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[Continued on next page]

(54) Title: SYSTEMS, METHODS, AND SOFTWARE FOR FLEXIBLE MANUFACTURING OF HOT-RUNNER ASSEMBLIES

(57) Abstract: Methods of manufacturing hot-runner assemblies based on concurrent part fabrication. A set of separate components, such as nozzles, manifold, cavity plate, backing plate, etc., are manufactured concurrently with one another. This allows the manufacturing process from fabrication to assembly to shipping to be linearized and to be flexible to changes to a manufacturing request queue. Corresponding software and hot-runner-manufacturing systems are also disclosed.

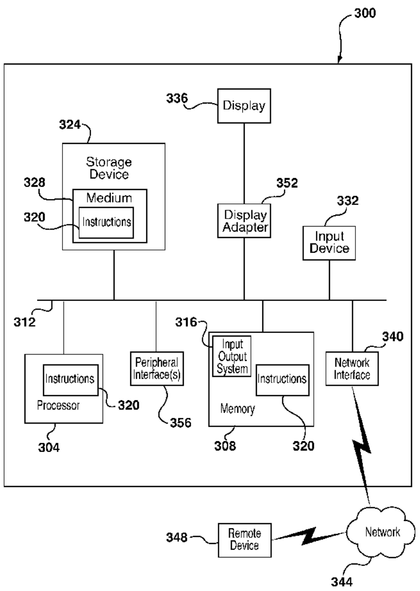

FIG. 3

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SYSTEMS, METHODS, AND SOFTWARE FOR FLEXIBLE MANUFACTURING OF HOT-RUNNER ASSEMBLIES

FIELD OF THE INVENTION

[0001] The present invention generally relates to the field of hot-runner manufacturing. In particular, the present invention is directed to systems, methods, and software for flexible manufacturing of hot-runner assemblies.

BACKGROUND

[0002] Conventional hot-runner assemblies for injection molding are typically composed of multiple components, such as a manifold, nozzles, cavity plate, backing plate, and sprue bushing, that are generally fabricated at differing fabrication stations, often within a single manufacturing facility and sometimes at multiple manufacturing facilities. In addition, each of a number of these components are fabricated using a series of fabrication stations. For example, the fabrication of a typical hot-runner manifold often starts with a blank being cut from a piece of sheet steel at a cutting station. Then, the blank is moved to an exterior milling station that mills the exterior of the blank. Following exterior milling, the blank is moved to at least one drilling station where the blank is drilled with multiple holes used to form the internal melt channels within the manifold. Then, the manifold is moved to a plugging station where plugs, which are typically fabricated at another station, are added to the openings of many of the drilled holes to close the holes to form the melt channels. After plugging, the manifold is then sent to other stations for additional manufacturing steps, such as adding heating elements, installing nozzles, etc. Cavity plates and backing plates typically have a similar progression through multiple cutting, milling, drilling (tapping), and other fabrication stations.

SUMMARY OF THE DISCLOSURE

[0003] In one implementation, the present disclosure is directed to a method of manufacturing hot-runner assemblies. The method being executed in a computer-controlled hot-runner-manufacturing system includes receiving a first order for a hot-runner assembly that includes a component set comprising a plurality of components of differing types, wherein the plurality of components are separate from one another; generating, as a function of the receiving the order, fabrication instructions designed and configured to instruct freeform-fabrication equipment to concurrently fabricate the plurality of components; and controlling, based on the fabrication instructions, freeform-fabrication equipment to form the plurality of components concurrently with one another.

[0004] In another implementation, the present disclosure is directed to a machine-readable storage medium containing machine-executable instructions for performing a method of manufacturing hot-runner assemblies. The machine-executable instructions include a first set of machine-executable instructions for generating, as a function of receiving an order for a hot-runner assembly that includes a component set comprising a plurality of separate components of differing types, fabrication instructions designed and configured to instruct freeform-fabrication equipment to concurrently fabricate the plurality of components; a second set of machine-executable instructions for providing the fabrication instructions to a fabrication controller in operative communication with the freeform-fabrication equipment; and a third set of machine-executable instructions for controlling, based on the fabrication instructions, freeform-fabrication equipment to form the plurality of components concurrently with one another.

[0005] In yet another implementation, the present disclosure is directed to a manufacturing system for manufacturing a hot-runner assembly in response to receiving an order. The fabrication system includes freeform-fabrication equipment designed and configured to manufacture separate components of the hot-runner assembly; a fabrication controller in operative communication with the freeform-fabrication equipment, the fabrication controller configured to be responsive to fabrication instructions that control the freeform-fabrication equipment to concurrently form the components of the hot-runner assembly; and a manufacturing scheduler in operative communication with the fabrication controller, the manufacturing scheduler programmed to generate the fabrication instructions; and provide the fabrication instructions to the fabrication controller.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] For the purpose of illustrating the invention, the drawings show aspects of one or more embodiments of the invention. However, it should be understood that the present invention is not limited to the precise arrangements and instrumentalities shown in the drawings, wherein:

FIG. 1 is a schematic diagram illustrating a hot-runner-manufacturing system made in accordance with the present invention;

FIG. 2 is a flow diagram illustrating a method of fabricating a hot-runner assembly in accordance with the present invention; and

FIG. 3 is a block diagram of a computer system that may be used in implementing any one or more aspects of the system of FIG. 1 and the method of FIG. 2.

DETAILED DESCRIPTION

[0007] In one aspect, the present invention is directed to a method of fabricating hot-runner assemblies in a highly flexible manner and with high efficiency and linearity. The present inventor has observed that conventional hot-runner-assembly manufacturing can be cumbersome in terms of the number of fabrication steps needed to manufacture the various components of a hot-runner assembly, such as a manifold, cavity plate, nozzles, etc., and also in terms of the challenges encountered when desiring to add a new hot-runner assembly to the manufacturing queue ahead of other hot-runner assemblies already in the queue and being at various stages of manufacture. With conventional hot-runner-assembly manufacturing and as mentioned in the background section above, the various components of the assembly are manufactured in an array of multistep processes, some of which take longer than others and can have differing amounts of resources available such that the fabrication processes for the various components of a single hot-runner assembly can have differing throughput rates. For example, the nozzle fabrication process may have greater throughput than the manifold fabrication process, such that the nozzles for a particular assembly can be ready and waiting while the manifold is still being fabricated. This can result in needing to keep close track of the fabrication of the various components and having to shelve some components while others are still being made. This situation requires a very high-level of process management and oversight.

[0008] These problems are magnified whenever a new manifold assembly has a higher priority than other manifold assemblies already within the manufacturing process. For example, when a particular customer has a shorter deadline for receiving its manifold assembly than the customers having their manifold assemblies already in the manufacturing process, that “new” manifold assembly is given priority over the other manifold assemblies and is taken out of turn in the manufacturing queue. Those skilled in the art can readily appreciate that with the differing throughputs for the differing components, the entire manufacturing operations can be significantly disrupted. For example, if the critical path through the entire manufacturing process is the manufacturing of the manifold, then putting a “new” manifold ahead of others already in the queue will cause that much more of a delay with yet-to-be-manufactured manifolds as well as ripple effects that can occur with the non-critical-path components. In any event, the interruption of a manufacturing queue of existing manifold-assembly orders with one or more orders taken out of turn can be highly disruptive to manufacturing operations. In contrast, a manufacturing method of the present disclosure reduces the disruption to manufacturing operations by reducing the number of manufacturing steps involved with manufacturing each hot-runner assembly and by fabricating multiple major components of each hot-runner assembly concurrently with one another and, in some embodiments, additionally fabricating sets of major components of multiple hot-runner assemblies concurrently with one another. These and other aspects of the present invention will become apparent to those skilled in the art upon reading this entire disclosure.

[0009] Referring now to the drawings, FIG. 1 illustrates an exemplary hot-runner-assembly manufacturing system 100 that includes and/or enables various aspects and features of the present invention. System 100 is designed and configured for efficient, highly flexible, and linear manufacturing of hot-runner assemblies, such as hot-runner assemblies 104(1) to 104(N), by allowing multiple components of each hot-runner assembly in a manufacturing queue 108 to be fabricated concurrently with one another. In the example shown, the components being manufactured concurrently include a set 112(1) of nozzles, a manifold 116(1), a cavity plate 120(1), and a backing plate 124(1), which together form a component set 126(1) that are used to make corresponding hot-runner assembly 104(1). While components 112(1), 116(1), 120(1), and 124(1) are shown for the sake of illustration, those skilled in the art will readily appreciate that more or fewer components may be at issue with other assembly designs. For example, in some alternative embodiments, a hot-runner assembly may have nozzles integrally formed with the manifold, such that the component set includes a monolithic manifold-nozzle component, a cavity plate, and a backing plate. As another example, in some alternative embodiments, a hot-runner assembly may have a manifold integrated monolithically with a cavity plate and backing plate, such that the component set includes a monolithic manifold-cavity plate-backing plate component and a set of nozzles. Such alternatives and aspects of such alternatives are disclosed in the Provisional Application No. 61/884,069, filed on September 29, 2013, and titled "UNITARY MONOLITHICALLY FORMED INJECTION-MOLDING ASSEMBLIES," which is incorporated herein by reference for its teaching of the noted hot-runner constructions.

[0010] In one embodiment, the concurrent fabrication of component set 126(1) is performed using an additive-manufacturing process that utilizes, for example, freeform-fabrication (FFF) equipment, such as FFF equipment 128(1) shown in FIG. 1. As those skilled in the art will understand, FFF equipment 128(1) may include one or more individual FFF machines in any suitable combination. Following are a number of FFF techniques that can be used in conjunction with the present invention to perform the concurrent fabrication of the multiple components of a component set, such as component set 126(1): (A) electron beam melting (fully fused void-free solid metal parts from powder stock); (B) electron beam freeform-fabrication (fully fused void-free solid metal parts from wire feedstock); (C) fused deposition modeling (fused deposition modeling extrudes hot plastic through a nozzle, building up a model); (D) laminated object manufacturing (sheets of paper or plastic film are attached to previous layers by either sprayed glue, heating, or embedded adhesive, and then the desired outline of the layer is cut by laser or knife (finished product typically looks and acts like wood); (E) laser-engineered net shaping (a laser is used to melt metal powder and deposit it on the part directly; this has the advantage that the part is fully solid and the metal alloy composition can be dynamically changed over the volume of the part); (F) POLYJET MATRIX (the first technology that enables simultaneous jetting of multiple types of materials); (G) selective laser sintering (selective laser sintering uses a laser to fuse powdered metal, nylon, or elastomer; additional processing is necessary to produce fully dense metal part); (H) shape deposition manufacturing (part and support materials are deposited by a printhead and then machined to near-final shape); (I) solid ground curing (shines a UV light on an electrostatic mask to cure a layer of photopolymers; uses solid wax for support); (J) stereolithography (stereolithography uses a laser to cure liquid photopolymers); (K) three-dimensional printing (this label encompasses many technologies of modern 3D printers, all of which use inkjet-like printheads to deposit material in layers; commonly, this includes, but is not limited to, thermal phase change inkjets and photopolymer phase change inkjets); and/or (L) robocasting (robocasting refers to depositing material from a robotically-controlled syringe or extrusion head).

[0011] Whichever FFF process(es) and corresponding FFF machine(s) are used, an important feature is that FFF equipment 128(1) fabricate a plurality of differing components in a component set for a particular hot-runner assembly, here components 112(1), 116(1), 120(1), and 124(1) of component set 126(1), concurrently with one another so that all of the components are completed prior to fabricating a set of components for another hot-runner assembly that is in manufacturing queue behind the hot-runner assembly containing components 112(1), 116(1), 120(1), and 124(1). As used herein and in the appended claims, the terms “concurrent” and “concurrently” are used with the recognition of the fact that most FFF processes cannot truly fabricate any two separate components at exactly the same time due to the nature of the process. For example, an FFF process that uses a single movable writing “head” can generally only be positioned at one component at a time. Consequently, "concurrent" and "concurrently" in this context means that the parts are fabricated during the same FFF session as one another. It is recognized that FFF equipment 128(1) may be of such a scale that it has the capacity to manufacture two or more sets of components for two or more corresponding hot-runner assemblies. In such cases, FFF equipment 128(1) can be utilized at or below its capacity as needed/desired for a particular manufacturing scenario.

[0012] In the embodiment shown, FFF equipment 128(1) is controlled by a suitable fabrication controller 132(1) designed and configured to cause the FFF equipment to fabricate the component set at issue, here component set 126(1), in response to receiving fabrication instructions 136(1) corresponding to that component set. As those skilled in the art will readily appreciate, the form and format of fabrication instructions 136(1) will vary depending on the type of fabrication controller 132(1) and the type(s) of the FFF machine(s) that compose FFF equipment 128(1). In one example, when FFF equipment 128(1) comprises a 3D printer and fabrication controller 132(1) comprises a general purpose computer, fabrication instructions 136(1) comprises a design document, such as a stereolithography (STL) file, that provides the instructions of the 3D printer to fabricate the component set. Those skilled in the art will readily understand the wide variety of types of FFF equipment and fabrication controllers, and hence fabrication instructions 136(1), that can be used to implement various aspects and features of the present invention. Therefore, an exhaustive recitation of these is not necessary for those skilled in the art to understand how to implement these features and aspects of the present invention to their fullest scope.

[0013] Fabrication instructions 136(1) to 136(N) may be provided in any suitable manner, such as from a manufacturing scheduler 140 that controls the scheduling of some or all of the aspects of the manufacturing of the hot-runner assemblies 104(1) to 104(N) produced using hot-runner manufacturing system 100. As those skilled in the art will appreciate, manufacturing scheduler 140 may be any combination of software and corresponding hardware, such as a general purpose computer, server, etc., designed and configured to provide the requisite functionality. Manufacturing scheduler 140 generates manufacturing queue 108, which may comprise a set of manufacturing instructions 144(1) to 144(N) that correspondingly respectively include fabrication instructions 136(1) to 136(N). In some embodiments and as described below in more detail, manufacturing instructions 144(1) to 144(N) may also correspondingly respectively include assembly instructions 148(1) to 148(N) and/or shipping instructions 150(1) to 150(N). Manufacturing scheduler 140 may generate manufacturing instructions 144(1) to 144(N) and manufacturing queue 108 based on manufacturing requests 152(1) to 152(N) that each contain the necessary information for manufacturing one or more corresponding hot-runner assemblies, such as any one or more of hot-runner assemblies 104(1) to 104(N). Each manufacturing request 152(1) to 152(N) is typically based on a corresponding order 154(1) to 154(N), such as an order placed by a customer of the manufacturer that implements system 100. Each manufacturing request 152(1) to 152(N) may include information such as the corresponding fabrication instructions 136(1) to 136(N) and, optionally, corresponding assembly instructions 148(1) to 148(N) and a priority indicator, such as a deadline date or a numerical or other priority ranking, that provides manufacturing scheduler 140 information for properly ordering manufacturing instructions 144(1) to 144(N) in manufacturing queue 108.

[0014] As mentioned above, a feature of a hot-runner-manufacturing system of the present invention, such as hot-runner-manufacturing system 100, is its ability to be able to accommodate changes made to the manufacturing queue, here manufacturing queue 108, at any time because of the linear manufacturing process that includes the concurrent fabrication of hot-runner-assembly component sets, such as component set 126(1) to 126(N), and subsequent assembly of those sets into corresponding respective hot-runner assemblies, such as hot-runner assemblies 104(1) to 104(N). The inclusion of the priority indicator in each manufacturing request 152(1) to 152(N) allows manufacturing scheduler 140 to dynamically adjust the ordering of manufacturing instructions 144(1) to 144(N) within queue 108 according to the priority rankings of the incoming manufacturing requests and disrupt any first-in-first-out scheduling that may otherwise be the rule. In this manner, a hot-runner-manufacturing system of the present invention can readily adapt manufacturing scheduling to customer requirements and/or changing conditions, which can make a hot-runner manufacturer more desirable.

[0015] In the embodiment shown, manufacturing system 100 also includes an assembly station 156(1) where the component sets fabricated by FFF equipment 128(1), here, component set 126(1), are assembled into a hot-runner assembly, here, hot-runner assembly 104(1). Optionally, depending on the state of finish of the components, such as components 112(1), 116(1), 120(1), and 124(1) after fabrication by FFF equipment 128(1), system 100 may include suitable finishing equipment 160(1) for performing any one or more finishing operations needed for finishing any one or more of the components prior to assembly. Examples of finishing operations that finishing equipment 160(1) may perform include, but are not limited to, surface smoothing, de-burring, heat treatment, and chemical treatment, and any combination thereof, among others.

[0016] Assembly station 156(1) may be any suitable type of assembly station, from fully manual with human workers performing all assembly tasks to fully automated by one or more pieces of equipment, such as one or more robots and/or one or more other automated machines, and any combination of manual and automated tasking. In some embodiments, assembly station 156(1) may have at least one assembly controller 164(1) that controls the assembly of each hot-runner assembly 104(1) to 104(N) assembled at that assembly station. Those skilled in the art will readily understand that in addition to one or more robots and/or other pieces of automated assembly equipment, assembly station 156(1) may include various other items that assist in the assembly process, such as various tools, jigs, chucks, etc. If present, assembly controller 164(1) may receive assembly instructions 148(1) to 148(N) for assembling corresponding respective hot-runner assemblies 104(1) to 104(N) in any suitable manner, such as from manufacturing scheduler 140. In other embodiments, assembly controller 164(1) may receive assembly instructions 148(1) to 148(N) from another source, such as fabrication controller 132(1) if the assembly instructions accompany fabrication instructions 136(1) to 136(N) and the fabrication controller passes the assembly instructions off to the assembly controller after FFF equipment 128(1) has finished fabricating the corresponding components set, such as set of components 112(1), 116(1), 120(1), and 124(1).

[0017] Hot-runner-manufacturing system 100 may also include a shipping department 168 responsible for packing and shipping hot-runner assemblies 104(1) to 104(N). Shipping department 168 may receive shipping instructions 150(1) to 150(N) in any suitable manner, such as directly from manufacturing scheduler 140 or from another source, such as assembly controller 164(1) if the shipping instructions accompany assembly instruction 148(1) to 148(N). Shipping department 168 may be partially or fully automated, in which case the shipping department may be partially or fully controlled by a shipping controller 172. Alternatively, if shipping department 168 is configured such that shipping controller 172 is not necessary because there is nothing to be automatedly controlled, shipping instructions 150(1) to 150(N) may still be provided to the shipping department, such as in the form of instructions presented on the screen of a computing device (not shown) for a human worker to follow.

[0018] Those skilled in the art will readily appreciate that while the foregoing description focuses on a single set of resources, for example, FFF equipment 128(1), fabrication controller 132(1), assembly station 156(1), and assembly controller 164(1), in other embodiments of hot-runner-manufacturing system 100 any one or more of these resources may be present in a greater number. Some of these alternatives are illustrated in FIG. 1 with the optional presence of FFF equipment 128(2) to 128(N), corresponding respective fabrication controllers 132(2) to 132(N), assembly stations 156(2) to 156(N), and corresponding respective assembly controllers 164(2) to 164(N), indicating that any number of these resources may be present in a particular embodiment of hot-runner manufacturing system 100. It is noted, however, that many further alternative embodiments are possible. For example, while each FFF equipment 128(1) to 128(N) is shown as having its own fabrication controller 132(1) to 132(N), this need not be so. For example, a single fabrication controller, such as fabrication controller 132(1) may control two or more, including all, of the fabrication equipment. Similarly, while each assembly station 156(1) to 156(N) is shown as having its own assembly controller 164(1) to 164(N), a single assembly controller, such as assembly controller 164(1) may control two or more, including all, of the assembly stations. In addition, while manufacturing scheduler 140 is shown in the singular, embodiments of hot-runner-manufacturing system 100 may include more than one manufacturing scheduler, each of which may control one or more, or all, of downstream resources, such as FFF equipment 128(1) to 128(N), fabrication controllers 132(1) to 132(N), assembly stations 156(1) to 156(N), and assembly controllers 164(1) to 164(N). Those skilled in the art will readily appreciate the many combinations and permutations of the foregoing and other manufacturing resources that a hot-runner-manufacturing system of the present invention may have.

[0019] Referring to FIG. 2, this figure illustrates an exemplary method 200 of manufacturing one or more hot-runner assemblies in a hot-runner-manufacturing system, such as hot-runner-manufacturing system 100 of FIG. 1, that utilizes concurrent component manufacturing techniques in which two or more components of each hot-runner assembly are fabricated concurrently with one another, for example, in one or more FFF processes, such as any one or more of the FFF processes described above. For the convenience of illustrating method 200, it is described in the context of hot-runner-manufacturing system 100 of FIG. 1. Consequently, the following description of method 200 makes occasional reference to FIG. 1 and system 100, which have 100-series reference numerals for distinction from the 200-series reference numerals of FIG. 2 and method 200.

[0020] At step 205, hot-runner-manufacturing system 100 may receive an order, such as any one of orders 154(1) to 154(N) from a customer, say order 154(1), for the manufacture of a particular hot-runner assembly, which may be an assembly based on an existing design or a custom design. In this example, the hot-runner assembly at issue may be any one of hot-runner assemblies 104(1) to 104(N), say hot-runner assembly 104(1). Typically, with the order, the customer will specify a timing requirement for when it must take delivery of the hot-runner assembly. At step 210, the customer's order is turned into a manufacturing request, such as any one of manufacturing requests 152(1) to 152(N), say request 152(1), that includes an indicator of the priority that the manufacture of hot-runner assembly 104(1) needs/should have relative to other ones of the manufacturing requests in hot-runner-manufacturing system 100 at the time that manufacturing request 152(1) is added to the system. Manufacturing request 152(1) can be added to system 100 in any suitable manner, such as via input by a user into a suitable computerized user interface, among other ways.

[0021] At step 215, manufacturing request 152(1) is turned into manufacturing instructions, such as manufacturing instructions 144(1), and the manufacturing instructions are placed into queue 108 at a location that is in accordance with the priority indicator of the manufacturing request. In the example of hot-runner-manufacturing system 100 of FIG. 1, manufacturing scheduler 140 may make the determination of where to place manufacturing instructions 144(1) into queue to meet the customer's delivery requirements. As an example, in one embodiment the average time for a hot-runner assembly to be manufactured once the corresponding manufacturing instructions are issued by manufacturing scheduler 140 is 24 hours and the scheduler can issue a new set of manufacturing instructions about every 8 hours for the highest throughput. With two 8-hour shifts a day, only FFF equipment 128(1) present, and assuming that hot-runner-manufacturing system 100 can turn out a completed hot-runner assembly every 8 hours, then the capacity of the hot-runner-manufacturing system is two hot-runner assemblies per day. If the customer needs its hot runner in seven days, with three days allotted to shipping, manufacturing must get started no later than the third day after the order was received. This means that manufacturing scheduler 140 can issue no more than four or five sets of manufacturing instructions ahead of the manufacturing instructions for the hot-runner assembly at issue. Consequently, if there are currently ten sets of manufacturing instructions in queue when manufacturing scheduler 140 receives manufacturing request 152(1), then the scheduler must put manufacturing instructions 144(1) ahead of at least five or six sets of manufacturing instructions already in queue.

[0022] In the example that follows, hot-runner-manufacturing system 100 includes a fully automated assembly station 156(1) that is under control of assembly controller 164(1) and a fully automated shipping department 168 that is under control of shipping controller 172. Also in the example, each of fabrication controller 132(1), assembly controller 164(1), and shipping controller 172 have two-way communications with manufacturing scheduler 140, with each of these controllers not only receiving the corresponding respective fabrication instructions 136(1) to 136(N), assembly instructions 148(1) to 148(N), and shipping instructions 150(1) to 150(N) from the manufacturing scheduler, but also communicating status information, such as a task-completed indicator or an arrival alert, to the manufacturing scheduler. In this manner, manufacturing scheduler 140, which in this example issues fabrication instructions 136(1) to 136(N), assembly instructions 148(1) to 148(N), and shipping instructions 150(1) to 150(N), knows when a particular task has been completed or when a particular task should be started so that it knows when to issue the proper instructions for the next step in the process.

[0023] At step 220, manufacturing scheduler 140 issues fabrication instructions 144(1) to fabrication controller 132(1), which in turn controls FFF equipment 128(1) to fabricate component set 126(1) of hot-runner assembly 104(1). After FFF equipment 128(1) is done fabricating component set 126(1), at step 225 manufacturing scheduler 140 may issue assembly instructions 148(1) (no finishing is needed in this example) to assembly controller 164(1), which in turn controls assembly station 156(1) to assemble components 112(1), 116(1), 120(1), and 124(1) into hot-runner assembly 104(1). As noted above, manufacturing scheduler 140 may know when to issue assembly instructions 148(1), for example, by virtue of receiving a fabrication-completed indication from fabrication controller 132(1) or a component-set-arrival alert from assembly controller 164(1). That said, as noted above, alternative schemes can be implemented in which assembly instructions 148(1), if any, are passed from fabrication controller 132(1) to assembly controller 164(1) as fabricated component set 126(1) moves from FFF equipment 128(1) to assembly station 156(1).

[0024] After assembly station 156(1) is done assembling components 112(1), 116(1), 120(1), and 124(1) into hot-runner assembly 104(1), at step 230 manufacturing scheduler 140 may issue shipping instructions 150(1) to shipping controller 172, which in turn instructs shipping department 168 to package and/or otherwise prepare hot-runner assembly 104(1) for shipping. As noted above, manufacturing scheduler 140 may know when to issue shipping instructions 150(1), for example, by virtue of receiving an assembly-completed indication from assembly controller 164(1) or an assembly-arrival alert from shipping controller 172. However, as noted above, alternative schemes can be implemented in which shipping instructions 150(1), if any, are passed from assembly controller 164(1) to shipping controller 172 as hot-runner assembly 104(1) moves from assembly station 156(1) to shipping department 168.

[0025] It is to be noted that any one or more of the aspects and embodiments described herein may be conveniently implemented using one or more machines (e.g., one or more computing devices that are utilized as a user computing device for an electronic document, one or more server devices, such as a document server, etc.) programmed according to the teachings of the present specification, as will be apparent to those of ordinary skill in the computer art. Appropriate software coding can readily be prepared by skilled programmers based on the teachings of the present disclosure, as will be apparent to those of ordinary skill in the software art. Aspects and implementations discussed above employing software and/or software modules may also include appropriate hardware for assisting in the implementation of the machine executable instructions of the software and/or software module.

[0026] Such software may be a computer program product that employs a machine-readable storage medium. A machine-readable storage medium may be any medium that is capable of storing and/or encoding a sequence of instructions for execution by a machine (e.g., a computing device) and that causes the machine to perform any one of the methodologies and/or embodiments described herein. Examples of a machine-readable storage medium include, but are not limited to, a magnetic disk, an optical disc (e.g., CD, CD-R, DVD, DVD-R, etc.), a magneto-optical disk, a read-only memory (ROM) device, a RAM device, a magnetic card, an optical card, a solid-state memory device, an EPROM, an EEPROM, and any combinations thereof. A machine-readable medium, as used herein, is intended to include a single medium as well as a collection of physically separate media, such as, for example, a collection of compact discs or one or more hard disk drives in combination with a computer memory. As used herein, a machine-readable storage medium does not include transitory forms of signal transmission.

[0027] Such software may also include information (e.g., data) carried as a data signal on a data carrier, such as a carrier wave. For example, machine-executable information may be included as a data-carrying signal embodied in a data carrier in which the signal encodes a sequence of instruction, or portion thereof, for execution by a machine (e.g., a computing device) and any related information (e.g., data structures and data) that causes the machine to perform any one of the methodologies and/or embodiments described herein.

[0028] Examples of a computing device include, but are not limited to, an electronic book reading device, a computer workstation, a terminal computer, a server computer, a handheld device (e.g., a tablet computer, a smartphone, etc.), a web appliance, a network router, a network switch, a network bridge, any machine capable of executing a sequence of instructions that specify an action to be taken by that machine, and any combinations thereof. In one example, a computing device may include and/or be included in a kiosk.

[0029] FIG. 3 shows one embodiment of a computing device in the exemplary form of a computer system 300 within which a set of instructions for causing a control system, such as any one or more of manufacturing scheduler 140, fabrication controller 132(1) to 132(N), assembly controller 164(1) to 164(N), and shipping controller 172, to perform any one or more of the aspects and/or methodologies of the present disclosure may be executed. It is also contemplated that multiple computing devices may be utilized to implement a specially configured set of instructions for causing one or more of the devices to perform any one or more of the aspects and/or methodologies of the present disclosure. Computer system 300 includes a processor 304 and a memory 308 that communicate with each other, and with other components, via a bus 312. Bus 312 may include any of several types of bus structures including, but not limited to, a memory bus, a memory controller, a peripheral bus, a local bus, and any combinations thereof, using any of a variety of bus architectures.

[0030] Memory 308 may include various components (e.g., machine readable media) including, but not limited to, a random access memory component, a read only component, and any combinations thereof. In one example, a basic input/output system 316 (BIOS), including basic routines that help to transfer information between elements within computer system 300, such as during start-up, may be stored in memory 308. Memory 308 may also include (e.g., stored on one or more machine-readable media) instructions (e.g., software) 320 embodying any one or more of the aspects and/or methodologies of the present disclosure. In another example, memory 308 may further include any number of program modules including, but not limited to, an operating system, one or more application programs, other program modules, program data, and any combinations thereof.

[0031] Computer system 300 may also include a storage device 324. Examples of a storage device (e.g., storage device 324) include, but are not limited to, a hard disk drive, a magnetic disk drive, an optical disc drive in combination with an optical medium, a solid-state memory device, and any combinations thereof. Storage device 324 may be connected to bus 312 by an appropriate interface (not shown). Example interfaces include, but are not limited to, SCSI, advanced technology attachment (ATA), serial ATA, universal serial bus (USB), IEEE 1394 (FIREWIRE), and any combinations thereof. In one example, storage device 324 (or one or more components thereof) may be removably interfaced with computer system 300 (e.g., via an external port connector (not shown)). Particularly, storage device 324 and an associated machine-readable medium 328 may provide nonvolatile and/or volatile storage of machine-readable instructions, data structures, program modules, and/or other data for computer system 300. In one example, software 320 may reside, completely or partially, within machine-readable medium 328. In another example, software 320 may reside, completely or partially, within processor 304.

[0032] Computer system 300 may also include an input device 332. In one example, a user of computer system 300 may enter commands and/or other information into computer system 300 via input device 332. Examples of an input device 332 include, but are not limited to, an alpha-numeric input device (e.g., a keyboard), a pointing device, a joystick, a gamepad, an audio input device (e.g., a microphone, a voice response system, etc.), a cursor control device (e.g., a mouse), a touchpad, an optical scanner, a video capture device (e.g., a still camera, a video camera), a touchscreen, and any combinations thereof. Input device 332 may be interfaced to bus 312 via any of a variety of interfaces (not shown) including, but not limited to, a serial interface, a parallel interface, a game port, a USB interface, a FIREWIRE interface, a direct interface to bus 312, and any combinations thereof. Input device 332 may include a touch screen interface that may be a part of or separate from display 336, discussed further below. Input device 332 may be utilized as a user selection device for selecting one or more graphical representations in a graphical interface as described above.

[0033] A user may also input commands and/or other information to computer system 300 via storage device 324 (e.g., a removable disk drive, a flash drive, etc.) and/or network interface device 340. A network interface device, such as network interface device 340, may be utilized for connecting computer system 300 to one or more of a variety of networks, such as network 344, and one or more remote devices 348 connected thereto. Examples of a network interface device include, but are not limited to, a network interface card (e.g., a mobile network interface card, a LAN card), a modem, and any combination thereof. Examples of a network include, but are not limited to, a wide area network (e.g., the Internet, an enterprise network), a local area network (e.g., a network associated with an office, a building, a campus or other relatively small geographic space), a telephone network, a data network associated with a telephone/voice provider (e.g., a mobile communications provider data and/or voice network), a direct connection between two computing devices, and any combinations thereof. A network, such as network 344, may employ a wired and/or a wireless mode of communication. In general, any network topology may be used. Information (e.g., data, software 320, etc.) may be communicated to and/or from computer system 300 via network interface device 340.

[0034] Computer system 300 may further include a video display adapter 352 for communicating a displayable image to a display device, such as display device 336. Examples of a display device include, but are not limited to, a liquid crystal display (LCD), a cathode ray tube (CRT), a plasma display, a light emitting diode (LED) display, and any combinations thereof. Display adapter 352 and display device 336 may be utilized in combination with processor 304 to provide graphical representations of aspects of the present disclosure. In addition to a display device, computer system 300 may include one or more other peripheral output devices including, but not limited to, an audio speaker, a printer, and any combinations thereof. Such peripheral output devices may be connected to bus 312 via a peripheral interface 356. Examples of a peripheral interface include, but are not limited to, a serial port, a USB connection, a FIREWIRE connection, a parallel connection, and any combinations thereof.

[0035] The foregoing has been a detailed description of illustrative embodiments of the invention. Various modifications and additions can be made without departing from the spirit and scope of this invention. Features of each of the various embodiments described above may be combined with features of other described embodiments as appropriate in order to provide a multiplicity of feature combinations in associated new embodiments. Furthermore, while the foregoing describes a number of separate embodiments, what has been described herein is merely illustrative of the application of the principles of the present invention. Additionally, although particular methods herein may be illustrated and/or described as being performed in a specific order, the ordering is highly variable within ordinary skill to achieve methods and software according to the present disclosure. Accordingly, this description is meant to be taken only by way of example, and not to otherwise limit the scope of this invention.

[0036] Exemplary embodiments have been disclosed above and illustrated in the accompanying drawings. It will be understood by those skilled in the art that various changes, omissions and additions may be made to that which is specifically disclosed herein without departing from the spirit and scope of the present invention.

What is claimed is:

1. A method of manufacturing hot-runner assemblies, the method being executed in a computer-controlled hot-runner-manufacturing system and comprising:
receiving a first order for a hot-runner assembly that includes a component set comprising a plurality of components of differing types, wherein the plurality of components are separate from one another;
generating, as a function of said receiving the order, fabrication instructions designed and configured to instruct freeform-fabrication equipment to concurrently fabricate the plurality of components; and
controlling, based on the fabrication instructions, freeform-fabrication equipment to form the plurality of components concurrently with one another.

2. A method according to claim 1, further comprising:
generating, as a function of said receiving the order, assembly instructions; and
providing the assembly instructions to an assembly station for assembling the plurality of components into the hot-runner assembly.

3. A method according to claim 2, wherein the assembly station comprises automated assembly equipment and the assembly instructions include machine-executable instructions designed and configured to control the automated assembly equipment.

4. A method according to claim 2, further comprising:
generating, as a function of said receiving the order, shipping instructions; and
providing the shipping instructions to a shipping department.

5. A method according to claim 1, further comprising:
assigning a manufacturing priority indicator to manufacturing instructions that include the fabrication instructions; and
locating the manufacturing instructions in a manufacturing queue as a function of the manufacturing priority indicator.

6. A method according to claim 1, wherein said controlling freeform-fabrication equipment includes controlling a 3D printer to make the plurality of components concurrently with one another.

7. A method according to claim 1, wherein the hot-runner assembly includes a manifold and a plurality of injection nozzles separate from the manifold, wherein said controlling freeform-fabrication equipment includes controlling freeform-fabrication equipment to form the manifold and the plurality of injection nozzles concurrently with one another.

8. A machine-readable storage medium containing machine-executable instructions for performing a method of manufacturing hot-runner assemblies, said machine-executable instructions comprising:

   a first set of machine-executable instructions for generating, as a function of receiving an order for a hot-runner assembly that includes a component set comprising a plurality of separate components of differing types, fabrication instructions designed and configured to instruct freeform-fabrication equipment to concurrently fabricate the plurality of components;

   a second set of machine-executable instructions for providing the fabrication instructions to a fabrication controller in operative communication with the freeform-fabrication equipment; and

   a third set of machine-executable instructions for controlling, based on the fabrication instructions, freeform-fabrication equipment to form the plurality of components concurrently with one another.

9. A machine-readable storage medium according to claim 8, further comprising:

   a fourth set of machine-executable instructions for generating assembly instructions as a function of the receiving of the order; and

   a fifth set of machine-executable instructions for providing the assembly instructions to an assembly station for assembling the plurality of components into the hot-runner assembly.

10. A machine-readable storage medium according to claim 9, wherein the assembly station comprises automated assembly equipment and the assembly instructions include machine-executable instructions designed and configured to control the automated assembly equipment.

11. A machine-readable storage medium according to claim 9, further comprising:

   a sixth set of machine-executable instructions for generating shipping instructions as a function of said receiving the order; and

   a seventh set of machine executable instructions for providing the shipping instructions to a shipping department.

12. A machine-readable storage medium according to claim 8, further comprising:
    a fourth set of machine-executable instructions for assigning a manufacturing priority indicator to manufacturing instructions that include the fabrication instructions; and
    a fifth set of machine-executable instructions for locating the manufacturing instructions in a manufacturing queue as a function of the manufacturing priority indicator.

13. A machine-readable storage medium according to claim 8, wherein said third set of machine-executable instruction include machine-executable instructions for controlling a 3D printer to make the plurality of components concurrently with one another.

14. A machine-readable storage medium according to claim 8, wherein the hot-runner assembly includes a manifold and a plurality of injection nozzles separate from the manifold, wherein said third set of machine-executable instructions include machine-executable instructions for controlling freeform-fabrication equipment to form the manifold and the plurality of injection nozzles concurrently with one another.

15. A manufacturing system for manufacturing a hot-runner assembly in response to receiving an order, the fabrication system comprising:
    freeform-fabrication equipment designed and configured to manufacture separate components of the hot-runner assembly;
    a fabrication controller in operative communication with said freeform-fabrication equipment, said fabrication controller configured to be responsive to fabrication instructions that control said freeform-fabrication equipment to concurrently form the components of the hot-runner assembly; and
    a manufacturing scheduler in operative communication with said fabrication controller, said manufacturing scheduler programmed to:
        generate the fabrication instructions; and
        provide the fabrication instructions to said fabrication controller.

16. A manufacturing system according to claim 15, wherein said manufacturing scheduler is designed and configured to:
    assemble a manufacturing queue containing manufacturing requests each having a priority indicator; and

order the manufacturing requests in the manufacturing queue as a function of each priority indicator.

17. A manufacturing system according to claim 15, further comprising an assembly station designed and configured for assembling the hot-runner assembly using the components, wherein said manufacturing scheduler is designed and configured to generate, as a function of receiving the order, assembly instructions for said assembly station.

18. A manufacturing system according to claim 17, wherein said assembly station comprises automated assembly equipment and said manufacturing scheduler is designed and configured to generate assembly instructions for said automated assembly equipment.

19. A manufacturing system according to claim 17, further comprising a shipping department designed and configured for shipping the hot-runner assembly after assembly, wherein said manufacturing scheduler is designed and configured to generate shipping instructions for said shipping department.

20. A manufacturing system according to claim 15, wherein the hot-runner assembly includes a manifold and a plurality of nozzles separate from the manifold, wherein said scheduler is programmed to generate the fabrication instructions so that the fabrication instructions control said freeform-fabrication equipment so as to fabricate the manifold and the plurality of nozzles concurrently with one another.

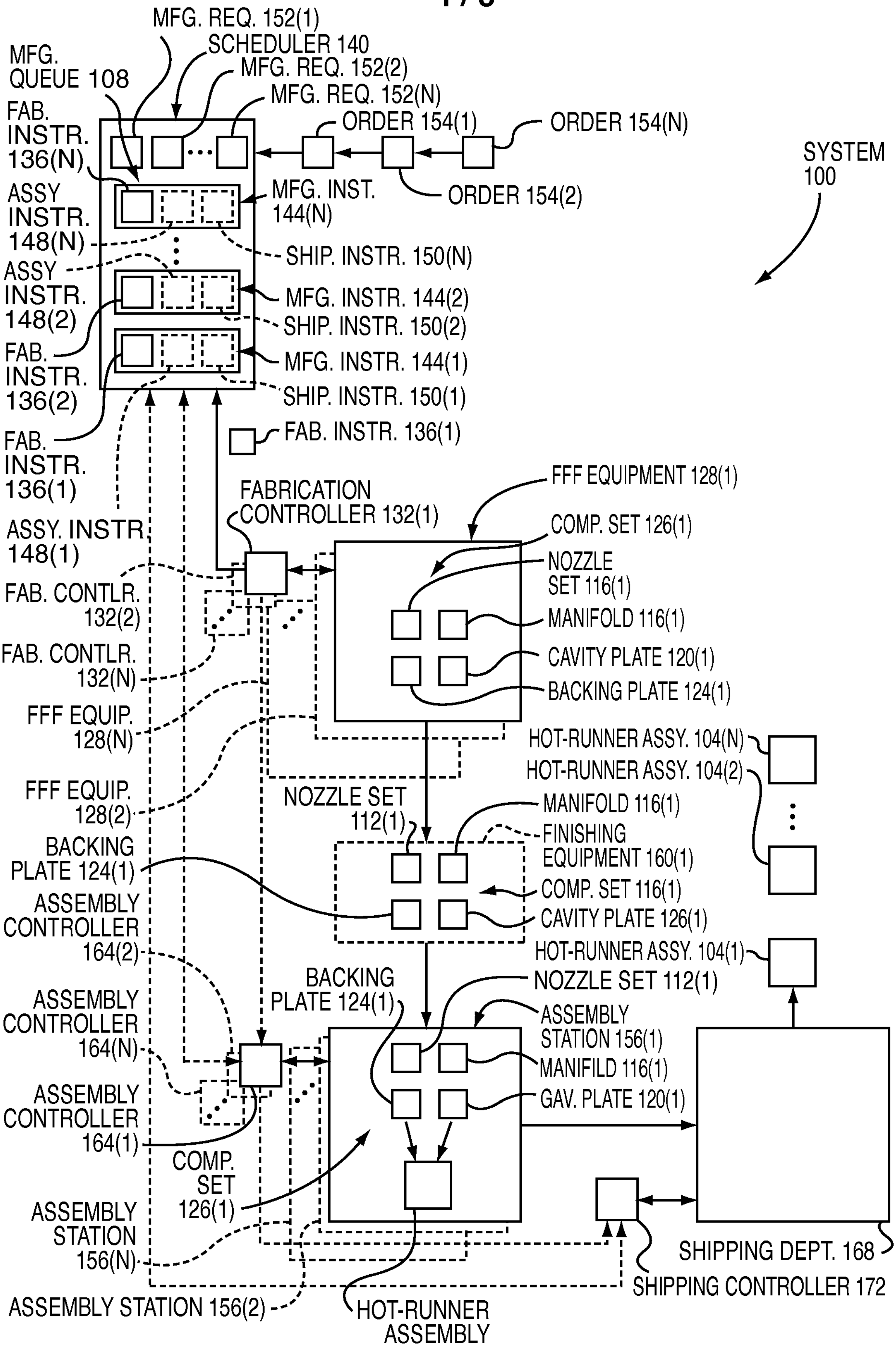

MFG. REQ. 152(1)
SCHEDULER 140
MFG. QUEUE 108
MFG. REQ. 152(2)
MFG. REQ. 152(N)
ORDER 154(1)
ORDER 154(N)
SYSTEM 100
FAB. INSTR. 136(N)
ORDER 154(2)
ASSY INSTR. 148(N)
MFG. INST. 144(N)
SHIP. INSTR. 150(N)
ASSY INSTR. 148(2)
MFG. INSTR. 144(2)
SHIP. INSTR. 150(2)
FAB. INSTR. 136(2)
MFG. INSTR. 144(1)
SHIP. INSTR. 150(1)
FAB. INSTR. 136(1)
FAB. INSTR. 136(1)
FFF EQUIPMENT 128(1)
FABRICATION CONTROLLER 132(1)
ASSY. INSTR. 148(1)
COMP. SET 126(1)
NOZZLE SET 116(1)
FAB. CONTLR. 132(2)
MANIFOLD 116(1)
FAB. CONTLR. 132(N)
CAVITY PLATE 120(1)
BACKING PLATE 124(1)
FFF EQUIP. 128(N)
HOT-RUNNER ASSY. 104(N)
HOT-RUNNER ASSY. 104(2)
FFF EQUIP. 128(2)
NOZZLE SET 112(1)
MANIFOLD 116(1)
FINISHING EQUIPMENT 160(1)
BACKING PLATE 124(1)
COMP. SET 116(1)
ASSEMBLY CONTROLLER 164(2)
CAVITY PLATE 126(1)
HOT-RUNNER ASSY. 104(1)
BACKING PLATE 124(1)
NOZZLE SET 112(1)
ASSEMBLY CONTROLLER 164(N)
ASSEMBLY STATION 156(1)
MANIFILD 116(1)
ASSEMBLY CONTROLLER 164(1)
GAV. PLATE 120(1)
COMP. SET 126(1)
ASSEMBLY STATION 156(N)
SHIPPING DEPT. 168
SHIPPING CONTROLLER 172
ASSEMBLY STATION 156(2)
HOT-RUNNER ASSEMBLY

FIG. 1

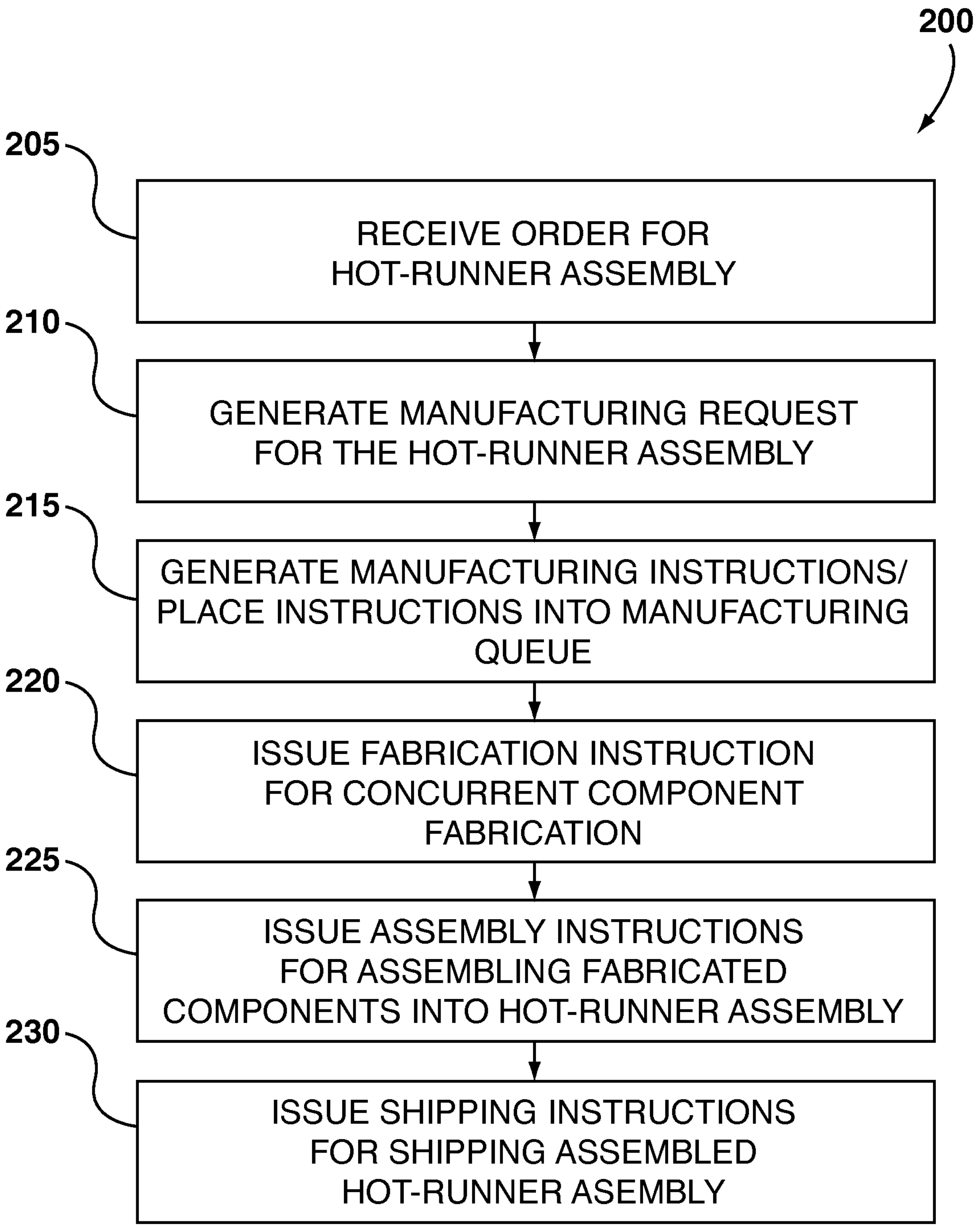
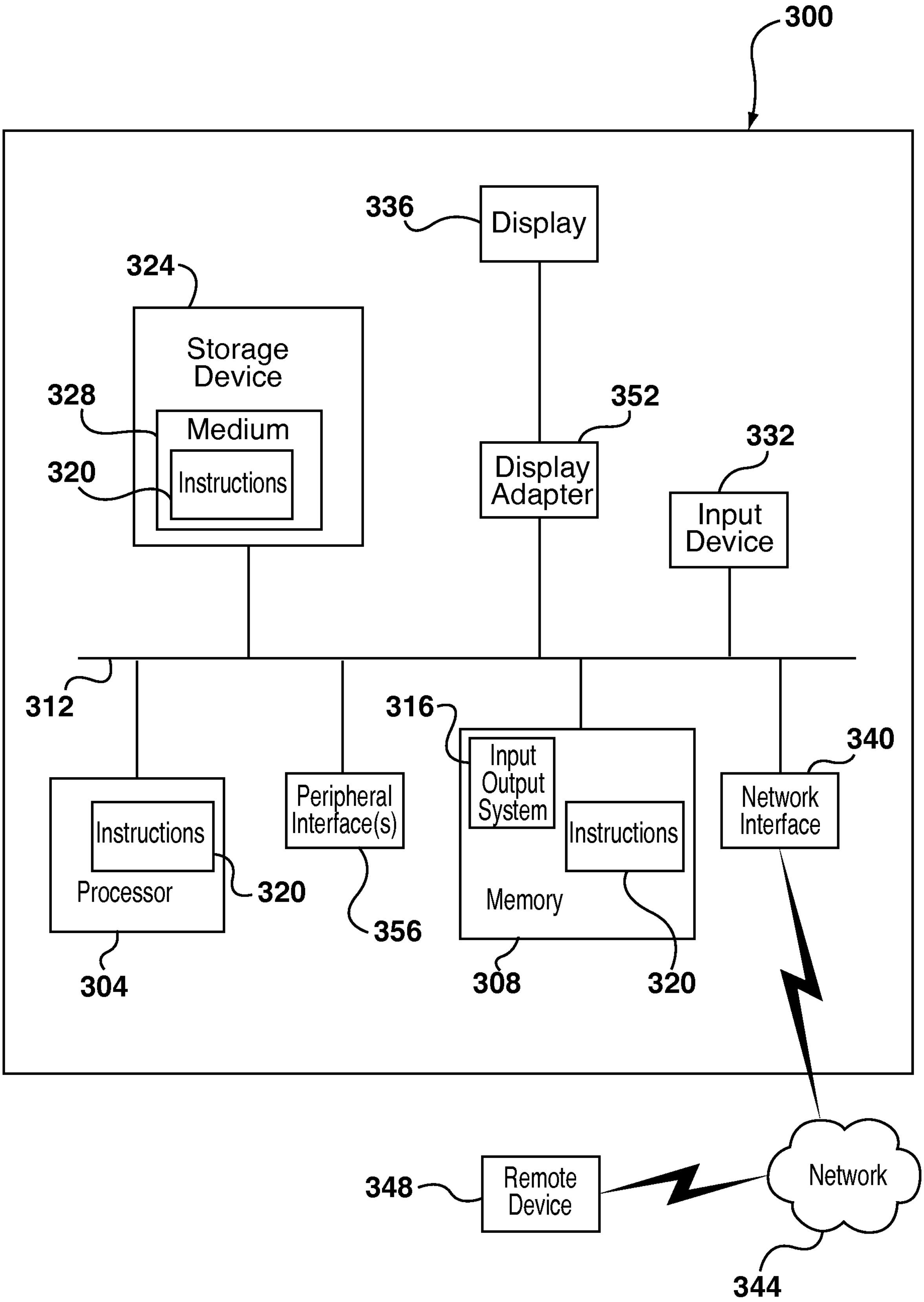

200
205
RECEIVE ORDER FOR HOT-RUNNER ASSEMBLY
210
GENERATE MANUFACTURING REQUEST FOR THE HOT-RUNNER ASSEMBLY
215
GENERATE MANUFACTURING INSTRUCTIONS/ PLACE INSTRUCTIONS INTO MANUFACTURING QUEUE
220
ISSUE FABRICATION INSTRUCTION FOR CONCURRENT COMPONENT FABRICATION
225
ISSUE ASSEMBLY INSTRUCTIONS FOR ASSEMBLING FABRICATED COMPONENTS INTO HOT-RUNNER ASSEMBLY
230
ISSUE SHIPPING INSTRUCTIONS FOR SHIPPING ASSEMBLED HOT-RUNNER ASEMBLY

FIG. 2



300
336
Display
324
Storage Device
352
328
Medium
332
320
Instructions
Display Adapter
Input Device
312
316
340
Input Output System
Peripheral Interface(s)
Network Interface
Instructions
Instructions
Processor
320
Memory
356
304
308
320
348
Remote Device
Network
344

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/018373

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - B29C 51/02 (2015.01)
CPC - B29C 45/1603 (2015.04)
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8) - A21C 3/00, 11/00; A23G 1/20, 1/22, 3/00; A23P 1/00; B28B 13/00; B29C 31/00, 51/02, 63/00 (2015.01)
USPC -264/255, 294, 297.1, 297.4, 297.8; 425/130, 145, 175, 465, 572, 576

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
CPC - B29C 45/1603, 45/1607, 45/1734, 45/1735, 45/2725 (2015.04) (keyword delimited)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Orbit, Google Patents, Google Scholar, Google.
Search terms used:manufacture, fabricate, production, assembly, making, freeform, flexible, linear, additive, controller, computer, processor, microprocesor, cpu, schedule, plan, arrange, organize, timetable, priority, important, queue, line, order, request

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2013/0147092 A1 (JENKO et al.) 13 June 2013 (13.06.2013) entire document	1-20
Y	US 6,785,581 B2 (MOUNTCASTLE III et al.) 31 August 2004 (31.08.2004) entire document	1-20
Y	EP 0331478 A2 (KATZ et al.) 06 September 1989 (06.09.1989) entire document	2-4,9-11, 17-19
Y	US 6,055,533 A (HOGGE) 25 April 2000 (25.04.2000) entire document	5, 12, 16
A	US 2012/0092724 A1 (PETTIS) 19 April 2012 (19.04.2012) entire document	1-20
A	US 2011/0008532 A1 (FEICK) 13 January 2011 (13.01.2011) entire document	1-20
A	US 8,165,714 B2 (MIER et al.) 24 April 2012 (24.04.2012) entire document	1-20
A	US 7,565,221 B2 (FISCHER et al.) 21 July 2009 (21.07.2009) entire document	1-20

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
05 May 2015	26 JUN 2015

Name and mailing address of the ISA/US	Authorized officer:
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774