A machining spindle shaft assembly for a machine having a tool contact detection system. The shaft assembly (4) comprises a hollow non-metallic shaft member (41) which houses a tool holder (5) for holding a machining tool D. An electrically conductive coating (41a) is provided on an outer surface of the non-metallic shaft member (41) and an electrical conduction path is provided through the interior of the shaft member (41) such that the tool holder is electrically connected to the conductive coating at a location towards an end of the shaft member which is remote from the tool holder.
This invention relates to machining spindle shaft assemblies as well as machining spindles and machines including such machining spindle shaft assemblies.

In certain types of machining operation, in particular drilling operations (for example printed circuit board (PCB) drilling), there is a desire to know when the tool (for example drill bit) contacts with a workpiece. Examples of such contact detecting systems are shown in US4765784 and US6309151.

Often the spindle used in such a machining apparatus will be an air bearing spindle where the shaft carrying the tool for rotation is journaled in one or more radial air bearings. As such any physical mechanical contact between the spindle body and the shaft assembly is undesirable. As a consequence of this, contact drilling detection systems often make use of capacitive coupling between the shaft assembly and the spindle body. Thus for example, the contact drilling system may operate by virtue of there being a signal circuit including electrical contact with the spindle body and the workpiece to be machined and including capacitive coupling between the spindle body and the shaft assembly. The circuit can then be completed when a tool carried by the shaft assembly contacts with the workpiece. Contact between the tool and workpiece can be detected due to the completion of this circuit and a change in the electrical characteristics of the system as a result.

Typically shaft assemblies in such machining apparatus are made of steel or at least comprise a hollow steel, tube-like, shaft member within which other components are carried. This metallic tube provides a large area of conductive surface facing the spindle body which allows effective capacitive coupling.

However in some circumstances, in particular where particularly high speeds of rotation of a tool are required, there can be an advantage in using a non-metallic shaft member in place of a steel shaft member.
If this is done it causes a problem where there is desire to continue to use a tool contact detection system.

The present invention aims at addressing this issue.

According to one aspect of the present invention there is provided a machining spindle shaft assembly for a machine having a tool contact detection system, the shaft assembly comprising, a hollow non-metallic shaft member which houses a tool holder for holding a machining tool, wherein an electrically conductive coating is provided on an outer surface of the non-metallic shaft member and an electrical conduction path is provided through the interior of the shaft member such that the tool holder is electrically connected to the conductive coating at a location towards an end of the shaft member which is remote from the tool holder.

This enables electrical connection between a tool carried in the tool holder and the metallic coating hence allowing operation of a tool contact detection system of a machine with which the shaft is used, whilst avoiding relying on contact provided in the region of the tool holder.

As an initial attempt to allow use of a non-metallic shaft member one might provide an electrically conductive coating on the outer surface of such a non-metallic shaft member and provide for electrical contact between this coating and the tool holder at the nose of the spindle. Whilst this goes some way to providing a workable solution a further problem can arise. This is that the electrically conductive coating can tend to be damaged due to erosion or touch down events in the region of the nose of the spindle. This in turn can have the result of providing inadequate electrical connection between a carried tool and a sufficient area of the electrically conductive coating provided on the outside of the shaft member to give good capacitive coupling. The present invention also addresses this problem.

The non-metallic shaft member may be a ceramic shaft member.
The electrically conductive coating may be a metallic coating. The electrically conductive coating may be provided on the outer curved surface of the shaft member and on at least one axial end surface, in particular the end remote from the tool holder.

The shaft assembly may comprise a plurality of metallic parts besides the tool holder housed within the hollow shaft member. The conduction path may comprise the tool holder and at least some of said plurality of metallic parts.

At least some of the tool holder and plurality of metallic parts may be bonded with adhesive to the internal wall of the hollow shaft member. The adhesive may be a structural adhesive, and may for example be an epoxy based adhesive. The adhesive may be a resilient adhesive. This may be more resilient than a conventional epoxy based adhesive. Two different adhesives may be used, each at respective different locations. The adhesives may be chosen such that one of the adhesives is more resilient than the other. A first of the adhesives may be a structural adhesive the second adhesive may be more resilient.

The tool holder may be bonded by adhesive to the interior of shaft member towards a first end of the shaft member.

The shaft assembly may comprise a thrust runner insert fitted to the end of the shaft member which is remote from the tool holder. The thrust runner may be bonded by adhesive to the interior of shaft member towards said remote end of the shaft member.

In a region where the thrust runner insert meets the remote end of the shaft member, the thrust runner insert may be bonded to the shaft member by an electrically conductive adhesive for helping ensure electrical contact to the electrically conductive coating provided on the shaft member.

In a region where the thrust runner insert meets the remote end of the shaft member, the thrust runner insert may be bonded to the shaft member by a
resilient adhesive for helping ensure electrical contact to the electrically conductive coating provided on the shaft member.

The electrically conductive adhesive may be resilient.

In other regions, the thrust runner insert may be bonded to the shaft member with a different, structural, adhesive. Such an adhesive will typically have a better load bearing capability than the conductive and/or resilient adhesive.

The tool holder may comprise a tapered collet for holding a tool. The collet may be received in a sleeve having a correspondingly tapered bore. The sleeve may be bonded to the shaft member.

The tool holder may comprise a spring pack for drawing the collet into the sleeve to grip a carried tool.

The shaft assembly may comprise a magnet arrangement for forming part of a motor for rotationally driving the shaft. The magnet arrangement may be bonded to the shaft member.

The tool holder may comprise a rod for actuating the collet.

Said rod may extend through an axial hole provided through the magnet arrangement.

The magnet arrangement may comprise an end ring at at least one axial end of the arrangement. The end ring may guide the rod.

Said rod may comprise a push rod arranged to act on the spring pack to allow the collet to be moved against the action of the spring pack to release a carried tool.

Said rod may comprise a draw bar arranged to allow the spring pack to act on the collet.
A balance insert may be provided for use in balancing the shaft assembly. The balance insert may be bonded to the shaft member.

The conduction path may comprise any one of or any combination of: the collet, the rod, the magnet arrangement (for example the end ring), the balance insert, the thrust runner insert.

Conductive grease may be provided between respective adjacent metallic components within the hollow shaft to help ensure a continuous conduction path. Conductive adhesive may be provided between respective adjacent metallic components within the hollow shaft to help ensure a continuous conduction path.

According to another aspect of the present invention there is provided a machining spindle for a machine having a tool contact detection system, the machining spindle comprising a spindle body in which a shaft assembly as defined above is journalled for rotation.

Preferably the spindle comprises at least one radial air bearing.

According to another aspect of the present invention there is provided a machine comprising a machining spindle and a tool contact detection system for detecting when a tool carried by the machining spindle contacts a work piece, wherein the machining spindle comprises a spindle body in which a shaft assembly as defined above is journalled for rotation, and the tool contact detection system comprises means for applying an electrical signal to and/or sensing an electrical signal in the conductive coating provided on the shaft member.

The machining spindle shaft assembly may be a drilling spindle shaft assembly.

The machining spindle may be a drilling spindle.
The machine may be a drilling machine.

Embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings in which:

5 Figure 1 schematically shows a PCB drilling machine;

Figure 2 schematically shows a drilling spindle of the drilling machine shown in Figure 1;

10 Figure 3 shows in more detail a drilling spindle shaft assembly of the drilling spindle shown in Figure 2;

Figure 4 schematically shows a non-metallic shaft member of the shaft assembly shown in Figure 3; and

15 Figure 5 shows a detail of a thrust runner insert which forms part of the shaft assembly shown in Figure 3.

Figure 1 schematically shows a PCB drilling machine 1 comprising a drilling spindle 2 which in turn comprises a spindle body 3 and a shaft assembly 4. The shaft assembly 4 is arranged for holding a tool, in this instance a drill bit D, and is arranged for rotation relative to the spindle body 3 such that tool D can be used to machine, in this case drill, a workpiece W. The drilling machine 1 also comprises a tool contact detection system 11 which is arranged for detecting when a carried tool D contacts with a workpiece W. The detailed structure and operation of the drilling machine in general and the tool contact detection system 11 is not particularly pertinent to the present invention save for the fact that the shaft assembly 4 is designed for operation in such a system where the tool contact detection system 11 relies on capacitive coupling between the shaft assembly 4 and the spindle body 3. Thus further description of the drilling machine and tool contact detection system 11 is omitted.

Figure 2 shows more detail of the drilling spindle 2, although still in schematic form. The shaft assembly 4 is journalled for rotation in two radial aerostatic air
bearings 31 with an outer surface of a tube-like shaft member 41 of the shaft assembly facing the air bearings 31. The shaft assembly 4 is also supported by a thrust bearing 31 via thrust runner insert 42. A motor M1, M2 is provided for rotationally driving the shaft assembly 4 relative to the spindle body 3. The motor comprises a stator M1 in the spindle body 3 and a rotor M2 comprising a magnet arrangement comprising a permanent magnet housed within the tube-like shaft member 41.

Figure 3 shows the shaft assembly 4 in further detail.

In the present system the tube-like shaft member 41 is a non-metallic tube-like hollow shaft member 41 in which are housed the other components of the shaft assembly 4. The shaft member 41 houses a rotary tool holder 5 for holding a tool such as the drill D. The rotary tool holder 5 comprises a tapered collet 51 which runs within a complementary tapered sleeve 52 and is acted upon by a spring pack 53 for drawing collet 51 into the sleeve 52 to grip a carried tool. Mounted to the end of the tapered collet 51 is a push rod 54 which extends through a hole in the magnet arrangement M2 which forms the rotor of the motor M1, M2. The push rod 54 extends through a balance insert 55 which can be used in balancing the shaft assembly and which is provided on the side of the magnet M2 opposite to the collet 51. At each end of the magnet arrangement M2, an end ring M2a is provided which contacts with and supports the push rod 54. One of these end rings M2a contacts with the balance insert 55.

The thrust runner insert 42 has an insert portion 42a which is located within the hollow shaft member 41 and a thrust runner portion 42b which is supported in the thrust bearing 31 of the spindle body 3. The insert portion 42a is extended within the shaft member 41 so as to reach and contact with the balance insert 55.

As schematically illustrated in Figure 4 the non-conductive hollow shaft member 41 is provided with an electrically conductive coating 41a over the outer curved surface of the tube-like member as well as the annular axial end surfaces 41b of
the tube. In the present embodiment the hollow non-metallic shaft member 41 is a ceramic shaft member and the coating 41a is a metallic coating.

In order to allow the shaft assembly 4 to be useful as part of a drilling machine 1 including a tool contact detection system 11, an electrical conduction path is provided through the components internal to the tube-like shaft member 41 to the metallic coating 41a.

As mentioned in the introduction whilst one might first assume that such a connection path might be provided at the nose of the spindle where the rotary tool holder 5 and in particular the collet 51 is located, in practice this is undesirable. Erosion of the coating 41a at the nose of the spindle and/or touch down events in the front bearing 31 due to drilling operation would tend to cause an undesirable deterioration or complete severing of such an electrical connection path to the vast majority of the metallic coating 41a. Thus in the present embodiment an electrical conduction path is provided through the rotary tool holder 5, the balance insert 55, and the thrust runner insert 42 to the rear of the shaft member 41. In particular the conduction path runs through the collet 51, the push rod 54, at least one of the end rings M2a, the balance insert 55 and the thrust runner insert 42, which components are arranged to be in mechanical and electrical contact with one another. Furthermore, conductive grease and/or conductive adhesive may be provided at various locations between these components to help ensure good electrical contact. In particular, conductive grease may be provided between the push rod 54 and the end rings M2a and conductive adhesive may be provided between the balance insert 55 and the thrust runner insert 42.

The internal components of the shaft assembly 4 are bonded to the internal surface of the hollow shaft member 41 via a structural adhesive which may be an epoxy based adhesive. In particular the sleeve portion 52, an outer sleeve of the spring pack 53, an outer sleeve of the magnet M2, the balance insert 55 and the thrust runner insert 42 are adhesively bonded to the internal curved surface of the hollow shaft member 41. Structural adhesive is used for bonding each of these components in place. However a portion of the insert portion 42a of the
thrust runner insert 42 close to the thrust runner portion 42b is bonded using a flexible (or resilient) electrically conductive adhesive. Suitable adhesives for this purpose include Loctite (RTM) 3880 which has a composition including: Silver, Epichlorohydrin-4.4'-isopropylidene Diphenol Resin, Epoxy Resin, Aliphatic Polyepoxide, Polyamide Hardener, Aliphatic Amine, Diethylene Glycol Monoethyl Ether Acetate, Resin. This portion of the thrust runner insert 42 close to the thrust portion 42b is shown enlarged in Figure 5.

Ideally one might to try to avoid the existence of adhesive between the end annular surface 41b of the hollow shaft member 41 and the thrust runner portion 42b. This is for two reasons. First the presence of the adhesive might interfere with electrical contact between the thrust runner insert 42 and the conductive coating 41a. Second during high speed rotation, the thrust runner portion 42b will tend to exhibit diametrical growth due to centrifugal effects and this may cause stress on the hollow shaft member 41 which would be undesirable. However in practice avoiding the presence of adhesive in this region is impractical and the use of electrically conductive flexible adhesive resolves this problem.

The thrust runner insert 42 comprises an undercut 42c in the region where the thrust runner portion 42b meets the insert portion 42a. This undercut 42c is filled with electrically conductive flexible adhesive which helps ensure electrical contact between the thrust runner insert 42 and the coating 41a on the hollow shaft member 41. At the same time this undercut 42c allows for diametrical growth of the thrust runner insert 42 in the region of the thrust runner portion 42b whilst removing or alleviating any stress that this may cause on the end of the hollow shaft member 41.

Rather than using a flexible conductive adhesive in this region of the undercut 42c and the region between the end of the hollow shaft member 41 and thrust runner portion 42b, the use of conductive grease might be attempted. However this grease would tend to extrude out of this space due to centrifugal effects during high speed rotation in use, degrading the quality of the electrical conductive path between a carried tool and the electrically conductive coating and/or the non-conductive structural adhesive used elsewhere on the thrust
runner portion 42b might tend to get transferred/driven into this region during assembly and again disrupt the conduction path.
CLAIMS

1. A machining spindle shaft assembly for a machine having a tool contact detection system, the shaft assembly comprising,

5 a hollow non-metallic shaft member which houses a tool holder for holding a machining tool, wherein an electrically conductive coating is provided on an outer surface of the non-metallic shaft member and an electrical conduction path is provided through the interior of the shaft member such that the tool holder is electrically connected to the conductive coating at a location towards an end of the shaft member which is remote from the tool holder.

2. A machining spindle shaft assembly according to claim 1 in which the non-metallic shaft member is a ceramic shaft member.

3. A machining spindle shaft assembly according to claim 1 or claim 2 in which the electrically conductive coating is a metallic coating.

4. A machining spindle shaft assembly according to any one of claims 1 to 3 in which the shaft assembly comprises a plurality of metallic parts besides the tool holder housed within the hollow shaft member and the conduction path comprises the tool holder and at least some of said plurality of metallic parts.

5. A machining spindle shaft assembly according to claim 4 in which at least some of the tool holder and plurality of metallic parts are bonded with adhesive to the internal wall of the hollow shaft member.

6. A machining spindle shaft assembly according to claim 5 in which two different adhesives are used, each at respective different locations, wherein one of the adhesives is more resilient than the other.

7. A machining spindle shaft assembly according to claim 6 in which the more resilient adhesive is electrically conductive.
8. A machining spindle shaft assembly according to any preceding claim in which the shaft assembly comprises a thrust runner insert fitted to the end of the shaft member which is remote from the tool holder wherein the tool holder is bonded by adhesive to the interior of shaft member towards a first end of the shaft member and the thrust runner is bonded by adhesive to the interior of shaft member towards said remote end of the shaft member.

9. A machining spindle shaft assembly according to claim 8 in which in a region where the thrust runner insert meets the remote end of the shaft member, the thrust runner insert is bonded to the shaft member by an electrically conductive adhesive for helping ensure electrical contact to the electrically conductive coating provided on the shaft member.

10. A machining spindle shaft assembly according to claim 9 in which the electrically conductive adhesive is resilient.

11. A machining spindle shaft assembly according to claim 9 or claim 10 in which, in other regions, the thrust runner insert is bonded to the shaft member with a different, structural, adhesive.

12. A machining spindle shaft assembly according to any preceding claim in which the shaft assembly comprises a thrust runner insert and the tool holder comprises a tapered collet for holding a tool, the collet being received in a sleeve having a correspondingly tapered bore, and the tool holder comprising a spring pack for drawing the collet into the sleeve to grip a carried tool, wherein the tool holder comprises a rod for actuating the collet, and the conduction path comprises the collet, the rod and the thrust runner insert.

13. A machining spindle for a machine having a tool contact detection system, the machining spindle comprising a spindle body in which a shaft assembly according to any preceding claim is journalled for rotation.
14. A machine comprising a machining spindle and a tool contact detection system for detecting when a tool carried by the machining spindle contacts a work piece, wherein the machining spindle comprises a spindle body in which a shaft assembly according to any one of claims 1 to 12 is journalled for rotation, and the tool contact detection system comprises means for applying an electrical signal to and/or sensing an electrical signal in the conductive coating provided on the shaft member.
INTERNATIONAL SEARCH REPORT

PCT/GB2015/054032

A. CLASSIFICATION OF SUBJECT MATTER

INV. B23Q1/70 B23Q17/09

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B23Q

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 practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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