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(71) Applicant *(for all designated States except US)*: **THE BOEING COMPANY** [US/US]; 100 North Riverside Plaza, Chicago, IL 60606-2016 (US).

(72) Inventor; and

(75) Inventor/Applicant *(for US only)*: **WINKLER, Daniel, S.** [US/US]; 6431 East Heather Drive, Mesa, AZ 85215-2915 (US).

(74) Agents: **HALPERIN, Brett, L.** et al.; The Boeing Company, P.O. Box 2515, MC 110-SD54, Seal Beach, CA 90740-1515 (US).

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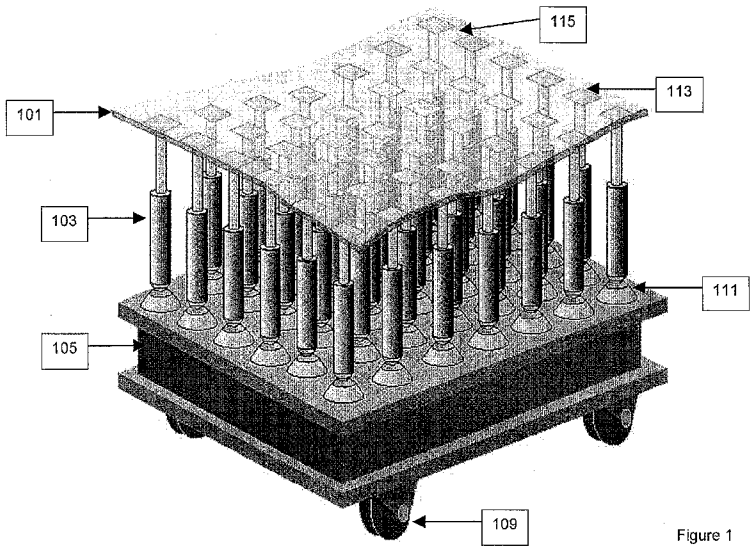


Figure 1

(57) Abstract: Embodiments of the disclosure provide methods, apparatus, and articles for making a plurality of molds described by CAD data in machine readable form using a reusable mold-forming device. Various embodiments include configuring a plurality of adjustable actuators fixed to a base of a mold-forming device, where the top surface of the adjustable actuators takes the form of the mold required to make the part described by the CAD data. The adjustable actuators may then be readjusted to form another mold surface.

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REUSABLE MOLD FORMING TOOL

FIELD

The present embodiments of the disclosure relates to the field of manufacturing molded parts, in particular, the method and apparatuses related to making molds.

BACKGROUND

In a manufacturing system environment, where small numbers of repeatable molded parts are required (e.g., aerospace industry, rapid prototyping), typically individual molds are machined from billets using Numerically Controlled (NC) methods from a Computer Aided-Design (CAD) model or surface, or a plaster splash from a machined male tool. Numerically Controlled (NC) machines continue to play an important role in the machining of metal tools having 3-D contoured shapes for production or prototype applications. Many organizations still machine high density foam to close tolerances to fabricate a form onto which composite tooling may be made; this is a labor-intensive method, but still a viable approach for deep drawn objects such as fighter radomes, or helicopter tailbooms. These methods are expensive due to each part requiring its own mold. Modifications and minor changes to molded parts are common as a design matures, requiring new molds. These modifications may be expensive as a new mold and splash are needed; typically, this slows the design and manufacturing process. The cost of storing individual molds for archiving tool changes and later use is expensive and time consuming. If manufacturing is occurring in different physical geographical locations there is also the added cost and time of transporting molds.

In the 1990s, rapid tooling became popular using methods like Selective Laser Sintering (SLS) and Stereolithography (SLA); although this method was faster and more cost effective than conventional machined or touch composite tooling, it could not be used for production due to its low temperature polymer composition, physical size limitations, high frangibility and poor ability to hold required tolerances.

Electron Beam Curing (EBC) was developed to speed the process of curing composites, but still relies heavily on traditional tooling. Currently, there are no disruptive tooling approaches for manufacturing advanced aerospace composite components, typically aerospace tooling costs approximately three times the production price of an aircraft, making it a large source of costs for the final product.

SUMMARY

Illustrative embodiments of the disclosure mold differently shaped parts using the same mold-forming device, which is adjustable and allows for modifications of the mold. This embodiment may comprise a plurality of adjustable actuators fixed perpendicular to a base, and arranged in a matrix, the ends of the adjustable actuators not fixed to the base being free to move in a direction perpendicular to the base.

The mold may be created by taking the CAD data of a part to be molded, using the CAD data to compute adjustments to the plurality of adjustable actuators into positions that represent the surface of a mold for the part to be formed. A repeatable flexible caul plate may then be placed on top of the adjustable actuators to form a mold surface. Once the adjustable actuators are in position they may be adjusted by the mold-forming device for thermal expansion, composite part spring-back, and thickness of the material to be formed using the mold. In this embodiment the adjustable actuators may have a feedback system allowing the adjustable actuators to be calibrated and their positions determined. The determined positions of the adjustable actuators may be corroborated against the input data allowing for quality control of the mold-forming device. Once the position of the adjustable actuators is verified with the input data the adjustable actuators may be locked into position. The embodiment may then have power withdrawn from the device and the actuators will hold their position, providing a stable tooling surface, and allowing the mold to be reused in the set position for more than one molded part. In various embodiments, the mold-forming device may be mobile and may be maneuvered into a curing device such as an autoclave. The mold-forming device may be constructed in a modular form so that a plurality of mold-forming devices may be joined together allowing for the possibility of manufacturing larger molded parts. Storage of molds is no longer required as the data to create the mold using the mold-forming device is all that is required to be stored. The data may be sent to distant geographical locations that are in possession of an embodiment of the mold-forming device, allowing manufacturing to take place quickly and cheaply wherever the devices are located. Rapid prototyping and modification is possible as the mold of molded part can quickly and easily be adjusted using the new data of the adjusted part, allowing for individual molded part comparisons to be carried out in their application environment.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the disclosure will be readily understood by the following detailed description in conjunction with the accompanying drawings. Embodiments of the disclosure are illustrated by way of example and not by way of limitation in the figures of the accompanying drawings.

Figure 1 depicts an embodiment of the mold-forming device used in various embodiments of the present disclosure.

Figure 2 depicts a flowchart view of selected operations of the methods used in accordance with various embodiments of the present disclosure.

Figure 3 depicts an exemplary architecture of selected computing components of the mold-forming device of figure 1 suitable for use to perform selected automated operations of figure 2, in accordance with various embodiments of the present disclosure.

Figure 4 is a flow diagram of aircraft production and service method, in accordance with various embodiments of the present disclosure.

Figure 5 is a block diagram of an aircraft, in accordance with various embodiments of the present disclosure.

DETAILED DESCRIPTION

Illustrative embodiments of the disclosure include, but are not limited to, methods, apparatuses, and articles of manufacture for a multiuse mold-forming device that may be electronically adjusted. Embodiments may contain a plurality of adjustable actuators fixed to a base, where the adjustable actuators are affixed perpendicular to the base. The adjustable actuators may be arranged in a matrix, where the adjustable actuator ends are opposite to the base end, are free to move, and are configurable. The mold-forming device may be mobile and contain a module capable of adjusting the adjustable actuators into a plurality of positions dependent upon input data coming from a CAD model or surface. The module adjusting the matrix arrangement of adjustable actuators may then allow the data from the CAD surface or solid model to position the adjustable actuator thereby configuring the top surface of the adjustable actuators to form the exact shape of the CAD surface to be tooled, this may be a male or female mold.

Various operations may be described as multiple discrete operations in turn, in a manner that may be helpful in understanding various embodiments; however, the order of description should not be construed to imply that these operations are order dependent.

The description may use perspective-based descriptions such as up/down, back/front, and top/bottom. Such descriptions are merely used to facilitate the discussion and are not intended to restrict the application of the embodiments.

The terms "coupled" and "connected," along with their derivatives, may be used. It should be understood that these terms are not intended as synonyms for each other. Rather, in particular embodiments, "connected" may be used to indicate that two or more elements are in direct physical or electrical contact with each other. "Coupled" may mean that two or more elements are in direct physical or electrical contact. However "coupled" may also mean that two or more elements are not in direct contact with each other, but yet still cooperate or interact with each other.

For the purposes of the description, a phrase in the form "A/B" means A or B. For the purposes of the description, a phrase in the form "A and/or B" means "(A), (B), or (A and B)." For the purposes of the description, a phrase in the form "at least one of A, B, and C" means "(A), (B), (C), (A and B), (A and C), (B and C), or (A, B and C)." For the purposes of the description, a phrase in the form "(A) B" means "(B) or (AB)," that is, A is an optional element.

The description may use the phrases, "various embodiments," "in an embodiment," or "in embodiments," which may each refer to one or more of the same or different embodiments. Furthermore, the terms "comprising," "including," "having," and the like, as used with respect to embodiments as described in the present disclosure, are synonymous.

Figure 1 depicts an embodiment of the mold-forming device used in various embodiments of the disclosure. As illustrated, a mold-forming device may have a base **105**, and the base may be a solid rectangular structure capable of supporting a matrix of electronic actuators; items for carrying out data processing, controlling devices for the adjustable actuators **103**, a caul plate that may rest on the top surface **113** of the adjustable actuators **103**, and any mold-forming material. The base may be set on casters **109** or a similar device allowing the mold-forming device to be maneuverable; allowing the device to be mobile within the manufacturing environment. This may allow the device to be maneuvered into a curing environment such as an autoclave. It may also allow the device to be maneuvered into a position allowing the mold-forming device to be locked together with other mold-forming devices. The mold-forming device may include a locking device (not shown) that couples the mold-forming

device to other mold-forming devices, allowing a larger mold-forming device to be created from the smaller modular mold-forming devices. This larger mold-forming device made up of the embodiment allows for larger molded pieces to be created. The mold-forming device may also include an electronic interconnect module (not shown) allowing data to be transferred between the mold-forming devices when a plurality are joined to create a larger mold-forming device for creating larger molded parts. This may allow data to pass through the plurality of mold-forming devices so that the appropriate mold-forming device is configured, allowing the plurality of mold-forming devices to act as one large mold-forming device. The electronic interconnect module may allow data to be input into the mold-forming device from an external source, where the CAD model or surface data is stored or directly from a computer device that is capable of transferring mold data to the mold-forming device. The mold data may then be input into a module (not shown) that contains adjustable actuator logic and a storage medium for positions of the adjustable actuators **103**, representing the CAD model or surface to be formed.

The base **105** of the mold-forming device may have a plurality of adjustable actuators **103** attached perpendicularly to the base **105** in the form of a matrix. The adjustable actuator base **111** may be fixed to the base **105** of the mold-forming device, the adjustable actuator **103** may be attached firmly holding the adjustable actuator perpendicular to the base **105** of the mold-forming device. In this embodiment, the adjustable actuators **103** are positioned as close together as possible to each other so that the top surface **113** of the adjustable actuators **103** may form a near contiguous surface.

CAD model data for a part or surface that may be molded by the device is input via the electronic interconnect module (not shown). The data may be computed using the module (not shown) into position data for the adjustable actuators **103.** The computed adjustable actuator position data represents the position for each adjustable actuator **103** so that the plurality of adjustable actuators **103** may be configured into positions to represent a shape, or surface of a mold that will form the part described in the CAD model or surface data.

In this embodiment, to compute the positions for each adjustable actuator **103**, the module that accepts the CAD model or surface data uses this data with one or more of the thermal expansion of the mold material, composite part spring-back of the mold, and thickness of the material to be formed using the mold.

Once the position data for each adjustable actuator **103** of the mold-forming device has been calculated, the module inputs the position data into the appropriate actuator driver which moves the adjustable actuator to the calculated position. Each adjustable actuator **103** is

connected to an electronic feedback system (not shown) allowing the precise position of each adjustable actuator **103** to be determined, allowing the mold-forming device to verify the precise position of each of the adjustable actuators **103** for quality control. This may be accomplished automatically as the adjustable actuator's actual positions may be matched to the CAD model or surfaces computed positions, eliminating the need for Coordinate Measurement Mapping (CMM) or other tool inspection procedures. This feedback system allows quality control to be carried out automatically as each new CAD mold or surface data set is input into the mold-forming device, as the mold-forming device forms the mold.

In this embodiment, the adjustable actuators **103** are locked into position once the position of each adjustable actuator is verified with the CAD model or surface. The locked actuator allows the mold-forming device to be detached from any power source and the electronic interconnect module (not shown). The locked adjustable actuators may now hold their positions which form the shape of the mold representing the part described by the CAD model or surface. A repeatable flexible caul plate **115** may now be laid on the top surface **113** of the automatic actuators. This may be a highly ductile material that is flexible in all directions, e.g., a Teflon plate, thin aluminum, or high temperature rubber.

The mold-forming device may now have the mold-forming material laid on top of the caul plate and the mold-forming device maneuvered into a curing environment for the particular mold-forming material being used. The mold-forming device may be used to make copies of this part as necessary. The mold-forming device may hold its shape as the adjustable actuators **103** are locked into position. When a new mold shape is required the mold-forming device is reattached using the electronic interconnect module (not shown) to a device holding the CAD model or surface of the new shape. The process may be repeated for the new mold shape. If the original shape is required at some time in the future, the data can be re-input into the mold-forming device so the device can again reposition the adjustable actuator into the original positions allowing the original shape to be formed.

Figure 2 depicts a flowchart view of selected operations of the methods used in accordance with various embodiments of the disclosure. In this embodiment, the mold-forming device may receive the data that represents the mold-form as CAD data of the model or surface, block **201**, to be shaped. In other embodiments the data may be in the form of electronic data representing the shape to be formed by the mold-forming device.

If more than one mold-forming device is required, block **210**, to form the mold, one or more mold-forming devices as required, may be connected together. The mold-forming devices

may have physical connectors that allow the mold-forming device to be locked together, block **202**. This locking together may physically attach one mold-forming device to another mold-forming device, where a process to detach them may be required to separate the mold-forming devices from one another. This may allow the mold-forming devices to revert back to their singular state. Once locked together the one or more mold-forming devices form a larger mold-forming device required to mold a larger part, this may be because the mold to be formed is too large to be formed on one mold-forming device.

The CAD data of the mold, block **201**, may be input into the mold-forming device through the electronic interconnect module, the data being input into a module containing computational logic **314** (shown in figure 3). The module generates data for the positions of the adjustable actuators, block **203**, using computational logic **314** (shown in figure 3) and actuator logic **316** (shown in figure 3). Once the position for each adjustable actuator **103** (shown in figure 1) has been calculated, further refinement of the adjustable actuator **103** (shown in figure 1) position may take place. In this embodiment the position of the adjustable actuator **103** (shown in figure 1) may be refined by further generating data for the position of the adjustable actuators **103** (shown in figure 1) based upon a thermal expansion, block **204**. This embodiment may include the position of the adjustable actuator **103** (shown in figure 1) being refined by further generating data for the position of the adjustable actuator **103** (shown in figure 1) based upon a composite part spring-back, block **206**. This embodiment may further refine the position of the adjustable actuator **103** (shown in figure 1) by further generating data for the position of the adjustable actuator **103** (shown in figure 1) based upon a thickness of the material to be formed, block **208**.

The position data for each adjustable actuator **103** (shown in figure 1) may then be used to configure each adjustable actuator via the data communication interconnect, block **205**, using the actuator driver **320** (shown in figure 3), contained in the module of the mold-forming device. The data communication interconnect socket may allow data to be transferred from an outside source; this may be another computer device from which the data is input into the mold-forming device. Once the adjustable actuators have been configured, the adjustable actuators may be locked, block **207**. An electronic feedback system may provide feedback of positions of adjustable actuators, block **209**, to allow the precise position of each adjustable actuator to be determined for quality control purposes. Once the precise position of the adjustable actuators has been provided, the mold-forming device verifies the position of the adjustable actuator, block **211**, with the CAD model data that was provided to determine the positions of the adjustable

actuators. If an adjustable actuator is found to be in the wrong position, the mold-forming device configures the adjustable actuator, block **205**, again. This process is repeated until the positions of all of the adjustable actuators can be verified with the input CAD model data.

In this embodiment of the disclosure, once the position of the adjustable actuators **103** (shown in figure 1) has been verified, block **211**, removal of power from the mold-forming device, block **212**, may be performed. The adjustable actuators **103** (shown in figure 1) are locked into their verified position and with the removal of power from the mold-forming device remain in the same position. The mold-forming device may be used one or more times without being reconnected to a power source, the locked adjustable actuator **103** (shown in figure 1), locked into the position determined by the CAD input data.

Once each of the adjustable actuator's positions has been verified, a flexible caul plate **115** (shown in figure 1) may be disposed upon the upper surface of the actuators, block **213**, with the caul plate in place the mold material may be applied to the mold, block **215**. The mold-forming device can now be moved to an environment to cure the mold and then ready the mold-forming device for another mold, block **217**. If the same part is required, the mold-forming device may be reused as the adjustable actuators are locked into position. If a new mold part is required, the operations are repeated, the mold-forming a new shape dependent upon the input data.

Figure 3 depicts an exemplary architecture of selected computing components of the mold-forming device suitable for performing the described operations of various embodiments of the present disclosure. As shown, computing components **300** may include one or more processors **302** and memory **304**. Additionally, computing system/device **300** may include mass storage devices **306** (such as diskette, hard drive, CD-ROM and so forth), and communication interfaces **310** (such as network interface cards, modems and so forth). The elements may be coupled to each other via system bus **312**, which represents one or more buses. In the case of multiple buses, they may be bridged by one or more bus bridges (not shown).

Mass storage **306** and memory **304** may be employed to store a working copy and a permanent copy of the programming instructions implementing one or more aspects of the above described teachings to practice the mold-forming device methods and apparatuses of the present disclosure, such as computational logic **314**. The programming instructions may be implemented in assembler instructions supported by processor(s) **302** or high level languages, such as C, that may be compiled into such instructions.

The permanent copy of the programming instructions may be placed into mass storage **306** in the factory, or in the field, through, e.g., a distribution medium (not shown) or through communication interface **310** (from a distribution server (not shown)).

Mass storage **306** may contain actuator logic **316** and storage for position data **318** for each adjustable actuator. The actuator logic may be the logic required to convert surface or model data into actuator position data, computing where each individual adjustable actuator from the plurality of adjustable actuators arranged in a matrix should be positioned to represent the surface or model of the CAD data to be molded. Once each adjustable actuator position is calculated the position data may be stored in the position data storage **318**. The adjustment of the adjustable actuators may require an actuator driver **320**, each adjustable actuator may have its own instance of the actuator driver, the position data for each adjustable actuator stored in the position data **318** may be communicated to the actuator driver **320** via the bus **312**. The actuator drivers **320** may then adjust the adjustable actuators to the computed position, allowing the plurality of adjustable actuators to form a surface with the end of adjustable actuators, the end being opposite to the end fixed to the base.

Referring more particularly to the drawings, embodiments of the disclosure may be described in the context of an aircraft manufacturing and service method **400** as shown in **Figure 4** and an aircraft **502** as shown in **Figure 5**. During preproduction, exemplary method **400** may include specification and design **404** of the aircraft **502** and material procurement **406**. During production, component and subassembly manufacturing **408** and system integration **410** of the aircraft **502** takes place. Thereafter, the aircraft **502** may go through certification and delivery **412** in order to be placed in service **414**. While in service by a customer, the aircraft **502** is scheduled for routine maintenance and service **416** (which may include modification, reconfiguration, refurbishment, and so on).

Each of the processes of method **400** may be performed or carried out by a system integrator, a third party, and/or an operator (e.g., a customer), as indicated by the "X" in the grid to the right of the flow diagram of **Figure 4**. For the purposes of this description, a system integrator may include without limitation any number of aircraft manufacturers and major-system subcontractors; a third party may include without limitation any number of venders, subcontractors, and suppliers; and an operator may be an airline, leasing company, military entity, service organization, and so on.

As shown in **Figure 5**, the aircraft **502** produced by exemplary method **400** may include an airframe **518** with a plurality of systems **520** and an interior **522**. Examples of high-level

systems **520** include one or more of a propulsion system **524**, an electrical system **526**, a hydraulic system **528**, and an environmental system **530**.

Apparatus and methods embodied herein may be employed during any one or more of the stages of the production and service method **400**. For example, components or subassemblies corresponding to production process **408** may be fabricated or manufactured in a manner similar to components or subassemblies produced while the aircraft **502** is in service. Also, one or more apparatus embodiments, method embodiments, or a combination thereof may be utilized during the production stages **408** and **410**, for example, by substantially expediting assembly of or reducing the cost of an aircraft **402**. Similarly, one or more of apparatus embodiments, method embodiments, or a combination thereof may be utilized while the aircraft **502** is in service, for example and without limitation, to maintenance and service **416**.

Although specific embodiments have been illustrated and described herein for purposes of description of the preferred embodiment, it will be appreciated by those of ordinary skill in the art that a wide variety of alternate and/or equivalent implementations may be substituted for the specific embodiment shown and described without departing from the scope of the disclosure. Those with skill in the art will readily appreciate that the present disclosure may be implemented in a very wide variety of embodiments. This application is intended to cover any adaptations or variations of the embodiments discussed herein. Therefore, it is manifestly intended that this disclosure be limited only by the claims and the equivalents thereof.

CLAIMS

What is claimed is:

1. A method for making a plurality of molds, comprising:

configuring a plurality of adjustable actuators of a mold-forming device to a first plurality of positions for forming a first mold, using first CAD data of the first mold;

forming the first mold using the mold-forming device;

reconfiguring the plurality of adjustable actuators of the mold-forming device to a second plurality of positions for forming a second mold, that is separate and distinct from the first mold, using second CAD data of the second mold; and

forming the second mold using the mold-forming device.

2. The method of claim 1, further comprising generating the data for positioning the plurality of adjustable actuators of the mold-forming device, the data describing a mold form.

3. The method of claim 1, further comprising locking the plurality of adjustable actuators in specified positions.

4. The method of claim 3, wherein the locking further comprises continuing locking the plurality of adjustable actuators in specified positions while the mold-forming device receives no power.

5. The method of claim 1, further comprising receiving electronic feedback from the at least one of the adjustable actuators, wherein the plurality of adjustable actuators include an electronic feedback system attached to each actuator, providing verification feedback of the current positions of the adjustable actuators.

6. The method of claim 5, wherein the verification feedback of the adjustable actuators is compared to input CAD data for the mold being formed.

7. The method of claim 1, further comprising locating the mold-forming device on a mobile platform.

8. The method of claim 7, wherein the mold-forming device on the mobile platform further comprises physical connectors allowing a plurality of mobile platforms to be joined.

9. The method of claim 1, wherein the configuring further comprises computing positions of each of the plurality of adjustable actuators based upon a thermal expansion.

10. The method of claim 1, wherein the configuring further comprises computing positions of each of the plurality of automatic adjustable actuators based upon a composite part spring-back.

11. The method of claim 1, wherein the configuring further comprises computing positions of each of the plurality of adjustable actuators, based upon a thickness of the material to be formed into a mold.

12. The method of claim 1, further comprising disposing a flexible caul plate upon the upper surface of the plurality of adjustable actuators.

13. The method of claim 1, further comprising providing an interconnect socket allowing the mold-forming device be coupled with a plurality of mold-forming devices, allowing data communications to transfer through the interconnect socket.

14. The method of claim 1, further comprising providing a data communication interconnect socket to the mold-forming device for receiving data at the mold-forming device.

15. An apparatus for forming a mold comprising:

a plurality of adjustable actuators each including an upper surface adapted to receive a material to be formed into a mold;

a base unit supporting the plurality of actuators; and

a module operatively coupled to the plurality of adjustable actuators and adapted to:

configure the plurality of adjustable actuators to a first plurality of positions for forming a first mold, using first CAD data of the first mold,

facilitate forming the first mold,

reconfigure the plurality of adjustable actuators to a second plurality of positions for forming a second mold, that is separate and distinct from the first mold, using second CAD data of the second mold; and

facilitate forming the second mold.

16. The apparatus of claim 15, wherein the module is further adapted to generate the data for positioning the plurality of adjustable actuators, the data describing a mold form.

17. The apparatus of claim 15, wherein the module is further adapted to lock the plurality of adjustable actuators in specified positions.

18. The apparatus of claim 15, wherein the module is further adapted to lock the plurality of adjustable actuators in specified positions while the mold-forming device receives no power.

19. The apparatus of claim 15, wherein the base unit is further located on a mobile platform.

20. The apparatus of claim 19, wherein the mobile platform further comprises physical connectors allowing a plurality of mobile platforms to be joined.

21. The apparatus of claim 15, wherein the module further comprises an interconnect socket allowing coupling with a plurality of modules, allowing data communications to transfer through the interconnect socket.

22. An article of manufacture comprising:

a storage medium; and

a plurality of programming instructions stored on the storage medium and configured to program a mold-forming device to

configure a plurality of adjustable actuators of a mold-forming device to a first plurality of positions to form a first mold, using first CAD data of the first mold;

form the first mold using the mold-forming device;

reconfigure the plurality of adjustable actuators of the mold-forming device to a second plurality of positions to form a second mold, that is separate and distinct from the first mold, using second CAD data of the second mold; and

form the second mold using the mold-forming device.

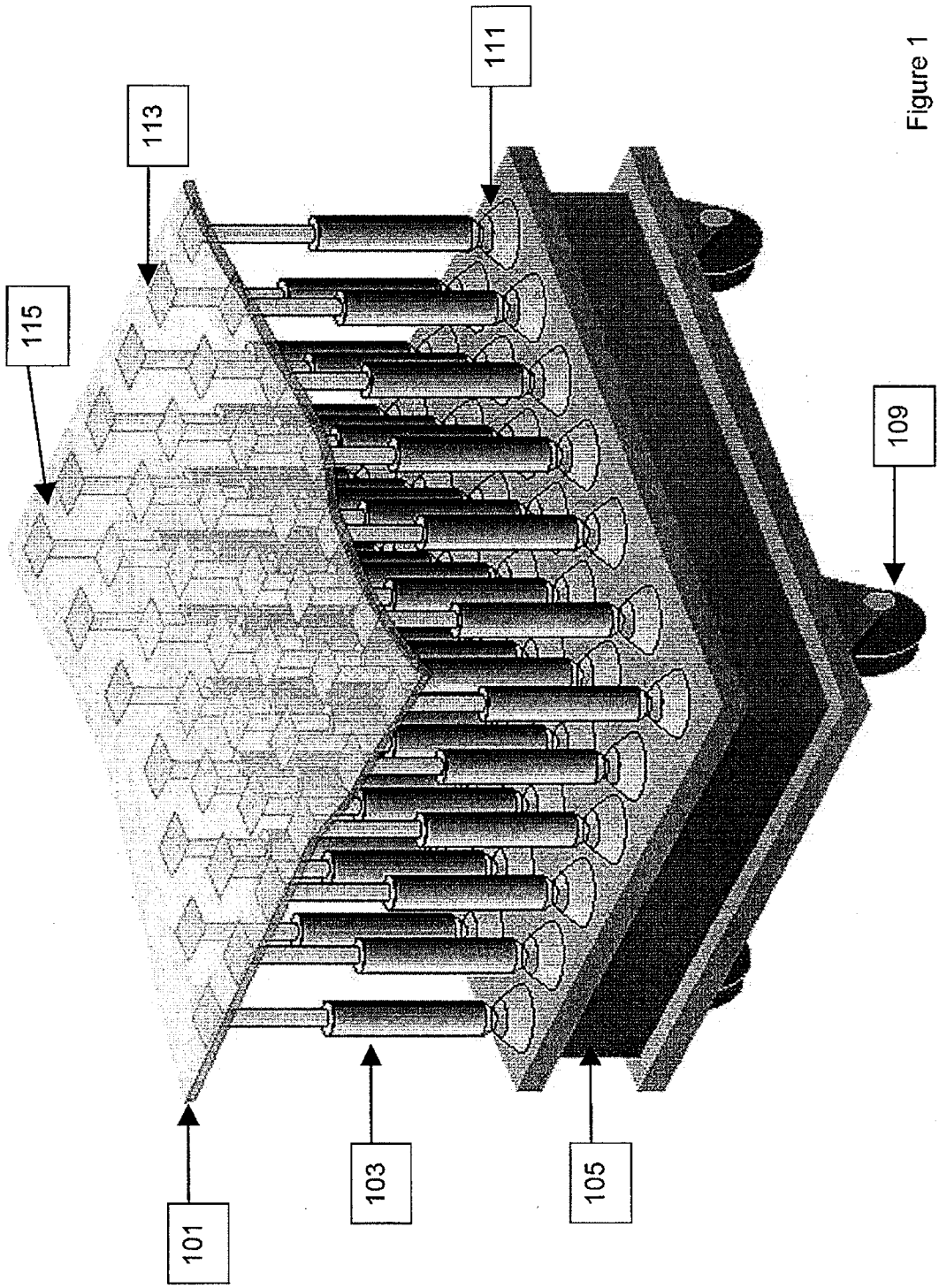


Figure 1

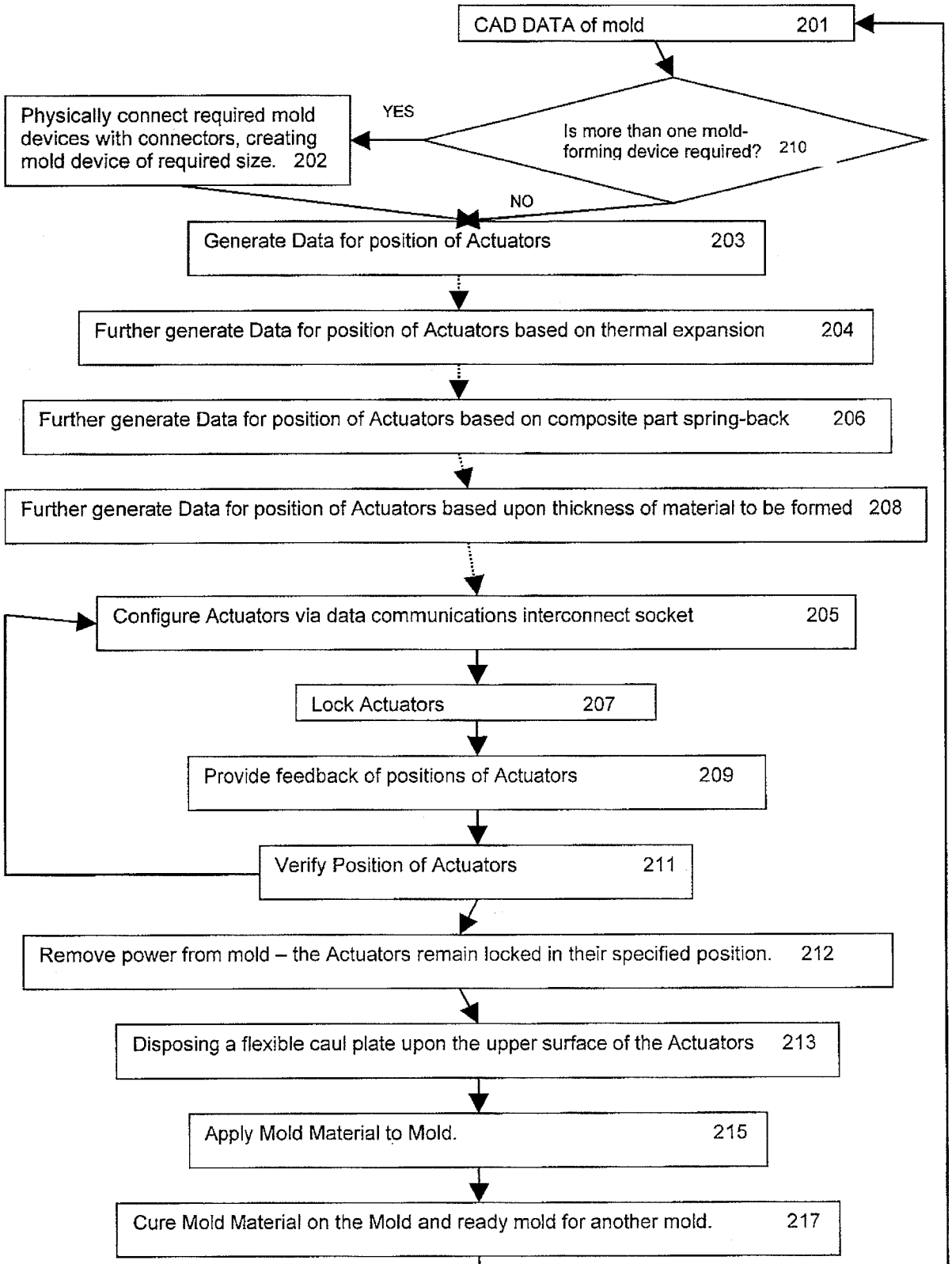

CAD DATA of mold 201
Is more than one mold-forming device required? 210
YES
Physically connect required mold devices with connectors, creating mold device of required size. 202
NO
Generate Data for position of Actuators 203
Further generate Data for position of Actuators based on thermal expansion 204
Further generate Data for position of Actuators based on composite part spring-back 206
Further generate Data for position of Actuators based upon thickness of material to be formed 208
Configure Actuators via data communications interconnect socket 205
Lock Actuators 207
Provide feedback of positions of Actuators 209
Verify Position of Actuators 211
Remove power from mold – the Actuators remain locked in their specified position. 212
Disposing a flexible caul plate upon the upper surface of the Actuators 213
Apply Mold Material to Mold. 215
Cure Mold Material on the Mold and ready mold for another mold. 217

Figure 2

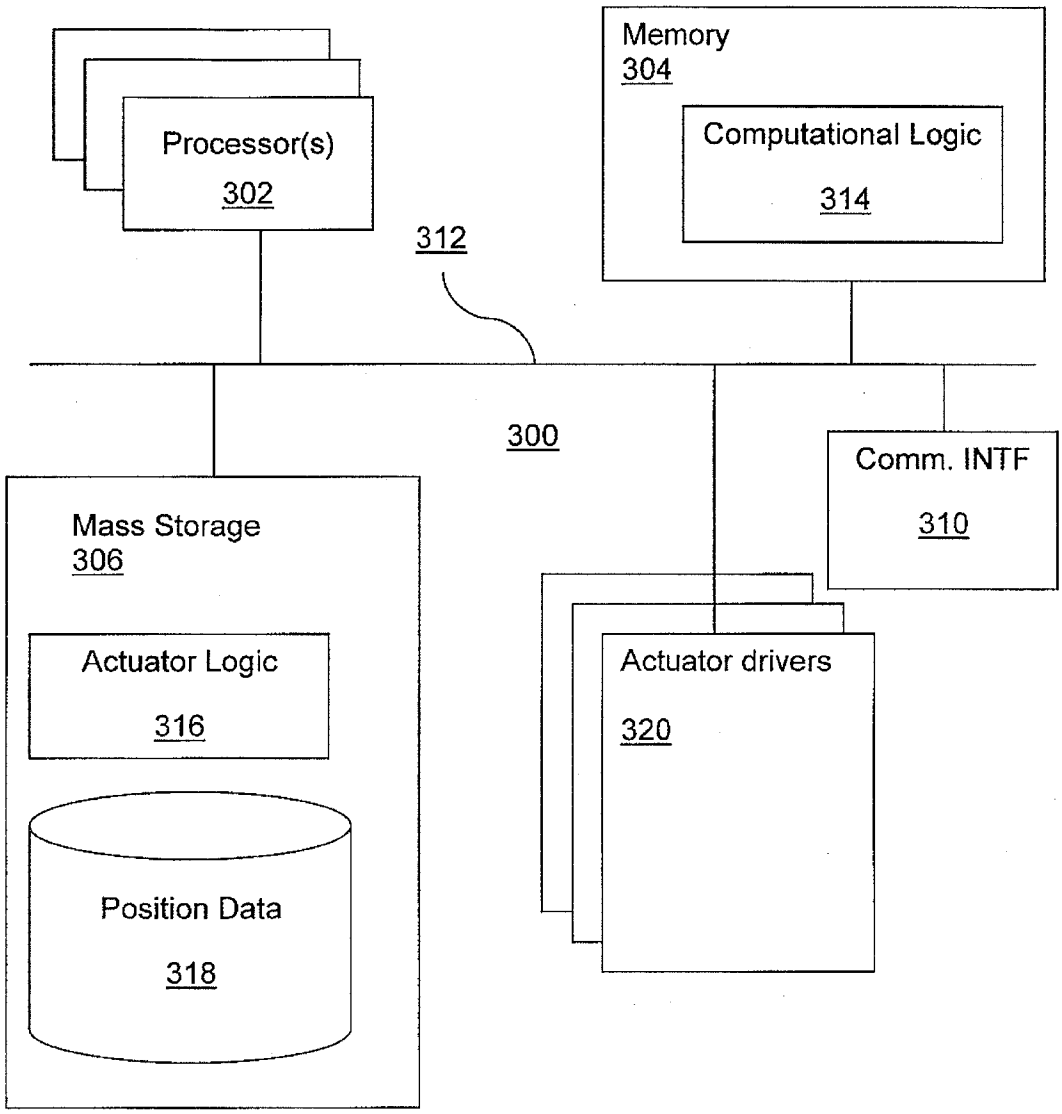

Memory
304
Computational Logic
314
Processor(s)
302
312
300
Comm. INTF
310
Mass Storage
306
Actuator Logic
316
Position Data
318
Actuator drivers
320

Figure 3

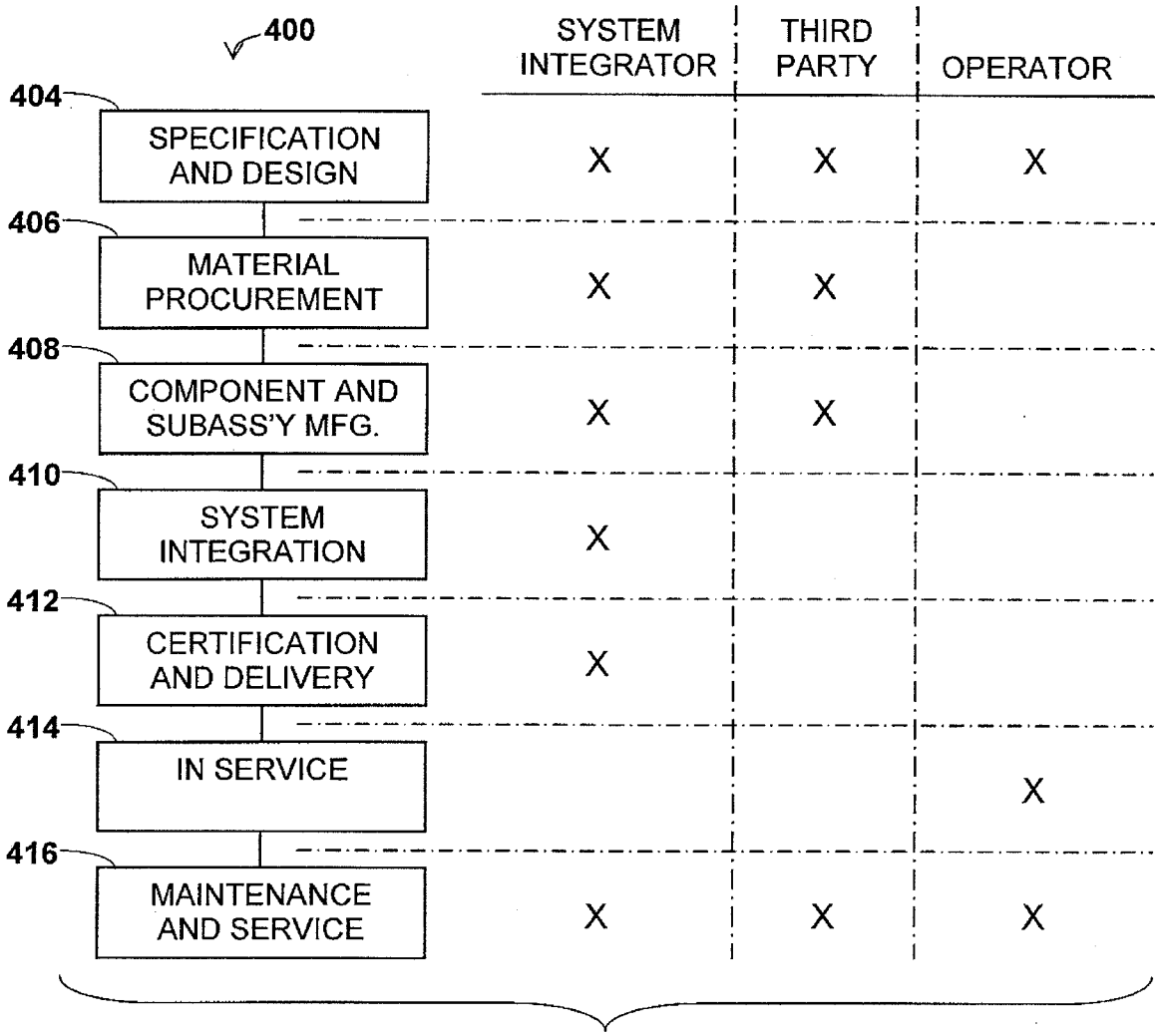

400
SYSTEM INTEGRATOR
THIRD PARTY
OPERATOR
404
SPECIFICATION AND DESIGN
X
X
X
406
MATERIAL PROCUREMENT
X
X
408
COMPONENT AND SUBASS'Y MFG.
X
X
410
SYSTEM INTEGRATION
X
412
CERTIFICATION AND DELIVERY
X
414
IN SERVICE
X
416
MAINTENANCE AND SERVICE
X
X
X

FIG. 4

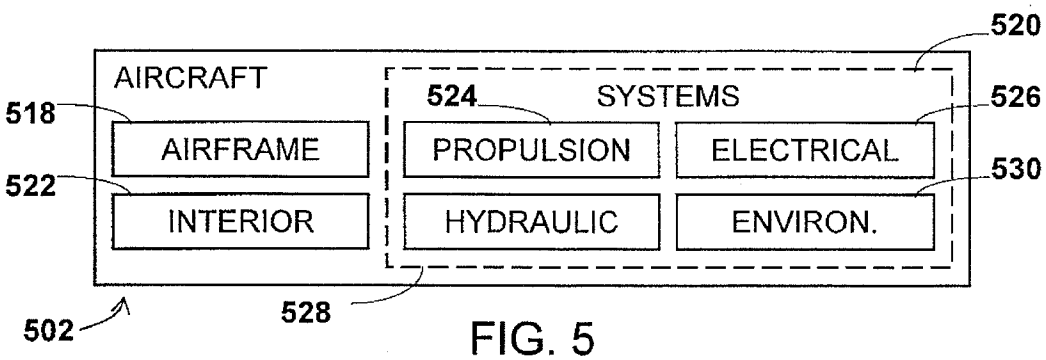

520
AIRCRAFT
524
SYSTEMS
526
518
AIRFRAME
PROPULSION
ELECTRICAL
530
522
INTERIOR
HYDRAULIC
ENVIRON.
502
528

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2008/064419

A. CLASSIFICATION OF SUBJECT MATTER
INV. G05B19/4099

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)
G05B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 546 784 A (HAAS EDWIN G [US] ET AL) 20 August 1996 (1996-08-20) columns 1,2,4,7; claims 1,23; figures 1-4	1-22
X	US 5 546 313 A (MASTERS WILLIAM E [US]) 13 August 1996 (1996-08-13) the whole document	1-22
X	WO 99/06917 A (NORTHROP GRUMMAN CORP [US]) 11 February 1999 (1999-02-11) the whole document	1-22
X	US 5 796 620 A (LASKOWSKI JOHN S [US] ET AL) 18 August 1998 (1998-08-18) the whole document	1-22

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

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"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
1 September 2008	19/09/2008

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Juillot, Olivier J.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2008/064419

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