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Description

The present invention relates to an apparatus for the thermal processing of a workpiece, the apparatus comprising a thermal processing tool which is supported
5 so as to be adjustable in a direction perpendicular to the workpiece surface, and a drive adjusting a work distance of the thermal processing tool from the surface, wherein the drive adjusting the work distance being in operative communication with the thermal processing tool or a part thereof is configured as a voice coil actuator, comprising a magnet that produces a magnetic field, and a coil arranged
10 in the magnetic field, said magnet and said coil being movable relative to each other along a movement axis in response to an electric current.

The thermal processing of workpieces particularly comprises welding, cutting and surface treatment for producing markings. Depending on the task to be handled, different processing machines and different types of processing tools are used.
15 Various processing tools such as oxyfuel torches, plasma torches or lasers are available for the thermal cutting of workpieces.

The thermal cutting of materials by using an oxyfuel torch is carried out by the combined use of a combustion gas jet and an oxygen gas jet. Material separation is here carried out in that the material is fused in the area of the cutting front by
20 the combustion heat and is expelled by the cutting gas jet out of the cutting front.

The thermal cutting of materials by means of a laser beam is carried out by the combined use of a focused laser beam and a gas jet. Depending on the separating mechanism, a distinction is here made between laser-beam fusion cutting, laser-beam evaporation cutting or laser flame cutting.
25 For a precise cutting of a workpiece it is important that a predetermined distance between the cutting tool and the workpiece is observed. The optimal distance depends on various factors, among these e.g. the workpiece quality and the workpiece thickness. This is true for the cutting by means of oxyfuel torches, wherein the flame produced by the torch has a characteristic temperature

distribution, and also for the focal position of the laser beam during thermal cutting by means of a laser beam.

Prior art

Many methods and apparatuses are known for adjusting and maintaining the
5 optimal distance.

For instance, DE 195 03 758 A1 discloses a driving device for the vertical adjustment of a burner of a gas cutting machine, wherein an electric motor type drive serves to adjust the distance between the tool (cutting head) and the workpiece. An electric motor in combination with a threaded spindle is used as the
10 drive.

DE 699 26 679 T2 discloses a method for adjusting the focal point position of a laser beam of a laser cutting machine, which is accomplished by varying the distance between a converging lens and an exit nozzle. The converging lens is locally fixed. A drive mechanism moves the laser head upwards and downwards
15 independently of the converging lens, whereby the distance between the converging lens and the exit nozzle is set. A motor which drives a ball screw is used as the drive device for the laser head.

Electric motors require some space, produce imbalances and contribute to a greater structural form of the apparatus, resulting in low machine dynamics.

20 As an alternative to electric motors, so-called voice coil actuators have become popular, especially when the generation of precise linear movements is of importance.

Such a voice coil actuator is e.g. suggested in EP 0 868 962 A2 for the three-dimensional movement of a tool. Shifting platforms are provided for movement in
25 the horizontal plane, each platform being arranged between two voice coil actuators. Only one voice coil actuator on which the tool is mounted is provided for movement in the vertical direction.

An apparatus according to the generic part of claim 1 is known from US 2010/0044355 A1.

A method and a generic apparatus in the form of a thermal processing machine for the processing of wafers by means of a laser are known from US 5 2005/0184036 A1. The voice coil actuator is here provided for focusing the lens system along the optical axis, and voice coil actuators are here arranged next to and also above or below the lens system.

Technical object

The arrangement of the tool between two voice coil actuators and also the 10 separate arrangement of the voice coils above, below or next to the lens require a lot of space and may contribute to imbalances in the case of fast movements.

It is therefore the object of the present invention to provide a drive for a thermal processing machine that affords a compact structural form and high machine dynamics.

15 General description of the invention

This object, starting from an apparatus of the aforementioned type, is achieved according to the invention by an apparatus that shows the features of claim 1.

In the apparatus according to the invention a voice coil actuator is provided for adjusting the work distance during the thermal processing of workpieces. Voice 20 coil actuators are per se known from the prior art. The drive movement is based on the fact that a current carrying coil is moveable in a magnetic field relative to the magnetic field lines. The drive movement is here carried out either by movement of the coil itself or of the magnet producing the magnetic field. In contrast to a distance adjustment e.g. by means of motor and threaded spindle, 25 the use of the voice coil actuator provides for a particularly compact and lightweight structural form of the apparatus. Voice coil actuators are not very prone to wear, produce no abrasion and permit a fast dynamic adjustment of the work distance.

An essential feature of the invention consists in that the voice coil actuator comprises a cavity which has arranged therein the processing tool, or a part thereof, which is in operative communication with the voice coil actuator. The tool part accommodated within the cavity would otherwise have to be arranged outside
5 the voice coil actuator. This arrangement therefore permits a particularly compact structural form. The processing tool or a part thereof is completely enclosed by the voice coil, but it may also project out of the cavity.

The processing tool is e.g. a laser or a torch. The coil has a one-part or multi-part configuration. In the simplest case the magnet is a ring magnet. However, the
10 magnet may also be composed of a plurality of ring magnets or of a plurality of magnetic components. The magnet may also be a coil.

To achieve enhanced machine dynamics and to avoid imbalances, it has turned out to be particularly advantageous when the processing tool or a part thereof is guided along a movement axis and the voice coil actuator is symmetrically
15 arranged about this movement axis.

The mechanical connection is established by means of a sleeve projecting into the cavity.

The sleeve serves to fasten the processing tool or a part thereof and can simultaneously be used as an adapter for different dimensions of the processing
20 tool or a part thereof.

According to a preferred variant of the apparatus the cavity is configured as an inner bore of a permanent magnet.

In contrast to the generation of a magnetic field e.g. by means of solenoids, no further electrical supply and no control are needed for the magnet if a permanent
25 magnet is used.

Preferably, for adjustment of the work distance is accomplished using a first device providing coarse adjustment and a second device providing fine adjustment, the first device comprising a coarse adjustment drive and the second device comprising a fine adjustment drive which is formed by the voice coil.

The coarse adjustment and the fine adjustment are preferably carried out at different speeds. To adjust the work distance, a coarse adjustment is first carried out, and the fine adjustment is then performed by means of the voice coil actuator.

A high speed during coarse adjustment will shorten the setup time; the dynamic
5 fine adjustment makes it possible that even minor irregularities of the workpiece that lead to inaccuracies in the cutting process can rapidly be taken into account.

It has turned out to be useful when the cavity is made continuously cylindrical and has a diameter in the range of 20 mm to 70 mm.

A continuous cavity can be manufactured easily. Thermal processing operations
10 typically use tools that have lateral dimensions of more than 20 mm. In the case of a cavity diameter of less than 20 mm, these common tools would no longer be operable with the drive according to the invention. Diameters of more than 150 mm result in heavy weights for the drive, such weights reducing the machine dynamics.

15 It has turned out to be useful when the stroke range of the voice coil actuator is 5 mm to 30 mm.

This stroke range is particularly suited for fine adjustment.

In an advantageous configuration of the apparatus the processing tool is a laser that comprises at least one lens which as part of the processing tool is
20 mechanically connected to the voice coil actuator and is arranged in the cavity.

The arrangement of the lens within the cavity of the voice coil actuator permits a particularly compact structure of the drive of the focusing unit of the laser. It can be integrated into a bevel-suited laser head with lateral lens adjustment. The positioning of the lens relative to the workpiece surface or of another beam-
25 forming optical component is regulated for the focusing of the laser beam by means of the voice coil actuator and permits short setup times.

It is foreseen that the lens is connected to the movably supported coil of the voice coil actuator.

The lens is supported within the cavity of the magnet to be movable along the movement axis and is moved by means of the coil. The mechanical connection between lens and coil is established by means of a sleeve e which projects into the cavity and is movable along the movement axis and which serves to hold the
5 lens at the same time.

By that it is taken into account that the coil and the magnet of the voice coil actuator are movable relative to one another and that the processing tool or a part thereof can be fastened to the coil.

It has turned out to be advantageous when the voice coil actuator comprises a
10 pressure window which seals the cavity outwardly.

This permits a dynamic adjustment of the work distance also in the case of increased or lowered gas pressures outside the cavity, as occur e.g. during the cutting process (so-called cutting pressure).

In a further advantageous configuration of the apparatus, the processing tool is a
15 torch which comprises a torch shaft and a torch head connected to the torch shaft, the torch shaft being mechanically connected to the voice coil actuator and projecting through the cavity.

The torch is a torch for welding, cutting, marking, soldering or scarfing.

The invention will now be described in more detail with reference to embodiments
20 and a drawing. The drawing shows in detail in schematic representation in:

Fig. 1 a first embodiment of the apparatus according to the invention with voice coil actuator for a processing machine for thermal laser processing;

Fig. 2 a second embodiment of the apparatus according to the invention
25 with voice coil actuator for a gas cutting machine with cutting torch;
and

Fig. 3 a third embodiment of the apparatus according which falls not into the scope of claim 1 with an alternative voice coil actuator for a processing machine for thermal laser processing.

Fig. 1 shows a drive for focusing a laser beam of a laser processing machine in the form of a voice coil actuator, which has reference numeral 1 assigned to it on the whole. The voice coil actuator 1 is composed of a housing part 2 in which a permanent magnet 3 with a north pole 3a and a south pole 3b is stationarily supported. The magnet 3 produces a magnetic field in which two coils 5a, 5b are positioned that in the direction of the movement axis 10 are fastened to a carrier 4 in spaced-apart relationship with each other. The carrier 4 comprises a surrounding sidewall 4a which is connected to an inwardly projecting flange 4b. The carrier 4 grips over the magnet in the manner of a bow. The sidewall 4a of the carrier 4 serves to receive the coils 5a, 5b. The carrier 4 has mounted thereon a connection element in the form of a sleeve 9 which, while leaving an annular work air gap, projects into the cavity 7 and is freely movably supported along the movement axis 10. Both coils 5a, 5b are connected via connections 6 to a voltage source (not shown).

It is essential for the present invention that the housing 2 encompasses a centric cylindrical cavity 7 which has arranged therein a framed lens 8 which serves to focus the laser beam. The lens 8 is mounted in the sleeve 9 which can be moved upwards and downwards within the cavity 7 along the movement axis 10. The sleeve 9 is screwed with the flange 4b. When current is applied to the coils 5a, 5b, a force will act on the coils 5a, 5b due to the Lorentz force and the carrier 4 and the sleeve 9 together with the lens 8 mounted therein will be moved thereby. With the control of the current, the work distance A between the lens 8 and the workpiece surface 16 and thus the focal position of the laser beam is set. The cavity 7 is sealed by a pressure window 11 to the outside, thereby preventing the penetration of cutting gases into the cavity 7 and damage to the lens 8.

The maximal stroke of the coils 5a, 5b in the work gap is 20 mm. The outer diameter of the whole voice coil actuator 1 is 110 mm and the height in the non-extended state is 115 mm. The inner diameter of the cavity 7 is 63 mm and the

outer diameter of the sleeve 9 is 60 mm and its inner diameter 54 mm. The carrier 4 and the sleeve 9 consist of aluminum. The lens 8 is a focusing lens of quartz glass. The actuator 1 is designed for a peak force of up to 120 N. It ensures a high repeat and positioning accuracy in the nanometer range and is free of hysteresis.

- 5 As far as Figs. 2 and 3 use the same reference numerals as Fig. 1, these designate structurally identical or equivalent members and components as have been explained above in more detail with reference to the description of the first embodiment of the voice coil actuator according to the invention.

Fig. 2 shows a second embodiment of the apparatus according to the invention in
10 which a torch 13 is used as the processing tool. The torch 13 consists of a torch shaft 14 and a torch head 15. It is essential for the present invention that the torch shaft 14 extends through the central cavity 7 of the voice coil actuator 21.

The voice coil actuator 21 is used for adjusting the work distance A between torch
13 and workpiece surface 16 and is symmetrically arranged about the torch shaft
15 14 in the embodiment.

The voice coil actuator 21 is composed of a surrounding housing part 2 of U-shaped cross-section in which a permanent magnet 3 with a north pole 3a and a south pole 3b is stationarily supported. The magnet 3 produces a magnetic field in which two coils 5a, 5b are positioned that when, viewed in the direction of the
20 movement axis, are arranged one above the other and spaced apart from each other and are fastened to a carrier 4. The carrier 4 comprises a surrounding sidewall 4a which is connected to an inwardly projecting flange 4b. The carrier 4 grips over the magnet in the manner of a bow. The sidewall 4a serves to receive the coils 5a, 5b. Both coils 5a, 5b are connected via connections 6 to a voltage
25 source (not shown). A sleeve 9 which projects into the cavity 7 and is freely movably supported along the movement axis 10 is mounted on the flange 4b.

The sleeve 9 is screwed to both the carrier 4 and the torch shaft 14. When current is applied to the coils 5a, 5b, a force will act on the coils 5a, 5b due to the Lorentz force and the carrier 4, the sleeve 9 and also the torch 13 mounted therein will be

moved thereby along the movement axis 10. Due to the control of the current on the coils 5a, 5b, the distance of the torch 13 from the workpiece surface 16 is set.

The maximal stroke of the coils 5a, 5b in the work gap is 25 mm. The outer diameter of the whole voice coil actuator 21 is 135 mm and the height in the non-extended state is 130 mm. The inner diameter of the cavity 7 is 63 mm and the outer diameter of the sleeve 9 is 60 mm and its inner diameter 54 mm. The carrier 4 and the sleeve 9 consist of aluminum. The torch is an oxyfuel cutting torch. The actuator is designed for a peak force of up to 1,110 N. It ensures a high repeat and positioning accuracy in the nanometer range and is free of hysteresis.

10 **Fig. 3** shows an apparatus which does not fall into the scope of claim 1 with an alternative voice coil actuator 31 for a processing machine for thermal laser treatment. The voice coil actuator 31 is composed of a housing part 32 in which two coils 35a, 35b are stationarily supported and spaced apart in the direction of the movement axis and positioned one above the other. The coils 35a, 35b are
15 fastened to a carrier 34 and produce a magnetic field in which a magnet 33 with a north pole 33a and a south pole 33b is positioned. The magnet 33 is connected to a carrier 36 on which, in turn, a connection element is mounted in the form of a sleeve 9 which, while leaving an annular work air gap, projects into the cavity 7 and is freely movably supported along the movement axis 10. Both coils 35a, 35b
20 are connected via the connections 6 to a voltage source (not shown).

The housing 32 encompasses a centric cylindrical cavity 7 which has arranged therein a framed lens 8 which serves to focus the laser beam. The lens 8 is mounted in the sleeve 9 which can be moved upwards and downwards within the cavity 7 along the movement axis 10. The sleeve 9 is screwed with the carrier 36.
25 When current is applied to the coils 35a, 35b, a force will act on the magnet 33 due to the Lorentz force and the carrier 36 and the sleeve 9 together with the lens 8 mounted therein will be moved thereby. With the control of the current, the work distance A between the lens 8 and the workpiece surface 16 and thus the focal position of the laser beam is set. The cavity 7 is sealed by a pressure window 11
30 to the outside, thereby preventing the penetration of cutting gases into the cavity 7 and damage to the lens 8.

The maximal stroke of the coils 35a, 35b in the work gap is 20 mm. The outer diameter of the whole voice coil actuator 31 is 110 mm and the height in the non-extended state is 115 mm. The inner diameter of the cavity 7 is 63 mm and the outer diameter of the sleeve 9 is 60 mm and its inner diameter 54 mm. The carrier
5 4 and the sleeve 9 consist of aluminum. The lens 8 is a focusing lens of quartz glass. The actuator 31 is designed for a peak force of up to 120 N. It ensures a high repeat and positioning accuracy in the nanometer range and is free of hysteresis.

P a t e n t k r a v

1. Indretning til den termiske bearbejdning af et emne med et termisk bearbejdningssværktøj, der kan indstilles vinkelret på emneoverfladen (16), og
5 med et drev (1; 21) til indstilling af en arbejdsafstand (A), hvor drevet (1; 21) med henblik på indstilling af en arbejdsafstand er i funktionsforbindelse med bearbejdningssværktøjet (13) eller en del af samme (8) og er udformet som et svingspoledrev (1; 21), med en magnet (3), som frembringer et magnetfelt, og med en spole (5a; 5b), som er anbragt i magnetfeltet, hvor magnet (3) og
10 spole (5a; 5b) kan bevæges i forhold til hinanden langs en bevægelsesakse (10) afhængigt af en elektrisk strøm, hvor magneten (3) har et hulrum (7), hvori bearbejdningssværktøjet (13), som er mekanisk forbundet med svingspoledrevet (1; 21), eller en del af samme (8) er anbragt, **kendetegnet ved, at** den mekaniske forbindelse sker ved hjælp af en muffe (9), som rager ind i
15 hulrummet (7), og at muffen (9) er anbragt på en bærer (4), som griber over magneten (3) på en bøjleagtig måde, på hvilken bærer spolen (5a; 5b) er fastgjort.

2. Indretning ifølge krav 1 **kendetegnet ved, at** bearbejdningssværktøjet (13)
20 eller dele af samme (8) føres langs med bevægelsesaksen (10), og at svingspoledrevet (1; 21) er anbragt symmetrisk omkring denne bevægelsesakse (10).

3. Indretning ifølge et af de foregående krav,
25 **kendetegnet ved, at** hulrummet (7) er udformet som en indvendig boring af en permanent magnet.

4. Indretning ifølge et af de foregående krav,
kendetegnet ved, at der med henblik på indstilling af arbejdsafstanden (A)
30 er tilvejebragt en første indretning til grovindstilling og en anden indretning til finindstilling, hvor den første indretning har et grovindstillingsdrev, og den anden indretning har et finindstillingsdrev, som dannes af svingspolen (1; 21).

5. Indretning ifølge et af de foregående krav, **kendetegnet ved, at** hulrummet (7) er udformet gennemgående cylinderformet og har en diameter i om-

rådet fra 20 mm til 70 mm.

- 5 **6.** Indretning ifølge et af de foregående krav,
kendetegnet ved, at der for svingspoledrevet (1; 21) er tilvejebragt et slag-
område fra 5 til 30 mm.
- 10 **7.** Indretning ifølge et af de foregående krav,
kendetegnet ved, at bearbejdningssværktøjet er en laser, som har mindst en
linse (8), der som del af bearbejdningssværktøjet er mekanisk forbundet med
svingspoledrevet (1) og er anbragt i hulrummet (7).
- 15 **8.** Indretning ifølge krav 7, **kendetegnet ved, at** linsen (8) er forbundet med
den bevægeligt lejrede spole (5a; 5b) af svingspoledrevet (1).
- 20 **9.** Indretning ifølge et af kravene 7 eller 8, **kendetegnet ved, at** svingspole-
drevet (1; 21) har et trykvindue (11), som tætnet hulrummet (7) udadtil.
- 25 **10.** Indretning ifølge et af kravene 1 til 6, **kendetegnet ved, at** bearbejd-
ningssværktøjet er en brænder (13), som har et brænderskaft (14) og et med
brænderskaftet (14) forbundet brænderhoved (15), hvor brænderskaftet (14)
er mekanisk forbundet med svingspoledrevet (21) og rager gennem hulrum-
met (7).

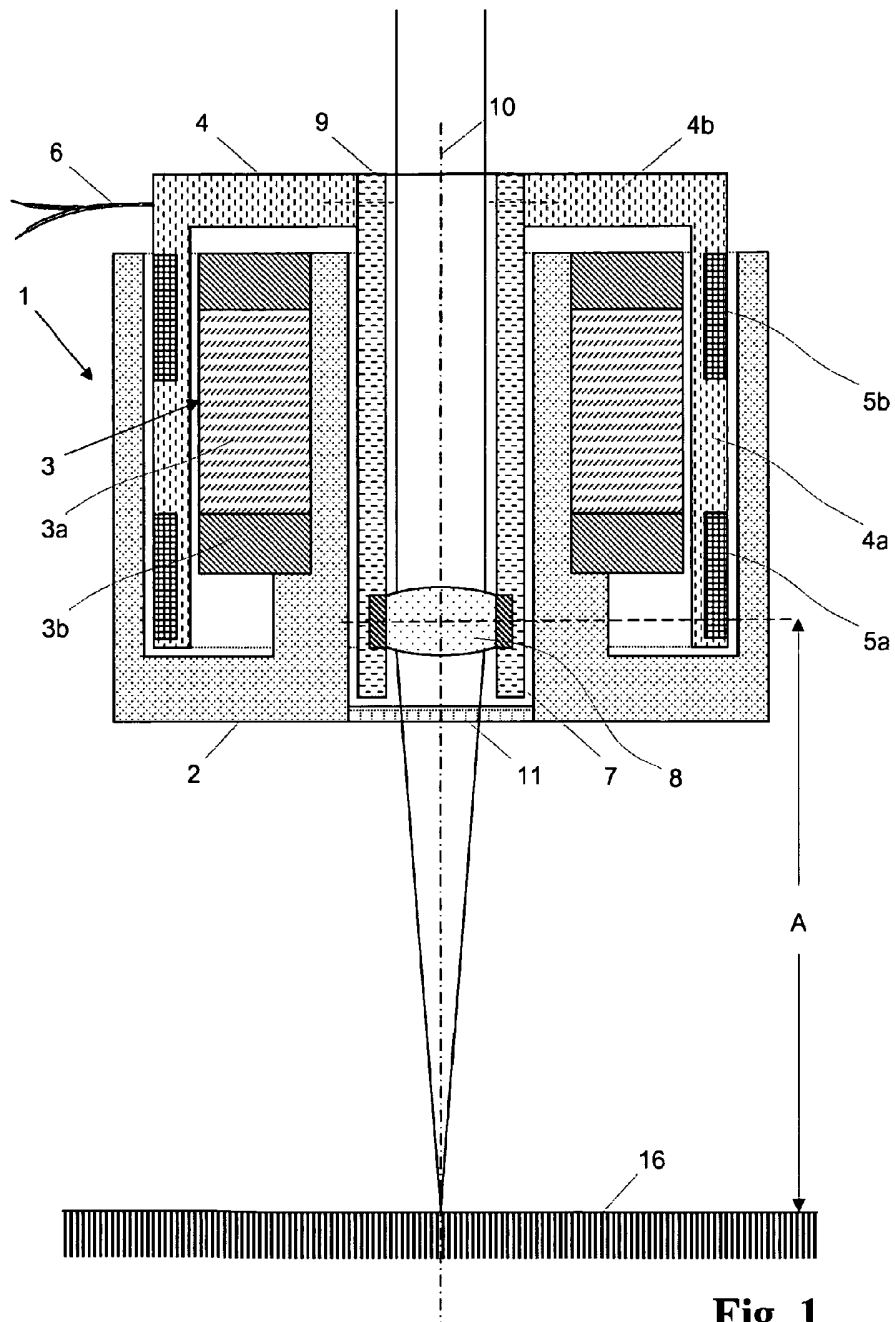


Fig. 1

