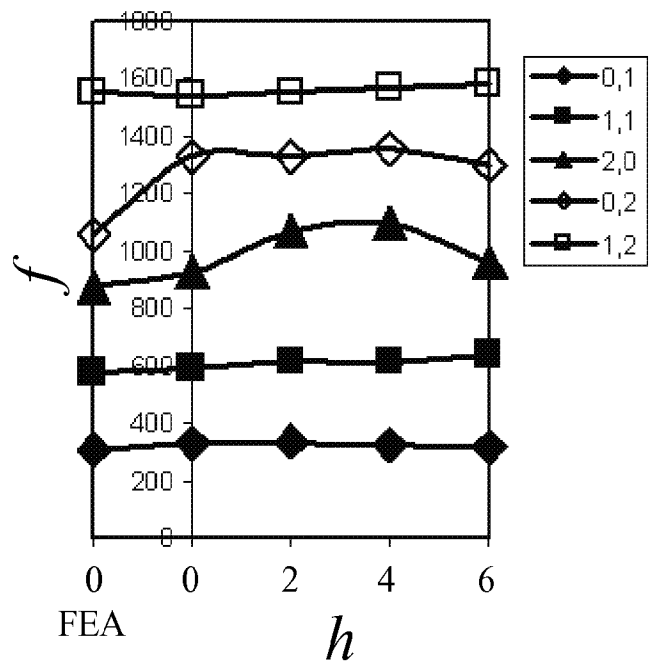


Figure 3B

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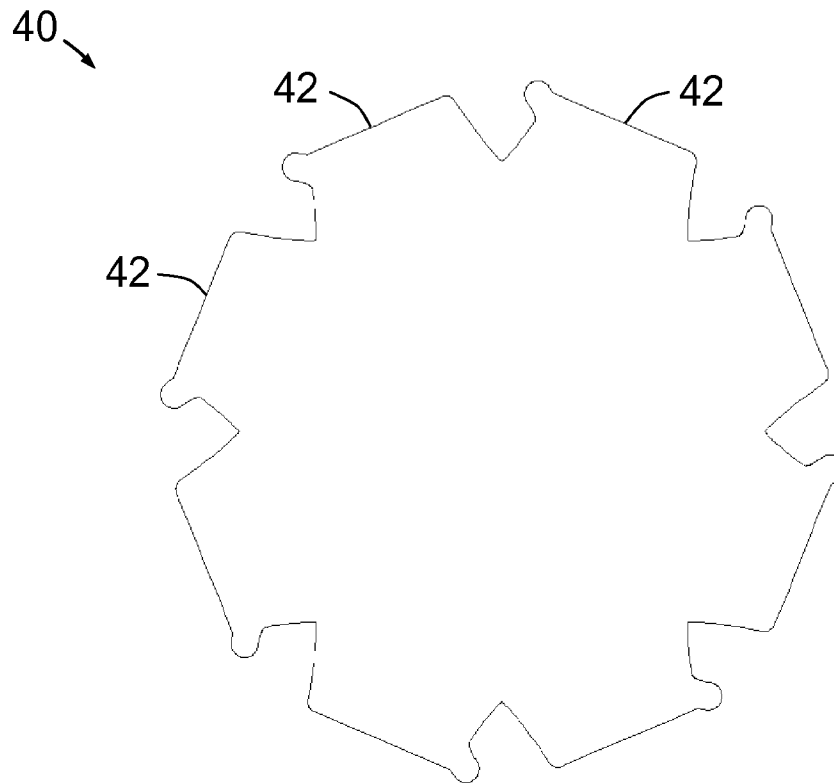


Figure 4

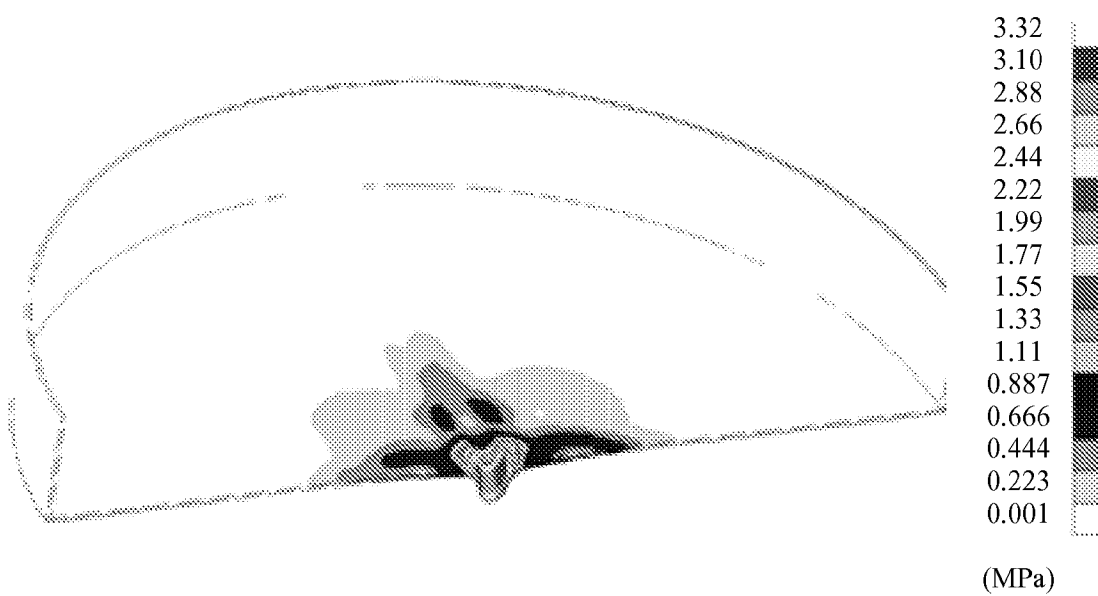


Figure 5

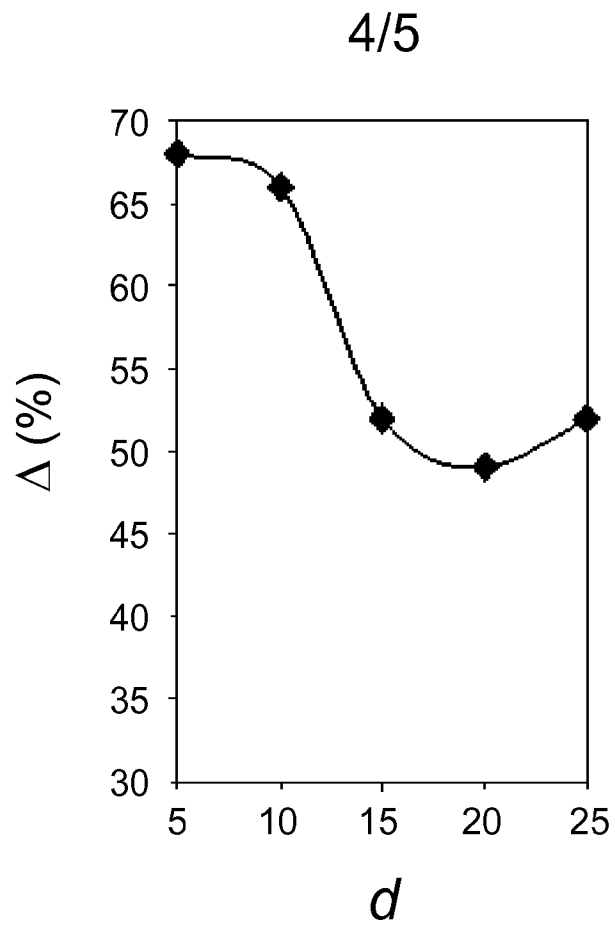


Figure 6

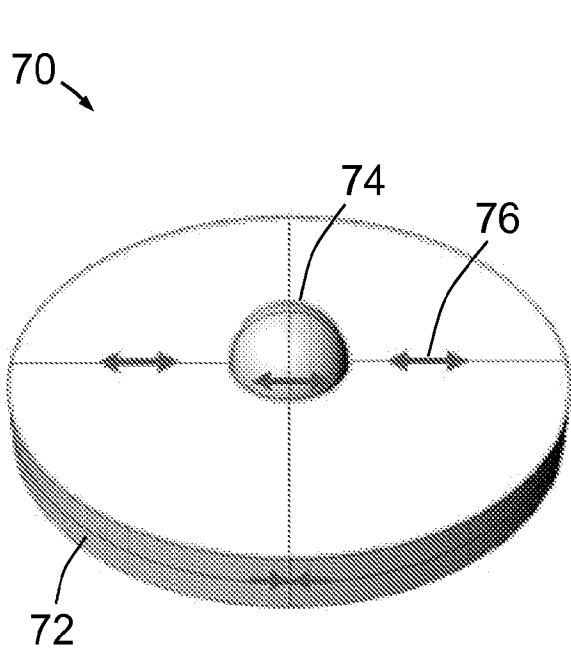


Figure 7A

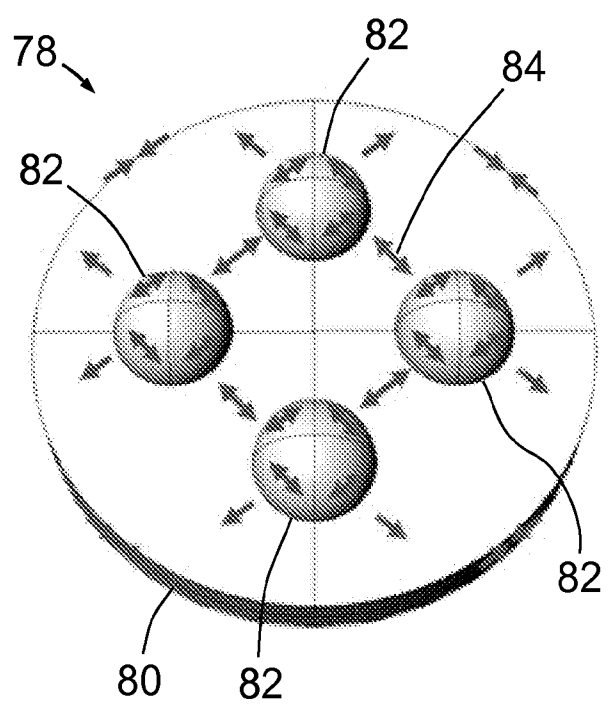


Figure 7B

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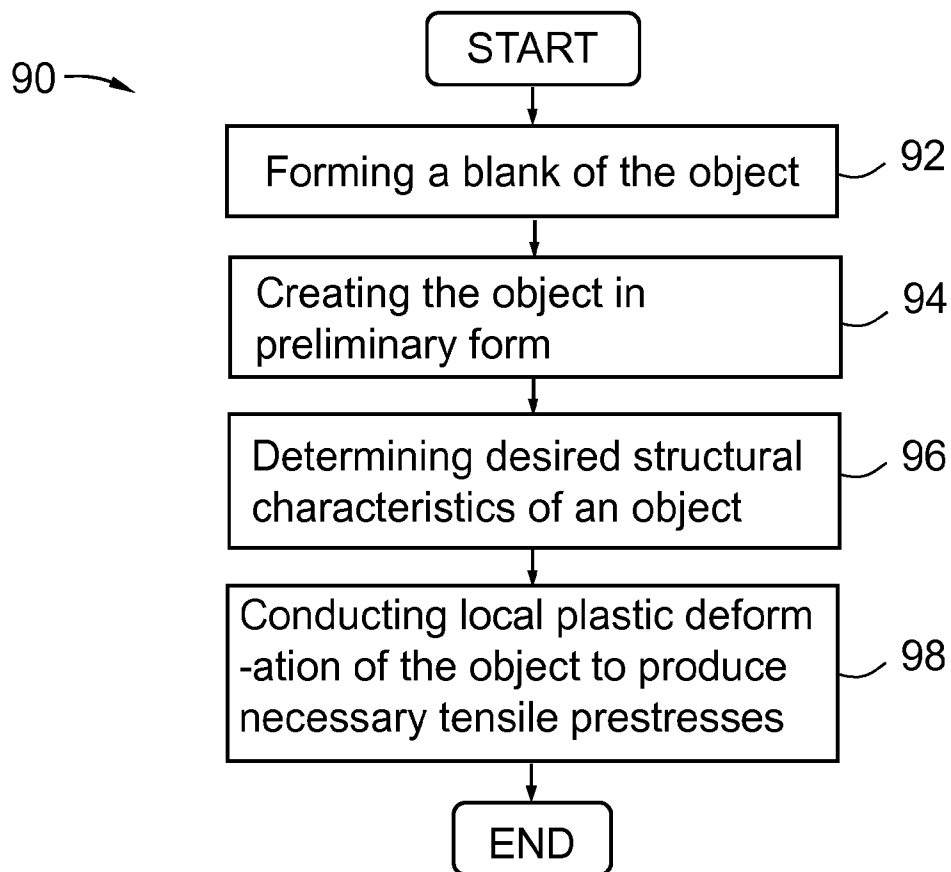


Figure 8

INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU2011/001022

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.: **B23P 15/00** (2006.01), **B23P 17/00** (2006.01).

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPODOC, WPI: ecl, ipc: (B23P 15/00, B23P 17/00, G10K 1) and keywords stress, preload, deform, zone, make, manufacture, tune, plastic, music, instrument, gong, percussion, harmony, tune, vibrate, resonate, gamelan, etc.)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4125929 A (RODE) 21 November 1978. Please see columns 1 and 3.	1-3, 5-8, 21.
X	US 6491182 B1 (HOLROYD et al.) 10 December 2002. Please see columns 1 to 3.	1-3, 5-8, 21.
P,X	US 2010/0236875 A1 (PLANTAN et al.) 23 September 2010. Please see pages 1 to 3 and figure 2c.	1-3, 5-8, 21.
X	WO 2004/058482 A2 (ROBERT BOSCH GMBH) 15 July 2004. Please see pages 5 to 7.	1-3, 5-8, 21.



Further documents are listed in the continuation of Box C



See patent family annex

* Special categories of cited documents:	
"A" document defining the general state of the art which is not considered to be of particular relevance	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E" earlier application or patent but published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search
04 October 2011Date of mailing of the international search report
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/AU2011/001022

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member			
US	4125929	NONE			
US	6491182	AU	36164/95	CA	2201313
		JP	H10508253	WO	9611759
US	2010236875	WO	2010107612		
WO	2004058482	CN	1732056	DE	10260856
		JP	2006513318	EP	1578547
Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.					
END OF ANNEX					