

[54] **SLIDER BEARING SURFACE GENERATION**

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51/324

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[56] **References Cited**

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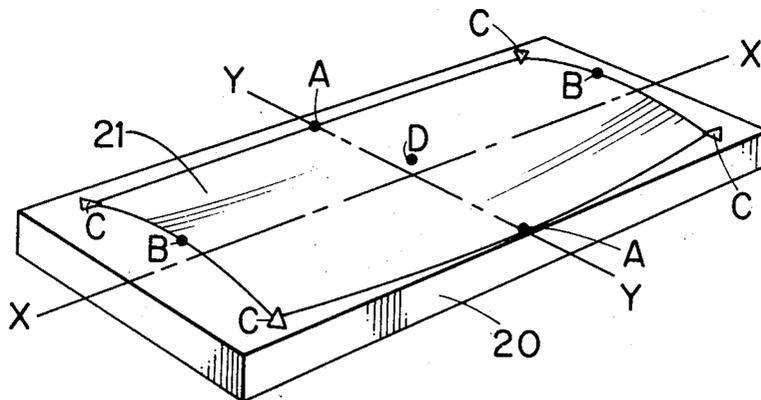
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[57] **ABSTRACT**

A method of generating the bearing surface on a "flying" magnetic recording head. The desired bearing surface is of compound curvature, having a significant crown along an axis parallel to the flying direction and a lesser concavity along an axis transverse to the flying direction. The bearing surface is produced by lapping an essential element of the head, henceforth called "slider" against a control surface. In a first embodiment of the method, the control surface comprises a thin sheet of glass, metal or ceramic distorted to a contour which is the inverse, or converse, of the desired shape; and the slider is lapped against the control surface using a combined lateral and cross-lateral motion. Alternatively, the slider may be clamped so as to distort it to a contour which is the inverse of the desired surface contour, lapped against a planar control surface, and then released from the clamp whereby the unstressed slider will have a bearing surface contour of the desired shape.

**4 Claims, 10 Drawing Figures**



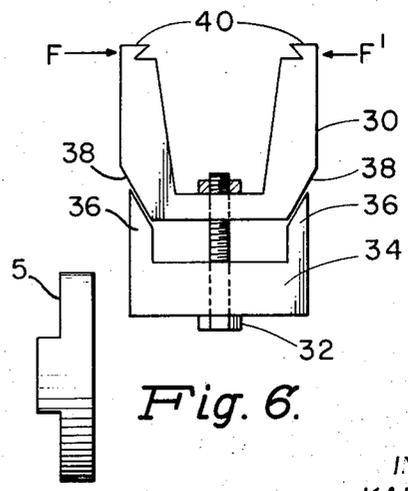
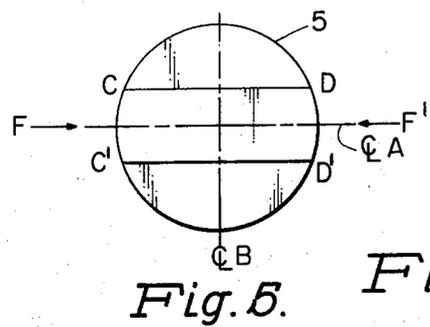
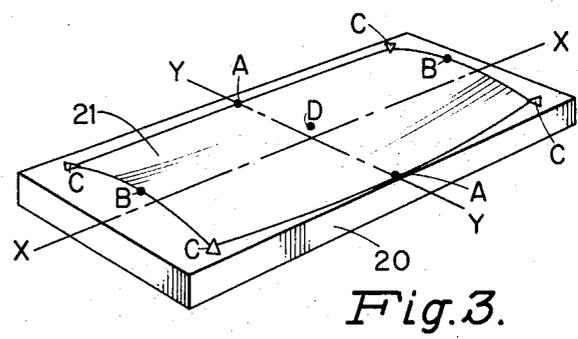
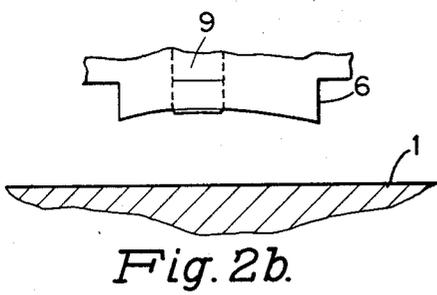
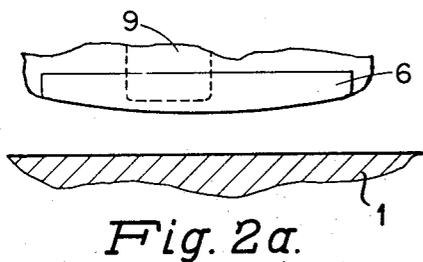
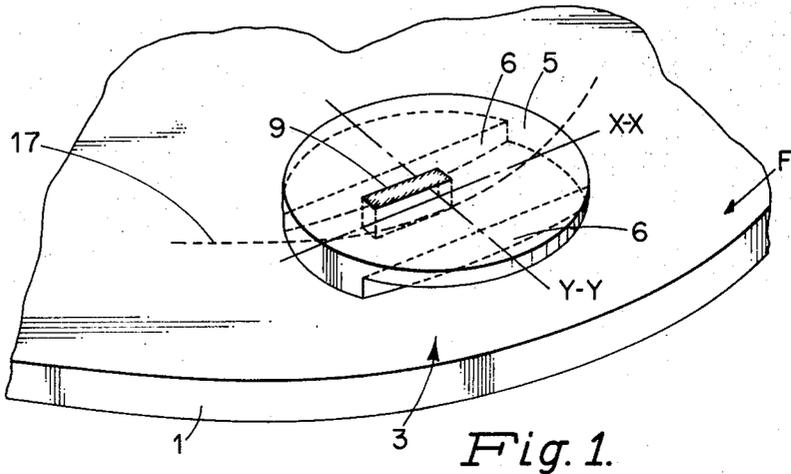


Fig. 5.

Fig. 5a

Fig. 6.

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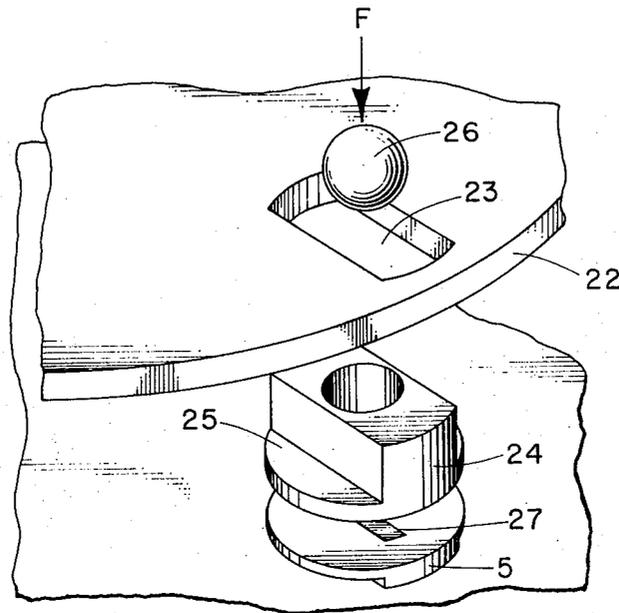


Fig. 4.

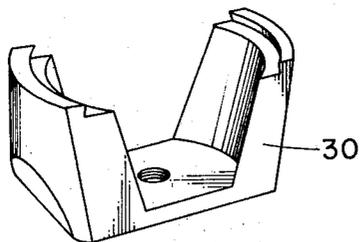


Fig. 7.

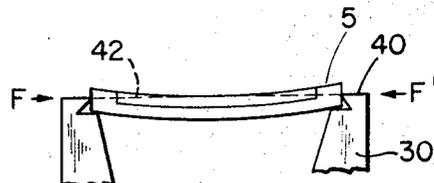


Fig. 8.

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## SLIDER BEARING SURFACE GENERATION

### BACKGROUND OF THE INVENTION

The present invention concerns a new and improved method for producing desired contours on the bearing surface of a slider. More particularly, the invention concerns a method of generating a desired surface contour on the slider of a magnetic recording head.

For purposes of illustration, the method is described in conjunction with the formation of a bearing surface of particular contour on a slider of a flying head used in a magnetic disc type data storage apparatus. However, it will be understood that the novel method of the present invention has utility in other widely varied applications.

Packs of rotatable discs, upon which data is encoded in the form of magnetic indicia, are widely used in the data processing industry. Since the discs rotate at high speeds, it is necessary to provide magnetic recording heads in a manner such as to successfully carry out read/write operations on the disc memory surfaces. Conventionally such recording heads have a bearing surface of a particular contour so as to maintain a film of air between the head and memory surface at operational speeds. For proper reading and writing of magnetic information, the air film must be small enough to allow efficient transfer of magnetic flux and yet be large enough whereby minor imperfections in the memory surface or dirt particles thereon will not cause the head to "crash", or contact the disc surface. In practice, this distance may be on the order of 100 micro-inches.

It has been found that use of a head slider having a compound curved bearing surface which resembles a saddle yields a satisfactory film of air between the slider and the memory surface. In manufacturing such heads, it is imperative that a highly polished bearing surface be produced which is finished to a tolerance in the micro-inch range. Heretofore, no economical method has been available for the production of heads having the desired properties. Furthermore, no simple method has been known which easily refinishes slightly damaged or worn heads.

### OBJECTS OF THE INVENTION

Accordingly, it is an object of the invention to provide a novel and improved method of generating a bearing surface for a magnetic head slider.

It is a further object of the invention to provide an economical method of generating a compound-curved bearing surface on a slider of a flying magnetic head.

It is yet another object of the invention to provide a simple method of generating a highly polished, precisely finished slider bearing surface, which method can be practiced at a field location by an operator without special training.

A still further object is to provide a method for forming a compound curved surface from a relatively flat blank of hard material.

### SUMMARY OF THE INVENTION

The foregoing objects are accomplished by the novel method of the invention which includes the formation of a desired surface by lapping the head slider blank against a control surface. In a first embodiment of the

invention, the control surface comprises a sheet of glass, stainless steel, or other suitable material which is mounted on a base member and distorted to a contour which is the inverse or converse of the desired slider bearing surface contour. The slider blank is lapped against the control surface, using a motion which includes rapid movement back and forth along a first control path and a slow movement back and forth along a second path transverse to the first path.

Alternatively, the slider blank may be placed in a clamp designed to distort the blank, within its elastic limits, to form a surface contour which is the inverse of the desired finished contour. The slider blank is then lapped against a planar control surface, comprising a sheet of glass, metal or ceramic and then released from stress to form the desired surface. It should be noted that, although the term "blank" is used for the unfinished slider, the slider may already contain a magnetic pole as described below.

### BRIEF DESCRIPTION OF THE DRAWINGS

Further objects of the invention, together with features and advantages thereof, will become apparent from the accompanying drawings in which:

FIG. 1 is a fragmentary perspective view of a magnetic recording disc having a head located in recording relationship with an information track thereon.

FIG. 2a is a front elevational view looking perpendicularly to edge 6 of FIG. 1 showing in highly exaggerated form the slider blank in highly exaggerated form and its orientation over the recording surface of the moving disc.

FIG. 2b is a left side view taken perpendicularly to the front elevation view of FIG. 2a and showing in highly exaggerated form the slider blank and its orientation over the recording surface of the moving disc.

FIG. 3 is a perspective view of a mounting plate and control surface against which the slider blanks are to be lapped in the practice of one embodiment of the present invention.

FIG. 4 is a partial exploded view of a bracket and clamping fixture designed for holding the slider blank against the control surface in the practice of one embodiment of the method of the invention.

FIG. 5 is a bearing surface view of a slider to be finished by the method of the second embodiment of the invention.

FIG. 5a is a non-deformed side view of a slider to be finished as shown in FIG. 5.

FIG. 6 is a side view of the clamp of FIG. 7 with a screw-type force applying means.

FIG. 7 is a perspective view of the gripping portion of a deforming clamp.

FIG. 8 is a side view of the blank of FIG. 5 in mounted relationship to the top portion of the clamp as shown in FIG. 6 showing the distortion caused by application of forces thereto.

### DETAILED DESCRIPTION OF THE INVENTION

In the drawings, the method of the present invention is described as it relates to the production and/or refinishing of magnetic recording head sliders for use in magnetic disc data storage systems. However, it should be understood that the invention has utility in a wide variety of other applications. Thus the method could be

used in the production of head sliders for use in drum type storage systems or for that matter in the production of any slider type device wherein a desired bearing surface contour is necessary. Application even wider than data transmission bearings are conceivable including the manufacture or refinishing of any compound-curved surfaces of high accuracy.

FIG. 1 shows a fragmentary view of a magnetic disc data storage element 1 having a recording surface 3 over which is suspended a magnetic recording head slider 5. The slider forms an essential element of a magnetic head assembly not completely shown. The magnetic head assembly is designed to perform read/write operations on the storage surface of the disc as the disc is rotatably driven at high speed by a spindle and driving means (not illustrated) in the direction shown by the arrow F.

The slider and head assembly are normally suspended at a location remote from the disc and are moved axially over the disc and suspended in operative relationship thereto by arm means (not shown) to enable read/write operations. Due to the relative movement between disc and head and the existence of an air film therebetween, this type of magnetic head is known in the art as a flying head.

The slider 5 may be of varied configurations, but is shown in FIG. 1 as comprising a circular disc having two parallel edges 6 formed thereon by removed portions thereof. In actual practice, the diameter of such a slider would range between 0.5 inches and 1 inch with the slider having a thickness of less than 0.5 inches. The slider might be fabricated of suitable ceramics, stainless steel, or hard-coated aluminum and is indented to accommodate a magnetic core element 9 including a read/write gap and an erase gap or gaps, not shown, arranged to follow a selected information track 17 in a conventional manner. As shown in FIG. 1, the core element is located slightly to the rear of the transverse axis  $y-y$  of the slider 5 and slightly to the inner side of the tracking axis  $x-x$  of the slider 5. This location of the magnetic core is precisely determined to place the core element close to the recording surface as the slider passes along the recording surface. In its movement the slider has a tendency to plane in two directions as it passes along the recording surface.

It has been found that a slider having a crown of 350 to 450 micro-inches along the flying axis, as shown in exaggerated fashion in FIG. 2a, and a slight concavity, for example 10 to 30 micro-inches, along an axis transverse to the flying axis as shown in exaggerated fashion in FIG. 2b, will maintain the desired air film between the magnetic head assembly and recording surface at recording speeds.

The present invention concerns a method of generating a slider bearing surface having the desired contours. One embodiment of the method includes the step of lapping the slider blank against a control surface which is distorted to have a contour which is the inverse of the desired finished slider surface, thus removing some of the slider material. Any object lapped against this control surface will then result in the desired slider profile. Alternatively, the method may include the distortion of the slider blank to a contour which is the inverse of the desired surface and then lapping of the distorted slider blank against a planar control surface.

In FIG. 3, a backing plate 20 of material sufficiently strong to accept unbalanced forces without distorting appreciably is shown supporting a control surface 21. The control surface comprises a thin sheet of distortable material such as glass or stainless steel. For example, a lapping surface consisting of photographic type glass in a plate 14 inches by 17 inches and having a thickness of 0.090 inches was used in one experimental embodiment of the invention. While this glass is found to be satisfactory, it had limited life. Consequently, a special glass having a high surface tension, for example, a glass marketed by Corning Glass under the trademark Chemcore, was found to have the desired flexibility and surface durability to enable many samples to be lapped without destruction of the glass. A drawback of using glass is that it is non-porous and will not hold lapping particles for finishing, but allows them to roll along the surface. Furthermore, the glass tends to become scratched during the lapping operation, partially because of the above mentioned rolling of the particles, and is difficult to clean. Alternatively, ceramic coated steel has been used as a control surface.

The control surface is clamped by suitable means, not shown, to the base at points A. Shims are then applied beneath the control surface at points B until the desired 300 to 400 micro-inch contour per  $\frac{1}{2}$  inch of lateral distance is achieved along the axis  $x-x$ .

Clamping may be, for example, by means of "L" bolts with rubber cushions or the like to prevent damage to the surface and to allow slight movement of the clamping points inwardly, toward the center of the surface as the surface is distorted as explained below. The slight inward movement of the clamping points approaches a twisting movement as opposed to a lateral movement, however, in view of the relative degree of displacement involved. The materials used for the control surface 21 and their dimensions are such that clamping of the control surface at points A and applying upward force at points B distorts the surface so that the contours C-A-C is nearer the backing plate than the contour B-D-B. This results in a slight crown in the direction A-D-A which will produce the desired saddle, or recess, in a slider blank lapped against this surface. It should be recognized that the control surface 21 is not bent beyond the elastic limits of the material, in order to prevent the surface from taking a permanent set and flattening the curve across points A-D-A. However, it has been found that such an arrangement resulted in a saddle which was deeper than that desired. Consequently, it was necessary to raise points C and thus, relatively lower point D. It should be noted that it is perfectly feasible to lap the head with the magnetic pole pieces installed. If, for example, the slider were stainless steel and the core were ferrite, the core will project slightly from the bearing surface when the lapping is complete because of the dissimilarity in the materials.

A single slider blank may be hand lapped against such a control surface with acceptable results. Hand lapping could be carried out in a reasonable time, for example, in 15 to 20 minutes, as a means for refinishing worn or slightly damaged heads. However, as a production process, hand lapping would be unnecessarily tedious and inefficient. Accordingly, it should be noted that the process of lapping could be automated.

In lapping the slider blank 5 against the control surface 21, a downward force of one-third pound to one pound is desirable. The lapping motion consists of movement of the slider blank back and forth along the lateral axis  $x-x$  at a fairly rapid rate combined with a cross movement at a much slower rate along the axis  $y-y$ . The cross motion is desirable to insure that an acceptable saddle in the transverse direction will be produced on the bearing surface. Lapping in a single direction only will produce an unacceptable crown in the transverse direction. Of course, a suitable lapping paste or flowing slurry may be used to enhance the material removal.

It should be noted that a bearing surface without the saddle contour in the transverse direction would be acceptable for use. However, the use of a 10 to 30 micro-inch saddle as shown in FIG. 2B places the surface of the core element 9 at a point between the concave saddle portion of the slider surface and the slider edges 6 and tends to protect the core element 9 in the event of magnetic head assembly to disc contact. As previously mentioned, in the event that the core element is denser than the slider, it will project slightly from the slider surface, i.e., a few micro-inches, when the slider blank is lapped with the core element already installed.

In FIG. 4 a bracket designed for lapping several slider blanks at once is shown. This bracket could be used in a hand operation but is preferably utilized where automated means are provided for carrying out the lapping step.

FIG. 4 shows an exploded fragmentary view of a clamping means including a fragmentary view of a disc 22, such as one marketed by Union Carbide under the trademark Micarta, having shaped recesses 23 (only one recess being shown in FIG. 4, the rest of the recesses are geometrically arranged around the disc) formed therein of the same shape as the upper portion 24 of a fixture 25, which is adapted to ride freely in a vertical direction while moving laterally under the control of the disc 22. This was done because the glass plate of a control surface, not shown in this Figure, did not have a perfectly uniform contour, and a rigidly attached slider would not be able to follow the imperfections. The center of the fixture 25 is drilled out to provide a cup for ball 26 as well as to provide clearance for the magnetic core blank 27 as the slider element 5 is adhered to the bottom of the fixture 25 by wax or other suitable means. Three or more slider blanks may be moved by the same disc. It should be apparent that downward force  $F$  is applied by means, not shown, through the ball 26 to the slider blank 5. Automated means can easily be provided to drive the disc. Thus by an arrangement of pulleys and motors driving a belt (not shown) attached to the disc 22, the disc can be drawn back and forth along axis  $x-x$  as well as simultaneously moved along axis  $y-y$  at the desired speeds.

Alternatively, as a second embodiment, it is possible to distort the blank to a shape which is the exact inverse of the needed contour. Thus, as shown in FIG. 5, if the slider blank 5 is grasped near the surface to be finished by a clamping means, not shown, and forces  $F, F'$  are applied through a suitable means, not shown, the blank will be deformed to a desirable shape by flat plate lapping.

FIG. 6 shows a suitable deforming mechanism which comprises a clamp 30, a screw 32 and a force applying member 34. The screw is passed between clamp 30 and force applying mechanism 34 in such a manner that when the screw is tightened, projections 36 act upon beveled edges 38 of clamp 30 to tend to force projections 40 inward, in a manner indicated by the arrows  $F, F'$ .

FIG. 7 shows a perspective view of the clamping member 30 without the force applying means connected thereto.

FIG. 8 shows a side view of the blank of FIG. 5, against the arrows  $F, F'$  indicating the applied force.

As the slider blank is grasped and deformed by clamp 30, it will bend as shown in FIG. 8. Major distortion will be produced in the direction of the forces  $F, F'$  thus tending to push the center of line B (FIG. 5) downward, and tending to raise the center of line A. Of course, in employing this method, care must be taken not to exceed the elastic limits of the material being used for the slider blank.

The slider is held clamped in the position shown in FIG. 8 with a desired force being applied and is lapped on a flat plate to remove material therefrom. The area removed is shown above the dotted line 42 in FIG. 8. Release of the forces  $F, F'$ , as, for example, by unscrewing the clamp allows the slider to assume its original shape, the lapped surface now having the desired contour which is the inverse of the contour produced in the initial bending operation. In practicing this method it is not necessary to use a cross-lapping motion. Rather, any suitable lapping motion is sufficient including a circular motion.

Experiments showed that the force necessary to produce the desired 300 to 400 micro-inch crown resulted in a saddle which was too deep, i.e., 50 micro-inches or more. Modification of the clamp fixture resulting in that shown in FIG. 7 concentrated the distributed pressure at points C, C', D and D' as shown in FIG. 5. This method has proven effective and workable using stainless steel, ceramic and aluminum. A critical requirement of this method is that the surfaces at which the slider is clamped must be true, unbroken accurate portions of a circle.

It should be apparent that with either of the two above-described embodiments, the slider may be removed periodically from the lapping surface and placed in a conventional optical instrument for monitoring the surface contour. Such conventional optical measuring techniques have been found to be adequate in quality control with respect to production units.

What is claimed is:

1. A method for producing a compound curved surface from a relatively flat blank comprising:
  - a. forming the inverse of a desired contour on an abrading surface by
    1. providing a relatively rectangular abrading surface,
    2. clamping said abrading surface to a flat rigid surface at the mid-points of one opposite pair of sides,
    3. raising the mid-points of an opposite pair of sides until the inverse of said desired contour is produced,
  - b. moving said blank in an abrading relation to said abrading surface in a first direction, and

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- c. reciprocating said blank in a second direction transverse to said first direction.
- 2. A method as in claim 1 wherein said movement in said first direction is a reciprocating movement.
- 3. A method as set forth in claim 1 wherein said

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abrading surface is ceramic coated steel.  
 4. A method as set forth in claim 1 wherein said blank is a recording head slider blank containing a magnetic core.

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