

HEAD DISC ASSEMBLY CONFIGURATION AND ASSEMBLY CONTROL SYSTEM FOR A DISC DRIVE

Related Applications

This application claims priority to United States Provisional Application No. 60/150,140 filed August 20, 1999.

Field of the Invention

The present invention relates generally to the field of disc drive data storage devices, and more particularly, but not by way of limitation, to an assembly and configuration control system for a head disc assembly of a disc drive.

Background

Modern hard disc drives are commonly used in a multitude of computer environments, ranging from super computers through notebook computers, to store large amounts of data in a form that can be made readily available to a user. Typically, a disc drive comprises one or more magnetic discs that are rotated by a spindle motor at a constant high speed. The surface of each disc is a data recording surface divided into a series of generally concentric recording tracks radially spaced across a band having an inner diameter and an outer diameter. The data tracks extend around the disc and store data within the tracks on the disc surfaces in the form of magnetic flux transitions. The flux transitions are induced by an array of transducers, otherwise commonly called read/write heads. Typically, each data track is divided into a number of data sectors that store fixed sized data blocks.

The read/write head includes an interactive element such as a magnetic transducer, which senses the magnetic transitions on a selected data track to read the data stored on the track. Alternatively, the read/write head transmits an electrical signal that induces magnetic transitions on the selected data track to write data to the track.

As is known in the art, each read/write head is mounted to a rotary actuator arm and is selectively positionable by the actuator arm over a selected data track of

the disc to either read data from or write data to the selected data track. The read/write head includes a slider assembly having an air-bearing surface that causes the read/write head to fly above the disc surface. The air bearing is developed as a result of load forces applied to the read/write head by a load arm interacting with air currents that are produced by rotation of the disc.

Typically, a plurality of open-center discs and open-centered spacer rings are alternately stacked on the hub of a spindle motor, followed by the attachment of a clampring to form a disc pack or disc stack. The hub, defining the core of the stack, serves to align the discs and spacer rings around a common centerline. Movement of the discs and spacer rings is typically constrained by a compressive load maintained by the clampring. The read/write heads mounted on a complementary stack of actuator arms, which compose an actuator assembly, commonly called an E-block, accesses the surfaces of the stacked discs of the disc pack. The E-block also generally includes read/write head wires which conduct electrical signals from the read/write heads to a flex circuit which, in turn, conducts the electrical signals to a printed circuit board assembly (PCB). When the E-block is merged with the disc pack into a base deck and a cover is attached to the base deck a head-disc assembly (HDA) is formed. For a general discussion of E-block assembly techniques, see U.S. Patent No. 5,404,636 entitled METHOD OF ASSEMBLING A DISC DRIVE ACTUATOR issued April 11, 1995 to Stefansky et al., assigned to the assignee of the present invention.

The head-disc assembly (HDA) of a disc drive is typically assembled in a clean room environment. The need for maintaining a clean room environment (free of contaminants of 0.3 micron and larger) is to ensure the head-disc interface remains unencumbered and damage free. The slightest damage to the surface of a disc or read/write head can result in a catastrophic failure of the disc drive. The primary causes of catastrophic failure, particularly read/write head crashes (a non-recoverable, catastrophic failure of the disc drive) are generally characterized as contamination, exposure to mechanically induced shock, and non-shock induced damage. The source of non-shock induced damage is typically traced to the assembly process, and generally stems from handling damage sustained by the disc

drive during the assembly process.

Several factors that bear particularly on the problem of assembly process induced damage are the physical size of the disc drive, the spacing of the components, the recording densities sought to be achieved and the level of precision to be maintained during the assembly process. The high levels of precision required by the assembly process are necessary to attain the operational tolerances required by the disc drive. The rigorous operational tolerances are in response to market demands that have driven the need to decrease the physical size of disc drive while simultaneously increasing disc drive storage capacity and performance characteristics.

Demands on disc drive mechanical components and assembly procedures have become increasingly more critical in order to support capability and size in the face of these new market demands. Part-to-part variation in critical functional attributes in the magnitude of a micro-inch can result in disc drive failures.

Additionally, as disc drive designs continue to decrease in size, smaller read/write heads, thinner substraights, longer and thinner actuator arms, and thinner gimbal assemblies will continue to be incorporated into the drives. This trend significantly increasing the need to improve the assembly processes to protect the read/write heads and discs from damage resulting from incidental contact between mating components. The aforementioned factors resultantly increase the difficulty of assembling disc drives. As the assembly process becomes more difficult, the need to invent new tools, methods, and control systems to deal with the emerging complexities pose unique problems in need of solutions.

Coupled with the size and performance improvement demands is further market driven requirements for ever increasing fault free performance. The progression of continually decreasing disc thickness and disc spacing, together with increasing track density and increasing numbers of discs in the disc pack, has resulted in a demand for tools, methods and control systems of ever increasing sophistication. A result of the growth in demand for sophisticated assembling equipment has been a decreasing number of assembly tasks involving direct operator intervention. Many of the tasks involved in modern methods are beyond the

capability of operators to reliably and repeatedly perform, further driving the need for automation equipment and tools.

In addition to the difficulties faced in assembling modern disc drives of high capacity and complex, physical product performance requirements have dictated the need to develop new process technologies to ensure compliance with operating specifications. The primary factors driving more stringent demands on the mechanical components and the assembly process are the continually increasing areal densities and data transfer rates of the disc drives.

The continuing trend in the disc drive industry is to develop products with ever increasing areal densities, decreasing access times and increasing rotational speeds. The combination of these factors, place greater demands on the ability of modern servo systems to control the position of read/write heads relative to data tracks.

By design, a disc drive typically has a discreet threshold level of resistance to withstand rotationally induced noise and instability, below which the servo system is not impaired. Also, a fixed range of load forces must be maintained on the read/write head to ensure proper fly height for data exchange. The operating performance of the disc drive servo system is affected by mechanical factors beyond the effects of mechanically induced read/write head oscillation from disc surface anomalies. Errors are traceable to mechanically induced noise that oscillate at frequencies sympathetic to operating frequencies of the servo system. Even with improved approaches to the generation of position error signals in the disc drive servo system, the ability of the system to deal with such issues is finite. The limits of the servo system capability to reliably control the position of the read/write head relative to the data track must not be consumed by the noise present in the HDA resulting from the assembly process.

Assuring each disc drive is configured with compatible components is a challenge faced by disc drive producers. The ability of assuring correct component configurations reduces the likelihood of performance conflicts encountered by the disc drive over its life. In addition to managing the configuration of the disc drive, continual monitoring of the assembly process steps is highly desirable, as a means of

minimizing and limiting damage induced into the disc drive by the assembly process. An ability to trap and resolve assembly problems, at the source of the problem, limits financial exposure to resulting reworking and scrap costs that escalate when assembly problems persist undetected. Control of both the configuration and assembly process leads to an assembly process capable of accommodating changes in attributes of the disc drive during the assembly process as a technique for producing disc drives with ample performance margins and consistent performance.

Consumption of the available margin by the assembly process leaves no margin in the system to accommodate changes in the disc drive attributes over the life of the product. An inability to accommodate changes in the disc drive attributes leads to field failures and an overall loss in product reliability, a detrimental impact to product market position.

Thus, in general, there is a need for an improved approach to disc drive-assembling technology to minimize the potential of damage during assembly, to produce product that is design compliant and reliable, and to minimize mechanically induced system noise. More particularly, there is a need for an assembly and configuration control system for an HDA of a disc drive.

Summary of the Invention

The present invention is directed to a computerized network system controlling the configuration and assembly steps of head disc assemblies (HDAs), assembled by an automated disc drive assembly line. With the addition of a disc drive printed circuit board assembly to the HDA disc drives are formed.

In accordance with preferred embodiments, a population of HDAs varying in configuration are assembled by several assembly stations within the automated disc drive assembly line. The selection of the assembly stations participating in the assembly of a particular HDA configuration is dictated by the configuration of the HDA being assembled. The computerized network system includes a network server with a master disc drive configuration data structure identifying the components and subassemblies, and associated serial numbers as appropriate,

constituting each HDA configuration. In response to the master data structure a host computer communicating with the network server constructs interface signals consistent with approved configurations to control the configuration and assembly of HDAs. Approved HDA configurations are identified for assembly and a micro controller translates and directs the constructed interface signals to the appropriate assembly station to execute corresponding assembly steps. For each HDA configuration, the host computer generates an approved sequence of assembly steps necessary to assemble the HDAs. Selected assembly stations are authorized to proceed in turn to carry out the assembly steps. Once assembly of the approved HDAs is completed, the host computer creates an as billed HDA serial number data structure, which is then used to update the master data structure.

These and other features and advantages which characterize the present invention will be apparent from a reading of the following detailed description and a review of the associated drawings.

Brief Description of the Drawings

FIG. 1 is a partially cutaway top view of a disc drive of the type assembled by the head stack assembly installation system of the present invention.

FIG. 2 is a plan view of a computerized network system showing configurations of station control systems for two typical stations within the network system.

FIG. 3 is a plan view of the control systems for one of the assembly stations within a automated disc drive assembly line.

FIG. 4 is a plan view of the communication electronics assembly of the computerized network system of FIG. 2.

FIG. 5 is a plan view of the address board of the computerized network system of FIG. 2.

FIG. 6 is a plan view of the automated disc drive assembly line served by the computerized network system of FIG. 2.

FIG. 7 is a flowchart of the software process steps used by a host computer of the computerized network system of FIG. 2 to construct a table of approved head disc assembly serial number configurations.

FIG. 8 is a flowchart of the software process steps used by the host computer of the computerized network system of FIG. 2 to control the configuration of head disc assemblies being assembled by the automated disc drive assembly line of FIG. 3.

FIG. 9 is a flowchart of the software process steps used by the host computer of the computerized network system of FIG. 2 to control the assembly of head disc assemblies undergoing assembly by the automated disc drive assembly line of FIG. 3.

FIG. 10 is a continuation of a flowchart of FIG. 9.

Detailed Description

Referring to the drawings in general, and more particularly to FIG. 1, shown therein is a top view of a disc drive 100 constructed in accordance with the present invention. The disc drive 100 includes a basedeck 102 that has several fastener receptacles 104, the basedeck 102 supporting various disc drive components, and a top cover 106 (shown in part), with several mounting apertures (not separately shown), secured to the basedeck 102 by top cover fasteners 108. The installed top cover 106 together with the basedeck 102 provides a sealed internal environment for the disc drive 100. Numerous details of construction of the disc drive 100 are not included in the following description as such are well known to those skilled in the art and are believed to be unnecessary for the purpose of describing the present invention.

Mounted to the basedeck 102 is a ramp load snubber assembly 110 secured to the basedeck 102 by a fastener 112, and a spindle motor 114 with a top cover attachment aperture 116. The spindle motor 114 supports several discs 118 for rotation at a constant high speed, the discs 118 mounted on a spindle motor hub 120 that are secured by a clampring 122 with clampring fasteners 124. In addition to providing support for the stacked discs 118, the spindle motor hub 120 also provides

a timing mark 126 used during the assembly process to reference the angular location of a source of rotational imbalance. Adjacent the discs 118 is an actuator assembly 128 (also referred to as an "E-block" or a head stack assembly (HSA)) which pivots about a bearing assembly 130 in a rotary fashion. The bearing
5 assembly supports a beveled pick and place member 132 that serves as a tooling grip during assembly operations. The HSA 128 includes actuator arms 134 (only one shown) that support load arms 136. Each load arm 136 in turn supports read/write heads 138, with each of the read/write heads 138 corresponding to a surface of one of the discs 118. As mentioned, each of the discs 118 has a data recording surface
10 divided into concentric circular data tracks 140 (only one shown), and the read/write heads 138 are positionably located over data tracks to read data from, or write data to, the tracks.

The HSA 128 is controllably positioned by a voice coil motor assembly (VCM) 142, comprising an actuator coil 144 immersed in the magnetic field
15 generated by a magnet assembly 146. A magnetically permeable flux path is provided by a steel plate 148 (also called a top pole piece) mounted above the actuator coil 144 to complete the magnetic circuit of the VCM 142.

When controlled DC current is passed through the actuator coil 144, an electromagnetic field is setup, which interacts with the magnetic circuit of the VCM
20 142 to cause the actuator coil 144 to move relative to the magnet assembly 146 in accordance with the well-known Lorentz relationship. As the actuator coil 144 moves, the HSA 128 pivots about the bearing assembly 130, causing the heads 138 to move over the surfaces of the discs 118 thereby allowing the heads 138 to interact with the data tracks 140 of the discs 118. When the disc drive 100 is turned off, the
25 VCM 142 parks the HSA 128 on the ramp load snubber assembly 110 to avoid shock induced contact between the read/write heads 138 and the discs 118.

To provide the requisite electrical conduction paths between the read/write heads 138 and disc drive read/write circuitry (not shown), read/write head wires (not shown) are affixed to a read/write flex circuit 150. Next the read/write flex 150 is
30 routed from the load arms 136 along the actuator arms 134 and into a flex circuit containment channel 152 and on to a flex connector body 154. The flex connector

body 154 supports the flex circuit 150 during passage of the read/write flex circuit 150 through the basedeck 102 and into electrical communication a disc drive printed circuit board assembly (PCBA) (not shown) mounted to the underside of the basedeck 102. The flex circuit containment channel 152 also supports read/write signal circuitry 156 used to condition read/write signals passed between the read/write circuitry (not shown) and the read/write heads 138. The disc drive PCBA provides the disc drive read/write circuitry, which controls the operation of the heads 138, as well as other interface and control circuitry for the disc drive 100.

To maintain the sealed internal environment for the disc drive 100, a seal gasket 158 is molded on to the top cover 106. Top cover 106 has a multitude of gasket attachment apertures 160 through, which gasket material flows during the gasket molding process. A continuum of symmetrically formed gasket material is disposed on both the top and bottom surfaces of the top cover 106 and injected through the apertures 160. During the cure process, the gasket material injected into the gasket attachment apertures 160 bonds the portion of the seal gasket adjacent the top surface of the top cover 106 to the portion of the seal gasket adjacent the bottom portion of the top cover 106, thereby sealing the gasket attachment apertures 160 and forming the seal gasket 158. A gasket material found to be useful for this application is "Fluorel" by the 3M Company, and more specifically, 3M "Fluorel", FE- 5621Q.

The disc drive 100 has two primary assemblies, the PCBA (not shown) and a head disc assembly (HDA) 162 attached to the PCBA. The HDA 162 typically contains the mechanically active assemblies and components of the disc drive 100. Typically included within the HDA 162 are the HSA 128, the VCM 142 and a disc stack 164 sustained within the sealed environment created when the top cover 106 supporting the seal gasket 158 is secured to the basedeck 102 by fasteners 108. The disc stack 164 is formed by stacking discs 118, interleaved with spacer rings (not shown), on the spindle hub 120 of the spindle motor 114 and securing the stack with the clampring 122 and fasteners 124.

During operation of the disc drive 100, spinning discs 118 generate airflow consistent with the direction of rotation of the spinning discs 118. To reduce

chances of a catastrophic failure of the disc drive 100 caused by particulate contamination internal to the HDA 162, an air filter 166 is provided internal to the HDA 162 to trap airborne particulate either present following assembly or generated during operation of the disc drive 100.

5 The computerized network system 200 shown by FIG. 2 includes a network server 200 communicating with a master disc drive configuration data structure 204 that includes a disc drive part number data structure 206. The disc drive part number data structure 206 includes part numbers representing each disc drive 100 approved as available for production along with configuration information for each
10 head disc assembly 162 associated with the particular disc drive 100 part number. Communicating with the network server 202 is a host computer 208 of the computerized network system 200. The host computer 208 generates interface signals used in controlling the configuration and assembly of the head disc assembly 162 executed by typical station control systems 212 and 214. A host micro
15 controller 216 communicates with the host computer 208 and with the typical station control systems 212 and 214 serving as an interpreter translating the interface signals from a host computer, communicated by the host computer using a RS 232 interface standard 218, into a RS 485 Interface standard 220 used by the station control systems such as 212 and 214.

20 FIG. 2 shows also a communication interface electronics assembly 222 communicating with the host micro controller 216. The communications interface electronics assembly 222 serves as a communication portal for variety of system input/output (I/O) managed and translated by the micro controller 224. An address board 226 is configured to accept interface signals generated by the host computer
25 208 and target specifically for the station control system served by the address board 226. Interface signals arriving at, and for, the typical station control system 212 are received via the RS 485 interface, passed on to the micro controller 224, reconfigured to RS 232 for particular device such as scanner 228, a display 230 or as an assembly step signal such as digital I/O 232 used by the assembly station for a
30 device such as a digital sensor 234. Also shown in FIG. 2 is a station controller 236 communicating with the communications interface electronics assembly 222 and a

tooling control assembly 238 used to control specific devices within the computerized network system 200 such as a robotic assembly 240, a component present sensor 242 or a feature detection assembly such as 246. Introduced in FIG. 2 is a head disc assembly station control system of FIG. 3.

Computer 250 is shown in FIG. 3 to illustrate the level of computing power available at any of the station control systems, such as station control system 214 of FIG. 2 or the head stack assembly station control system 248 of FIG. 3. The level of computing power is related directly to the complexity of the assembly steps performed by the assembly station served by the station control system for that particular station control system. In addition to the computer 250, FIG. 3 shows a measurement assembly 252 including a radial displacement potentiometer 254 a linear variable differential transformer 256 and a load cell 258 as among the devices capable of control by the station controller 236.

FIG. 4 shows the diversity of interface standards and connectors the computerized network system 200 utilizes in fulfilling the HDA 162 configuration and assembly control task assigned it. A typical 12 mm, 5 pin RS 485 connector 260 is shown in FIG. 4 along with a typical 8 mm 4 pin 262, a 9 pin DB9 female RS232 serial connector 264, a 9 pin DB9 male RS232 serial connector 266 as well as a RJ45 digital I/O communications connector 268, a 6 pin IDC interface connector 270 that includes a +24 volt pin 272, a standard 12 pin IDC connector 247 supporting ground, power, 4 output lines and three input lines. The last component shown by FIG. 4 is a plunger reset switch 276. The communication interface electronics assembly is designed to facilitate a wide range of interface standards as well as a wide range and physical connector types and includes three spare digital I/O connectors 278. The micro controller 224 of FIG. 2 is configured to efficiently translate and direct interface signals received from the host computer 208 to the appropriate devices under the control of the station control system such as 248 of FIG. 3.

FIG. 5 shows a six position dip switch 286 of the address board 226 and a 5 pin RS485 interface connector 288. A unique address has been assigned each of the control stations such as 212 and 214 the sixth toggle switches 290 of the dip

switch 286 is set for the station and serves to pass only those signals intended for the station control system to be passed from a interface connector 288 to be micro controller 224. Under the current embodiment the number of stations capable of being supported by the computerized network system is 31. With the incorporation of additional devices, such as a repeater, additional stations may be added to the network, should the need arise.

Shown in FIG. 6 is a head stack assembly installation station 292 serviced by the station control system 248 of FIG. 3. As can be seen by FIG. 6, 26 assembly stations collectively make up the automated disc drive assembly line 294. It will be noted a number of stations within the automated disc drive assembly line 294 perform a function of component removal. Such as the head stack assembly removal station 296 or the voice coil motor removal station 298. The inclusion of such removal stations within the automated disc drive assembly line is to accommodate failures in the assembly process encountered by one of the assembly stations such as the clampring installation station 300. For example, while processing a head disc assembly 162 the clampring installation station 298 may encounter a defective clampring fastener 124 of FIG. 1 while attempting attachment of the clampring 122 of FIG. 1 and the clampring fasteners 124 to the spindle motor hub 120 of all the spindle motor 114 of FIG. 1. Encountering such an event the station control system serving the clampring installation station 300 would halt the assembly steps assigned that station control system by a the host computer 208 of FIG. 2, electronically tag the serial number associated with the head disc assembly 162 undergoing the assembly steps assigned the clampring installation station 300 by the host computer 208, as unavailable for continued processing by stations subsequent to the clampring installation station 298.

As a result, the offending head disc assembly 162 undergoing the assembly process within the automated disc drive assembly line 294 would passed through all stations subsequent to the clampring installation station 300 until the offending head disc assembly reaches the clamp ring removal station 302. At which point in, the clamp ring removal station would execute process steps assigned the clamp ring removal station 302 by the host computer 208. In such cases, the host computer 208

accesses an assembly step configuration data structure within the master disc drive configuration data structure 204 and downloads a predetermined sequence of assembly steps approved for resolving the condition of the offending HDA 162.

To effectively control the configuration of the HDAs 162 of FIG. 1 being assembled by the automated disc drive assembly line 294 of FIG. 6, the ability of having HDA 162 configuration information readily available at the local level promotes network efficiency by minimizing the amount of traffic on the network resulting from a plurality of automated disc drive assembly lines connected to the network. A preferred embodiment of the present invention includes the software steps shown by FIG. 7, taken by host computer 208 in constructing a the HDA configuration table of approved HDA 162 as built serial number configurations 306. By building a table all of available HDA 162 configurations that constitutes any possible configuration of HDA 162 that can be assembled, based on the available components approved for assembly HDA 162, the host computer 208 has within its control the ability to construct sequences of assembly process steps required to assemble HDAs 162 of a particular configuration. Once the sequence of assembly steps are built the host computer 208 proceeds by assigning the process steps to selected station control systems, such as 214 of FIG. 2, monitoring the physical assembly process during execution of assigned assembly steps, collecting serial number information as the assembly process proceeds, using the collected serial number information to populate the HDA serial number data structure 210 of FIG. 2 thereby building an as built HDA serial number configuration and upon completion of the HDA 162, depositing the as built serial number configurations with the network server 202 of FIG. 2 to update the master disc drive configuration data structure 204 of FIG. 2.

Having built the HDA configuration table of approved HDA as built serial number configurations 306 of FIG. 7, the host computer 208 of FIG. 2 is positioned to execute the software steps embodied in the HDA assembly process configuration control 308, shown in FIG. 8. With the ability to verify, on the fly, the compatibility of HDA 162 components such as the discs 118 of FIG. 1, the spindle motor 114 of FIG. 1, in the head stack assembly 128 of FIG. 1, by checking the HDA

configuration table 308, the host computer 208 is able to preclude assembly of HDAs 162 failing to comply with approved configurations, and to do so with minimal effects on the output capability of the automated disc drive assembly line 294 of FIG. 6. The host computer 208 also monitors through put performance of each assembly station such as 300, as well as the overall through put performance of the automated disc drive assembly line 294.

FIG. 9 in FIG. 10 show the logical steps executed by the head disc assembly configuration assembly control systems software program when monitoring progress of an HDA 162 undergoing assembly by the automated disc drive assembly line 294 of FIG. 6. Upon entry into any of the assembly stations of the automated disc drive assembly line 294 the host computer 208 and the station control system such as 248 establish dialog to determine whether the assembly station, such as 292 of FIG. 6, served by the station control system, such as 248 of FIG 3, is to perform any assembly steps on the HDA 162. And if such steps are to be performed by the assembly station, such as 292, the station control system 248 must first gain approval from the host computer 208 for installation of serialized HDA components prior to proceeding with the assembly step instructions. The approval dialog sequence is the real time method use in safeguarding HDA 162 configurations. In addition to insuring configuration control FIG. 9 and FIG.10 show the station control systems 112 are compelled to report incidences of unsuccessful execution of assembly steps to the host computer 208 that, in effect, preclude the expenditure of additional resources and materials on the offending HDA 162 thereby minimizing the amount of assembly damage occurring to the HDA 162 or maximizing the benefit of existing resources.

Alternatively characterized, one embodiment of the present invention provides a head disc assembly configuration and assembly control system (such as 200) with a network server (such as 202) including a master disc drive configuration data structure (such as 204), a host computer (such as 208) communicating with the network server generating interface signals (such as 218) controlling configuration and assembly of a head disc assembly (such as 162) for several station control systems (such as 212). Each station control system operationally controlling an

assembly station (such as 300) of an automated disc drive assembly line (such as 294) assembling head disc assemblies. The system includes a host micro controller (such as 216) providing a communication link between the host computer and each assembly station and a communication interface board (such as 222) at each station translating the interface signals from the host computer for use as assembly step signals (such as 232) by the assembly station.

Optionally, the present invention further includes a server storage device (such as 204) which stores the master disc drive configuration data structure, and the master disc drive configuration data structure further includes a disc drive part member data structure (such as stored at 206).

It is clear that the present invention is well adapted to attain the ends and advantages mentioned as well as those inherent therein. While a presently preferred embodiment of the invention has been described for purposes of the disclosure, it will be understood that numerous changes can be made which will readily suggest themselves to those skilled in the art. Such changes are encompassed within the spirit of the invention disclosed and as defined in the appended claims.



What is claimed is:

1. A head disc assembly configuration and assembly control system for an automated disc drive assembly line having a communication and control network comprising:

- a network server with a master disc drive configuration data structure;
- a host computer communicating with the network server constructing interface signals controlling configuration and assembly of a head disc assembly based on the master disc drive configuration data structure;
- a host micro controller communicating with the host computer translating interface signals; and
- a plurality of station control systems communicating with the host micro controller responsive to the interface signals executing the configuration and assembly control interface signals.

2. The control system of claim 1 wherein the network server having a server storage device storing the master disc drive configuration data structure and wherein the master disc drive configuration data structure further having a disc drive part member data structure comprising:

- a part number representing each disc drive type available for production;
- a head disc assembly configuration linked to each disc drive part number;
- a plurality of head disc assembly serial numbers approved and available for use with the part number in forming the head disc assembly linked to the part number;
- a plurality of disc lot serial numbers of disc lots approved and available for use in the head disc assembly linked to the part number;
- a plurality of spindle motor assembly serial numbers of spindle motor assemblies approved and available for use in the head disc assembly linked to the part number; and



a plurality of head stack assembly serial numbers of head stack assemblies approved and available for use in the head disc assembly linked to the part number.

5 3. The control system of claim 2 wherein the host computer having a host storage device with a head disc assembly serial number configuration data structure comprising:

 a head disc assembly serial number selected from the plurality of approved and available head disc assemblies serial numbers;

10 a disc lot serial number of the disc lot use in forming the head disc assembly linked to the head disc assembly serial number;

 a spindle motor assembly serial number used in forming the head disc assembly linked to the head disc assembly serial number; and

 a head disc assembly serial number used in forming the head disc assembly linked to the head disc assembly serial number.

15 4. The control system of claim 1 wherein the host micro controller further communicating with the plurality of station control systems translating interface signals from the host computer to each of the station control systems.

20 5. The control system of claim 4 wherein the station control system comprises:
 a communications interface electronics assembly communicating with the host micro controller distributing interface signals between the station control system and the host micro controller and within the station control system;

25 an address board communicating with the communication interface electronics assembly selectively receiving interface signals for distribution by the communications interface electronics assembly;

30 a micro controller communicating with the communications interface electronics assembly and the address board processing interface



signals received from the address board for distribution by the communications interface electronics assembly;

a scanner communicating with the communications interface electronics assembly collecting head disc assembly configuration data for the head disc assembly data structure;

a sensor communicating with the communications interface electronics assembly providing status data to the host computer controlling the device assembly; and

a station controller communicating with the communications interface electronics assembly processing and distributing the configuration and assembly control interface signals.

6. The control system claim 5 wherein the station control system further having a tooling control assembly communicating with the station controller controlling assembly steps comprising:

a robotic assembly executing head disc assembly process steps;

a component present sensor responsive to the station controller sensing and reporting presence of a head disc assembly component for continued process step execution by the robotic assembly;

a motor responsive to the station controller delivering the component to the robotic assembly; and

a feature detection assembly responsive to the station controller detecting orientation of the component within the robotic assembly.

7. The control system of claim 4 wherein the station control system is a head stack assembly station control system comprising:

a communications interface electronics assembly communicating with the host micro controller distributing interface signals between the station control system and the host micro controller;



an address board communicating with the communication interface
electronics assembly selectively receiving interface signals for
distribution by the communications interface electronics assembly;
a micro controller communicating with the communications interface
electronics assembly and the address board processing interface
signals received from the address board for distribution by the
communications interface electronics assembly;
a head disc scanner communicating with the communications interface
electronics assembly collecting head disc assembly configuration data
for the head disc assembly data structure;
a head stack assembly scanner communicating with the communications
interface electronics assembly collecting head stack assembly
configuration data for the head disc assembly data structure;
a station controller communicating with the communications interface
electronics assembly processing and distributing the configuration
and assembly control interface signals;
a tooling control assembly communicating with the station controller
controlling assembly steps;
a measurement assembly communicating with the station controller
measuring process parameters for configuration control comprising:
a potentiometer supported by the end effector assembly measuring
and communicating radial displacement measurements of the
radially disposed positionable gripper sections relative to the
beveled pick and place member;
a linear variable differential transformer supported by the vertical
slide assembly measuring and communicating vertical
distance measurements traveled by the head stack assembly
relative to the tolerance ring the computer; and
a load cell supported by the end effector assembly measuring and
communicating mechanical resistance between the head stack
assembly and the tolerance ring to the computer.



8. The control system of claim 7 wherein the communications interface electronics assembly communicates with the host micro controller over an RS 485 interface and the host micro controller communicates with the host computer over an RS 232 interface and further wherein the communications interface electronics assembly communicates with the scanner over an RS 232 interface.

9. A head disc assembly configuration and assembly control system software program monitoring assembly steps and controlling configuration of a head disc assembly of a disc drive by steps comprising:

- (a) directing a host computer to structure a query accessing a disc drive part number data structure requesting disc drive part numbers available and approved for assembly;
- (b) determining head disc assembly configurations consistent with the disc drive part numbers available and approved for assembly;
- (c) instructing a head disc assembly automated assembly line having a plurality of assembly stations which assembly stations participate in assembling the head disc assembly based on the determined head disc assembly configuration;
- (d) monitoring assembly steps executed by the participating assembly stations for assembly step and configuration compliance; and
- (e) constructing an as assembled head disc assembly serial number data structure.

10. The software program of claim 9 wherein the directing step (a) further comprises:

- (a1) assimilating head disc assembly configuration data for head disc assemblies approved as meeting requirements of each disc drive part number available for assembly from the disc drive part number data structure;



- (a2) extracting lot serial numbers data of available discs from the disc drive part number data structure;
- (a3) retrieving serial numbers data of available spindle motor assemblies from the disc drive part number data structure;
- 5 (a4) gathering head stack assembly serial numbers data of available head stack assemblies from the disc drive part number data structure; and
- (a5) reading and recording head disc assembly serial numbers data of serial numbers allocated by the disc drive part number data structure for each head disc assembly configuration called for by each disc drive part number available for assembly.
- 10

11. The software program of claim 10 wherein the determining step (b) further comprises:

- (b1) analyzing by lot serial number which disc lots are approved for each approved head disc assembly configuration;
- 15 (b2) determining by serial number which head stack assemblies are approved for use with the disc lots approved for each head disc assembly configuration;
- (b3) selecting by serial number which spindle motor assemblies are approved for use in conjunction with the disc lots and the head disc assembly approved for each approved head disc assembly configuration; and
- 20 (b4) constructing an approved head disc assembly configuration table based on steps (b1) through (b3).

25 12. The software program of claim 11 wherein the instructing step (c) further comprises:

- (c1) analyzing a selected head disc assembly serial number for compliance with the constructed head disc assembly configuration table;
- (c2) constructing an approved sequence of assembly steps for an automated disc drive assembly line based on the selected head disc assembly serial number;
- 30



(c3) assigning select assembly steps from the approved sequence of assembly steps to a first assembly station of an automated disc drive assembly line capable of performing the selected assembly steps;

(c4) informing any assembly stations preceding the first assembly station performing selected assembly steps to pass any head disc assembly undergoing assembly and bearing the selected head disc assembly serial number to any subsequent assembly station in the automated disc drive assembly line;

(c5) directing and assigning approved assembly steps to any subsequent assembly station capable of performing selected assembly steps of the approved sequence of assembly steps upon encountering the head disc assembly undergoing assembly and bearing the selected head disc assembly serial number; and

(d) commanding assembly stations containing a serialized component to execute approved assembly steps installing the components and reporting the serial number of the component installed to the host computer.

13. The software program of claim 12 wherein the monitoring step (d) further comprises:

(d1) responding to requests from assembly stations executing assembly steps requesting continued execution of process steps authorization based on serial numbers of components available for assembly into the head disc assembly at the assembly stations;

(d2) detecting station complete signals from assembly stations assigned assembly steps; and

(d3) analyzing the station complete signals for satisfactory completion of the assigned assembly steps.

14. The software program of claim 13 wherein the constructing step (e) further comprising:



(e1) building a configuration data structure for each of the determined head disc assembly configurations;

(e2) collecting as assembled component serial number information from the assembly stations participating in assembly steps; and

5 (e) populating the configuration data structure with the as assembled component serial number data forming the as assembled head disc assembly serial number data structure.

10 15. The software program of claim 13 wherein the responding step (d1) further comprises:

(d1a) approving requests from assembly stations executing assembly steps continuing execution of process steps based on approval of serial numbers of components available at the assembly station for assembly into the head disc assembly at the requesting assembly station; and

15 (d1b) tagging electronically the head disc assembly undergoing assembly within the assembly station for continued processing based on the configuration of the head disc assembly compliance with the constructed head disc assembly configuration table.

20

16. The software program of claim 13 wherein the responding step (d1) further comprises:

(d1ai) disapproving requests from assembly stations executing assembly steps continuing execution of process steps based on disapproval of serial numbers of components available at the station for assembly into the head disc assembly at the requesting assembly station;

25

(d1bi) tagging electronically the head disc assembly undergoing assembly within the assembly station has withdrawn from continued processing based on the configuration of the head disc assembly failing to comply with the constructed head disc assembly configuration table; and

30



(d1ci) notifying subsequent assembly stations with the serial number of the head disc assembly withdrawn from continued processing.

5 17. The software program of claim 13 wherein the analyzing step (d3) further comprises:

(d3a) approving further processing by subsequent assembly stations the head disc assembly undergoing assembly based on successful completion of the assembly steps assigned to the current assembly station; and

10 (d3b) tagging electronically the head disc assembly undergoing assembly within the automated disc drive assembly line as approved for further processing by subsequent assembly stations based on the successful completion of the assigned process steps by the current assembly station.

15 18. The software program of claim 13 wherein the analyzing step (d3) further comprises:

(d3ai) disapproving further processing by subsequent assembly stations the head disc assembly undergoing assembly based on unsuccessful completion of the assembly steps assigned to the current assembly station;

20 (d3bi) tagging electronically the head disc assembly undergoing assembly within the automated disc drive assembly line as disapproved for further processing by subsequent assembly stations based on the unsuccessful completion of the assigned process steps by the current assembly station; and

25 (d3ci) notifying subsequent assembly stations with the serial number of the head disc assembly disapproved for further processing.

30 19. The software program of claim 12 wherein the serialized component is a disc.



20. The software program of claim 12 wherein the serialized component is a head stack assembly.

21. The software program of claim 12 wherein the serialized component is a spindle motor assembly.