

HYBRID BEARING ARRANGEMENT

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RELATED APPLICATIONS

[0001] This application claims the benefit of US Provisional Patent 63/448,953, filed February 28, 2023, which is herein incorporated by reference, in its entirety, for all purposes.

FIELD OF THE DISCLOSURE

[0002] The disclosure relates to high-speed, precision placement and, more particularly, to the reduction of distortion in gantries, using a hybrid bearing arrangement.

BACKGROUND

[0003] Gantry, i.e. platforms made to carry a traveling crane or similar that are supported by towers or side frames running on parallel tracks, are used in a wide variety of applications, such as in die bonding, loading and unloading of ships in port, and railroad car loading and unloading. Friction between the gantry and tracks in which it is slidingly disposed, however, can cause the gantry to flex. This is especially true where the gantry is driven on one side only (also referred to herein as the inboard side) and the friction is present on the non-driven side (also referred to herein as the outboard side) of the gantry. Any flexing of the gantry or gantry frame will cause distortion that results in placement inaccuracies, which are especially important to avoid where high-precision placement is required.

[0004] Additionally, any friction on a non-driven side of a gantry will result in a delay, or hysteresis, before the non-driven side catches up to (and potentially overshoots) the driven side, due to static friction. This results in a positional

mismatch between the driven and non-driven sides of the gantry that is especially noticeable during small movements and precision placements. While gantries that are driven on both sides, such as H-bridge gantries, do exist, these are more complex and costly compared to those that are driven on only one side.

[0005] To combat these phenomena, the gantry and/or gantry frame may be made stronger, however, this also typically increases weight, reducing the speed at which the gantry can travel and weight the gantry can lift, and/or cost. This additional weight also results in the gantry having a greater moment, which results in greater friction and flexure, requiring even more strength (and weight) to be added. Additionally, any extra weight increases shipping costs and environmental impact of the gantry, due to the increased resources required to transport the gantry and the additional material used during its manufacture.

[0006] Using die bonding as a non-limiting example, typical die bonding applications involve placing dies on substrates. This process must be completed as fast as possible to maximize productivity, however, due to the small scale of the components, placement must be done very carefully and accurately to ensure that the placed dies will function correctly and not be damaged during the bonding process. In this context, moving a relatively lightweight gantry rapidly and precisely, as is required to complete die bonding operations as fast as possible and keep overall cycle times low, induces unwanted flexing in such systems due to friction between the gantry and a frame in which it is disposed while this same friction also creates hysteresis in the system that prevents accurate placement, especially when movements are particularly small. This flex must be kept below a threshold value to ensure sufficient placement accuracy for the application.

[0007] While some gantries utilize air bearings on both a driven and non-driven side to reduce unwanted friction, this increases the size and cost of the gantry considerably, making packaging more difficult, while also requiring significant air usage, the cost of which can be significant.

[0008] What is needed, therefore, is a way to reduce gantry flexing, particularly during high-speed, precision placement operations, that does not increase the

weight, cost, or complexity of the gantry itself or require it to move more slowly, thereby retaining or improving on currently-achievable cycle times, while also not significantly increasing the size or resource requirements of the gantry.

SUMMARY

[0009] Disclosed herein is a hybrid bearing arrangement that reduces bowing of gantries and/or gantry frames and increases placement accuracy and repeatability and is suitable for use with a variety of gantry types, including those used in die bonding systems.

[0010] One object of the present disclosure is to reduce friction between a gantry and machine frame on which the gantry is mounted, friction having been found to be a significant cause of bowing, without significantly increasing the cost or resource requirements of the system.

[0011] In embodiments, friction is reduced by utilizing an air bearing on a non-driven side of a gantry, opposite a driven side thereof. In embodiments, the gantry is a three-bearing gantry, with two bearings on a driven side and a single bearing on a non-driven side. In embodiments, the driven-side bearings are rolling element linear bearings.

[0012] While such embodiments increase the size of the gantry as well as its resource (compressed air) requirements somewhat, such a design has been found to provide many of the same benefits of a design employing air bearings on both driven and non-driven sides while being much more cost effective, resource-efficient, and easier to package/smaller in size. Such a design also tends to be stiffer than designs employing air bearings on both driven and non-driven sides. Additionally, the outboard side of gantries, especially those used in typical die bonding systems, tends to have more space for an air bearing, relative to the driven side, resulting in the use of an air bearing on this side of the gantry typically being easier to incorporate into the overall system design.

[0013] Implementations of the approach described above may include a method or process, a system or apparatus, a kit, or computer software stored on a

computer-accessible medium. The details or one or more implementations are set forth in the accompanying drawings and the description below. Other features will be apparent from the description and drawings, and from the claims.

[0014] The features and advantages described herein are not all-inclusive and, in particular, many additional features and advantages will be apparent to one of ordinary skill in the art in view of the drawings, specification, and claims. Moreover, it should be noted that the language used in the specification has been selected principally for readability and instructional purposes and not to limit the scope of the inventive subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] Figure 1 is a top, front-right perspective view of a die bonding system including a gantry and frame, in accordance with embodiments of the present disclosure;

[0016] Figure 2 is a top, front-right perspective view of a gantry and frame, in accordance with embodiments of the present disclosure;

[0017] Figure 3 is a front elevation view of a gantry and frame, in accordance with embodiments of the present disclosure;

[0018] Figure 4 is a top, front-left, exploded perspective view of a gantry and frame, in accordance with embodiments of the present disclosure; and

[0019] Figure 5 shows the gantry itself, outside of a frame, in accordance with embodiments of the present disclosure.

[0020] These and other features of the present embodiments will be understood better by reading the following detailed description, taken together with the figures herein described. The accompanying drawings are not intended to be drawn to scale. For purposes of clarity, not every component may be labeled in every drawing.

DETAILED DESCRIPTION

[0021] Disclosed herein is a hybrid bearing arrangement suitable for use, *inter alia*, on gantries, such as those commonly used on die bonding systems **100**, such as that shown in Figure 1. Such an arrangement, however, could be used anywhere that high repeatability with a large, lightweight, cost-effective gantry is desired.

[0022] In current gantries, friction between the gantry **102** and tracks disposed in a machine frame **104** in which the gantry **102** is slidably disposed can cause the gantry **102** to flex. Friction on the non-driven side of gantries **102** having a driven and non-driven side has been found to be particularly problematic, resulting in almost all of the hysteresis observed in such systems. Any flexing of the gantry **102** or machine frame **104** can result in inaccurate placement, which is especially important to avoid where high precision placement is required.

[0023] Now referring to Figure 2, a gantry **102** in accordance with embodiments of the present disclosure is depicted. In this example, the gantry **102** is slidably disposed in a machine frame **104**, which may be a part of a larger system, such as a die bonding system **100**. In embodiments, the gantry **102** comprises an x-stage **110**, a y-stage **114**, and a z-stage **112**, allowing the gantry **102** to move an object in those three dimensions. On the driven side of the gantry **102**, which is depicted as and will typically be the wider side, linear bearings **106** may be used to allow the gantry **102** to slidably engage and traverse the machine frame **104** while, on the non-driven, side of the gantry **102**, substantially frictionless bearings **108** may be used to reduce hysteresis effects.

[0024] In practice, such an implementation has been found to remove substantially all hysteresis from the system without the need for frictionless bearings **108** on the driven side of the gantry **102**, keeping cost, size, and resource requirements low, relative to designs employing frictionless bearings **108** on both sides. Additionally, a major disadvantage of air bearings is that they are not very stiff, so typically benefit from a non-contact drive. By using a stiffer bearing, such as a linear bearing **106**, stiffness of the driven side can be increased, decreasing costs while improving performance and allowing the use of contact-

based drive means, in embodiments a linear motor, such as a ball screw linear motor.

[0025] In embodiments, the substantially frictionless bearings comprise air bearings **108**, in embodiments top and bottom air bearings **108**, which provide an essentially friction-free interface between the outboard portion of the gantry **102** and machine frame **104**.

[0026] In embodiments, an outboard end of the gantry **102** comprises at least two air bearings **108**, a top and bottom air bearing **108**, with those bearings being configured to slidably engage a portion of the machine frame **104** in which the gantry **102** is disposed.

[0027] In embodiments, the linear bearings **106** are rolling element linear bearings **106**.

[0028] In embodiments, the linear bearings **106** comprise linear bushings **106**.

[0029] In embodiments, a non-contact motor is used to drive the driven side of the gantry **102**.

[0030] In embodiments, the outboard end of the gantry **102** is lighter than the inboard end of the gantry **102**, reducing the gantry's moment.

[0031] In embodiments, accelerometers are attached to the gantry **102** and/or machine frame **104** and provide feedback to an open or closed loop control system configured to damp any vibrations, especially those associated with frame settling, allowing for improvements in cycle time and/or precision. In embodiments, the control system is configured to control the drive means to dampen vibrations.

[0032] The foregoing description of the embodiments of the present disclosure has been presented for the purposes of illustration and description. It is not intended to be exhaustive or to limit the present disclosure to the precise form disclosed. Many modifications and variations are possible in light of this disclosure. It is intended that the scope of the present disclosure be limited not by this detailed description, but rather by the claims appended hereto.

[0033] A number of implementations have been described. Nevertheless, it will be understood that various modifications may be made without departing from the scope of the disclosure. Although operations are depicted in the drawings in a particular order, this should not be understood as requiring that such operations be performed in the particular order shown or in sequential order, or that all illustrated operations be performed, to achieve desirable results.

CLAIMS

What is claimed is:

- 1 1. A die bonding system comprising:
2 a gantry having an inboard side and an outboard side, the gantry
3 comprising at least one substantially frictionless bearing
4 disposed on the outboard side;
5 a frame configured to support the gantry while providing for relative
6 motion between the gantry and frame in one dimension; and
7 a drive configured to drive the inboard side of the gantry,
8 wherein the at least one substantially frictionless bearing is configured
9 to slidingly engage an outboard portion of the frame, and
10 wherein the outboard side of the gantry is non-driven.
- 1 2. The die bonding system of claim 1, wherein the drive is a
2 contact-based drive.
- 1 3. The die bonding system of claim 1, wherein the at least one
2 substantially frictionless bearing comprises an air bearing.
- 1 4. The die bonding system of claim 3, wherein the air bearing
2 consists essentially of a top air bearing and a bottom air bearing, which are
3 configured to accept the outboard portion of the frame therebetween.
- 1 5. The die bonding system of claim 1, wherein the gantry further
2 comprises at least one linear bearing disposed on the inboard side, wherein
3 the at least one linear bearing is configured to slidingly engage an inboard
4 portion of the frame.
- 1 6. The die bonding system of claim 5, wherein the at least one
2 linear bearing is at least one rolling element linear bearing.

1 7. The die bonding system of claim 5, wherein the at least one
2 linear bearing consists essentially of two, spaced-apart rolling element linear
3 bearings.

1 8. The die bonding system of claim 1, wherein the gantry
2 comprises an x-stage, a y-stage, and a z-stage.

1 9. The die bonding system of claim 1, further comprising at least
2 one accelerometer attached to the gantry and/or frame and a control system
3 in operative communication with the at least one accelerometer and the drive,
4 wherein the at least one accelerometer is configured to provide feedback to
5 the control system, and wherein the control system is configured to damp
6 vibrations in the gantry and/or frame by controlling the drive.

1 10. A hybrid bearing arrangement, the hybrid bearing arrangement
2 comprising:

3 at least one substantially frictionless bearing disposed on a non-driven
4 side of a platform and at least one bearing disposed on a driven
5 side of the platform; and

6 a frame configured to slidably engage with the at least one
7 substantially frictionless bearing as well as with the at least one
8 bearing and thereby support the platform while allowing for
9 relative motion between the platform and frame in one
10 dimension.

1 11. The hybrid bearing arrangement of claim 10, further comprising
2 a contact contact-based drive configured to drive the platform.

1 12. The hybrid bearing arrangement of claim 10, wherein the at least
2 one substantially frictionless bearing comprises an air bearing.

1 13. The hybrid bearing arrangement of claim 12, wherein the air
2 bearing consists essentially of a top air bearing and a bottom air bearing,
3 which are configured to accept a portion of the frame therebetween.

1 14. The hybrid bearing arrangement of claim 10, wherein the at least
2 one bearing disposed on a driven side of the platform comprises at least one
3 linear bearing.

1 15. The hybrid bearing arrangement of claim 14, wherein the at least
2 one linear bearing is at least one rolling element linear bearing.

1 16. The hybrid bearing arrangement of claim 15, wherein the at least
2 one linear bearing consists essentially of two, spaced-apart rolling element
3 linear bearings.

1 17. The hybrid bearing arrangement of claim 10, wherein the
2 platform comprises an x-stage, a y-stage, and a z-stage.

1 18. The hybrid bearing arrangement of claim 10, further comprising
2 at least one accelerometer attached to the platform and/or frame and a control
3 system in operative communication with the at least one accelerometer and
4 a drive configured to drive the platform, wherein the at least one
5 accelerometer is configured to provide feedback to the control system, and
6 wherein the control system is configured to damp vibrations in the gantry
7 and/or frame by controlling the drive.

1 19. A die bonding system comprising:
2 a gantry having an inboard side and an outboard side, the gantry
3 comprising at least one air bearing disposed on the outboard
4 side, the at least one air bearing consisting essentially of a top
5 air bearing and a bottom air bearing, which are configured to
6 accept an outboard portion of the frame therebetween;

7 a frame configured to support the gantry while providing for relative
8 motion between the gantry and frame in one dimension;
9 a contact-based drive configured to drive the inboard side of the
10 gantry;
11 at least one accelerometer attached to the gantry and/or frame; and
12 a control system in operative communication with the at least one
13 accelerometer and the drive,
14 wherein the gantry further comprises at least one linear bearing
15 disposed on the inboard side,
16 wherein the at least one linear bearing is configured to slidably
17 engage an inboard portion of the frame,
18 wherein the outboard side of the gantry is non-driven,
19 wherein the at least one accelerometer is configured to provide
20 feedback to the control system,
21 wherein the control system is configured to damp vibrations in the
22 gantry and/or frame by controlling the drive, and
23 wherein the gantry comprises an x-stage, a y-stage, and a z-stage.

1 20. The die bonding system of claim 19, wherein the at least one
2 linear bearing is at least one rolling element linear bearing.