(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 650 480 A2

(12) # EUROPEAN PATENT APPLICATION

(43) Date of publication:
16.10.2013 Bulletin 2013/42

(51) Int Cl.:
F01D 9/02 *(2006.01)*

(21) Application number: **13163218.4**

(22) Date of filing: **10.04.2013**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

(30) Priority: **13.04.2012 US 201213446718**

(71) Applicant: **General Electric Company**
Schenectady, New York 12345 (US)

(72) Inventors:
- **DiCintio, Richard Martin**
  Greenville, SC South Carolina 29615 (US)
- **Melton, Patrick Benedict**
  Greenville, SC South Carolina 29615 (US)

(74) Representative: **Cleary, Fidelma**
GPO Europe
GE International Inc.
The Ark
201 Talgarth Road
Hammersmith
London W6 8BJ (GB)

(54) **Transition piece for a gas turbine engine, corresponding system and method**

(57) Disclosed herein are apparatus, method, and system for cross sectional area convergence reduction and selection of a transition piece (200) of a gas turbine engine. In an embodiment, an aft end cross sectional area (210) is determined for a transition piece and a forward end cross sectional area (205) is determined for the transition piece. The transition piece may be fabricated based on a constant slope of cross sectional area change between the aft end and the forward end.

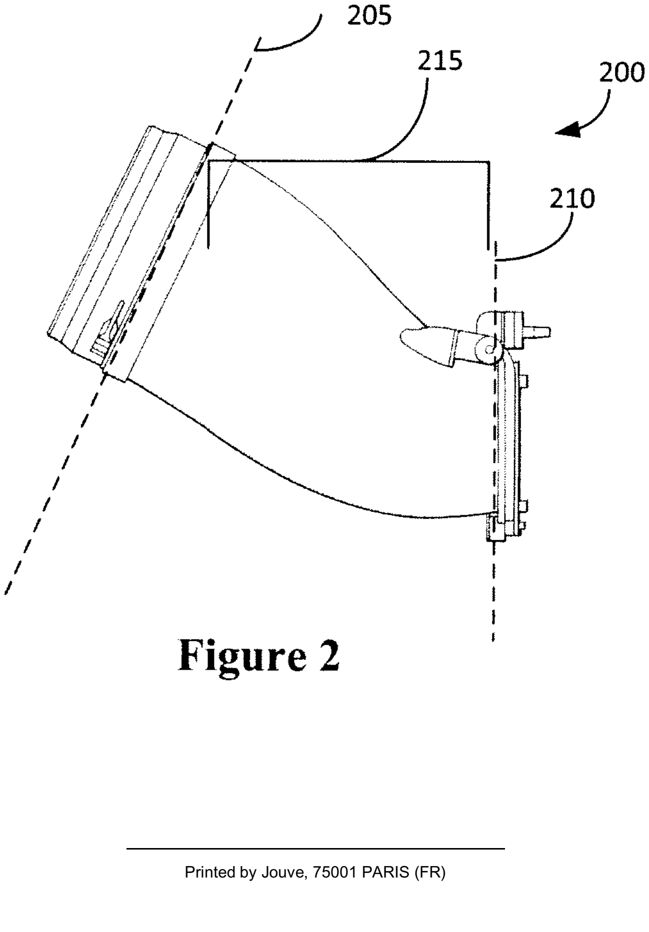

Figure 2

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Description

[0001] The subject matter disclosed herein relates generally to combustion systems and more specifically hot gas flow.

[0002] In a typical can annular gas turbine engine, a plurality of combustors are arranged in a generally annular array about the engine. The combustors receive pressurized air from the engine's compressor, add fuel to create a fuel and air mixture, and combust the mixture to produce hot gases. The hot gases exiting the combustors are utilized to turn a turbine, which is coupled to a shaft that drives a generator for generating electricity.

[0003] The hot combustion gas is conveyed from the combustor liner to the turbine by a transition piece or duct. The hot combustion gas flowing through the transition piece subjects the duct structure to very high temperatures and can lead to premature deterioration that requires repair and replacement of the transition ducts. A significant crack or other deterioration in a single area of an otherwise relatively undamaged transition piece may have a significant impact on gas turbine performance and may require replacement of the entire transition piece.

[0004] Disclosed herein are apparatuses, methods, and systems for transition piece cross sectional area convergence reduction and selection. In an embodiment, a method determines an aft end cross sectional area for a transition piece and a forward end cross sectional area for the transition piece. The transition piece may be fabricated based on a constant slope of cross sectional area change between the aft end and the forward end.

[0005] In an embodiment, a system has a first processor and a first memory. The first memory may be communicatively coupled to the first processor said first memory having stored therein computer-readable instructions that, if executed by the first processor, cause the processor to perform operations comprising determining an aft end cross sectional area for a transition piece; determining a forward end cross sectional area based on the aft end cross sectional area for the transition piece; determining the constant slope of cross sectional area change between the aft end and the forward end; and fabricating the transition piece based on the constant slope of cross sectional area.

[0006] In an embodiment, a transition piece comprises a cross sectional area along the length of the transition piece that stays within +/- 3% of a constant slope cross section area, wherein the constant slope cross sectional area is based on an aft end cross sectional area measurement and a corresponding forward end cross sectional area measurement at a respective length.

[0007] This Brief Description of the Invention is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Brief Description of the Invention is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used to limit the scope of the claimed subject matter. Furthermore, the claimed subject matter is not limited to limitations that solve any or all disadvantages noted in any part of this disclosure.

[0008] A more detailed understanding may be had from the following description, given by way of example in conjunction with the accompanying drawings wherein:

Figure 1 is an exemplary illustration of a transition piece;

Figure 2 is an exemplary illustration of a transition piece;

Figure 3 an exemplary graph that illustrates the change of the cross sectional areas of transition pieces from aft to forward end;

Figure 4 illustrates a non-limiting, exemplary method of implementing transition piece cross sectional area convergence as disclosed herein; and

Figure 5 is an exemplary block diagram representing a general purpose computer system in which aspects of the methods and systems disclosed herein thereof may be incorporated.

[0009] Figure 1 is an exemplary illustration of a transition piece 100. Transition piece 100 has a forward (inlet) end 105 and an aft (outlet) end 110. Hot gases flow into inlet 105 and flow through the length of transition piece 100. The hot gases exit transition piece 100 at outlet 110.

[0010] It has been shown that the life limiting area of a transition piece often has higher temperatures placed on it than other areas of the transition piece. These higher temperatures may cause a higher strain range for every start to stop cycle of the turbine. Over time, these strain cycles may accumulate and become the transition piece's life limit. These higher temperatures may also cause oxidation of the transition piece material. Over time, this oxidation may accumulate and become the transition piece's life limit. As stated herein, regardless of the relatively undamaged nature of the other portions of the transition piece, the entire transition piece is replaced when significant damage (e.g., cracking) is done to a particular area of the transition piece.

[0011] There are certain respective cross sectional areas of a transition piece at the forward (fwd) and aft end. Traditionally, as a rule of thumb, the forward end cross sectional area of a transition piece is 15% larger than the outlet (i.e., aft end) of the transition piece. The 15% rule of thumb is used for transition pieces in order to reduce recirculation in the transition piece. Figure 2 is an exemplary illustration of a transition piece 200. An inlet cross sectional area may be taken at 205 and an outlet cross sectional area may be taken at 210. Traditionally the percentage decrease of the inlet cross sectional area at 205 compared to the outlet cross sectional area at 210 would conform to the 15% rule of thumb. Traditionally the middle section 215 has a cross sectional area that diverges substantially before reaching the final 15% rule of thumb percentage.

[0012] Analysis has shown that hot spots are created within a transition piece because areas may diverge within the middle section of the transition piece and cause recirculation zones. As disclosed herein, reduction of a transition piece cross sectional area from forward end to aft end in a constant rather than divergent manner may substantially reduce hot spots. In an embodiment, reducing that amount of cross sectional area convergence from the 15% rule of thumb (e.g., the aft having a cross sectional area that is 6% less than the fwd) and/or maintaining within a tolerance range of at most +/- 3% may increase the life of a transition piece.

[0013] Figure 3 is an exemplary graph that illustrates the change of the cross sectional areas of transition pieces from aft to forward end. Axis y 302 denotes the cross sectional area of a transition piece and axis x 303 denotes the length of the transition piece from aft end to fwd end. Line 305 is a line that has a constant slope, wherein the cross sectional area changes constantly along the length from aft to forward end. The ideal or reference line 305 (hereinafter reference line) may be determined using standard algebraic equations and the like once the aft and fwd end cross sectional area and length are determined. Curve 310 is a curve that is out of the discussed +/- 3% range along the length of the transition piece. For example, point 311 shows that the transition piece represented by curve 310 has an approximate cross sectional area of 208 at length 15, while the transition piece represented by reference line 305 has an approximate cross sectional area of 188 at length 15. Using the aforementioned measurements point, 311 of curve 310 diverges by approximately 10 percent at the same length of the reference line 305.

[0014] Curve 315 is a curve that is within the discussed +/- 3% range along the length of the transition piece. For example, point 316 shows that the transition piece represented by curve 315 has an approximate cross sectional area of 192 at length 15, while the transition piece represented by line 305 has an approximate cross sectional area of 188 at length 15. Using the aforementioned measurements, point 316 diverges by approximately 2.1 % from the reference line 305.

[0015] A computer generated or physical manifestation of a transition piece may be created based on a predetermined calculated constant change cross sectional area reference line. An example of a physical manifestation may be a physical transition piece mold that conforms to the reference line with +/- 3% divergence in cross sectional area. Measurements of cross sectional area may be taken at every 1/10 interval of the length of the entire transition piece. More frequent measurements may be taken for more data points and better results when creating a transition piece.

[0016] Figure 4 illustrates a non-limiting, exemplary method of implementing transition piece cross sectional area convergence as disclosed herein. Method 400 may be performed by computing equipment including mobile devices (e.g., tablet computers), servers, or any other device that can execute computing functions.

[0017] In an embodiment at block 405, a transition piece aft shape and end cross sectional area may be determined. The aft end cross sectional area determination may be based on characteristics of a corresponding stage one nozzle (SIN). At block 410 the transition piece fwd end shape and cross sectional area may be determined. The fwd end cross sectional area may be based on the aft end cross sectional area. At block 415, the constant slope of cross sectional area change along the length of the transition piece between aft end and fwd end may be determined. At block 420, a transition piece may be created based on the constant slope of the cross sectional area and remaining within a +/- 3% tolerance level.

[0018] Experiments have shown that if care is taken to make sure the cross sectional area is within +/- 3% of a constant change cross sectional area reference line, then hot spots may be reduced and the life of the transition piece may be extended. Although a 15% rule of thumb is discussed herein for cross sectional area change of aft and fwd ends, other percentages may be appropriate. Experiments have shown that the 15% rule of thumb can be lowered (for example to 5%) with better results in transition piece life when the divergence of the cross sectional area along the length of the transition piece is within +/-3%. The closer the divergence of the cross sectional area is to 0% there may be less need to reduce the cross sectional area from the fwd to aft end and the 15% rule of thumb percentage may trend to 0% while giving superior results.

[0019] The technical effect of the method is the fabrication of a physical manifestation (e.g., metal) of a transition piece or the creation of a computer generated representation of a transition piece in a turbine system. Tests of the transition piece may be done using physical transition pieces with test equipment, computer specifications of a transition piece and corresponding computer analysis, or the like. Tests may be done on a particular transition piece design, such as a transition piece made for one or more generator models, and implemented in a physical form or digital form. Although measurements are described as being taken at the forward and aft end, it is reasonable to take measurements within an approximate area of either end.

[0020] Figure 5 and the following discussion are intended to provide a brief general description of a suitable computing environment in which the methods and systems disclosed herein and/or portions thereof may be implemented. Although not required, the methods and systems disclosed herein may be described in the general context of computer-executable instructions, such as program modules, being executed by a computer, such as a client workstation, server or personal computer. Generally, program modules include routines, programs, objects, components, data structures and the like that perform particular tasks or implement particular abstract data types. Moreover, it should be appreciated that the methods and systems disclosed herein and/or portions thereof may be practiced with other computer system configurations, including hand-held devices, multiprocessor systems, microprocessor-based or programmable consumer electronics, network PCs, minicomputers, mainframe computers and the like. The methods and systems disclosed herein may also be practiced in distributed computing environments where tasks are performed by remote processing devices that are linked through a communications network. In a distributed computing environment, program modules may be located in both local and remote memory storage devices.

[0021] Figure 5 is a block diagram representing a general purpose computer system in which aspects of the methods and systems disclosed herein and/or portions thereof may be incorporated. As shown, the exemplary general purpose computing system includes a computer 520 or the like, including a processing unit 521, a system memory 522, and a system bus 523 that couples various system components including the system memory to the processing unit 521. The system bus 523 may be any of several types of bus structures including a memory bus or memory controller, a peripheral bus, and a local bus using any of a variety of bus architectures. The system memory includes read-only memory (ROM) 524 and random access memory (RAM) 525. A basic input/output system 526 (BIOS), containing the basic routines that help to transfer information between elements within the computer 520, such as during start-up, is stored in ROM 524.

[0022] The computer 520 may further include a hard disk drive 527 for reading from and writing to a hard disk (not shown), a magnetic disk drive 528 for reading from or writing to a removable magnetic disk 529, and an optical disk drive 530 for reading from or writing to a removable optical disk 531 such as a CD-ROM or other optical media. The hard disk drive 527, magnetic disk drive 528, and optical disk drive 530 are connected to the system bus 523 by a hard disk drive interface 532, a magnetic disk drive interface 533, and an optical drive interface 534, respectively. The drives and their associated computer-readable media provide non-volatile storage of computer readable instructions, data structures, program modules and other data for the computer 520.

[0023] Although the exemplary environment described herein employs a hard disk, a removable magnetic disk 529, and a removable optical disk 531, it should be appreciated that other types of computer readable media which can store data that is accessible by a computer may also be used in the exemplary operating environment. Such other types of media include, but are not limited to, a magnetic cassette, a flash memory card, a digital video or versatile disk, a Bernoulli cartridge, a random access memory (RAM), a read-only memory (ROM), and the like.

[0024] A number of program modules may be stored on the hard disk, magnetic disk 529, optical disk 531, ROM 524 or RAM 525, including an operating system 535, one or more application programs 536, other program modules 537 and program data 538. A user may enter commands and information into the computer 520 through input devices such as a keyboard 540 and pointing device 542. Other input devices (not shown) may include a microphone, joystick, game pad, satellite disk, scanner, or the like. These and other input devices are often connected to the processing unit 521 through a serial port interface 546 that is coupled to the system bus, but may be connected by other interfaces, such as a parallel port, game port, or universal serial bus (USB). A monitor 547 or other type of display device is also connected to the system bus 523 via an interface, such as a video adapter 548. In addition to the monitor 547, a computer may include other peripheral output devices (not shown), such as speakers and printers. The exemplary system of Figure 5 also includes a host adapter 555, a Small Computer System Interface (SCSI) bus 556, and an external storage device 562 connected to the SCSI bus 556.

[0025] The computer 520 may operate in a networked environment using logical connections to one or more remote computers, such as a remote computer 549. The remote computer 549 may be a personal computer, a server, a router, a network PC, a peer device or other common network node, and may include many or all of the elements described above relative to the computer 520, although only a memory storage device 550 has been illustrated in Figure 5. The logical connections depicted in Figure 5 include a local area network (LAN) 551 and a wide area network (WAN) 552. Such networking environments are commonplace in offices, enterprise-wide computer networks, intranets, and the Internet.

[0026] When used in a LAN networking environment, the computer 520 is connected to the LAN 551 through a network interface or adapter 553. When used in a WAN networking environment, the computer 520 may include a modem 554 or other means for establishing communications over the wide area network 552, such as the Internet. The modem 554, which may be internal or external, is connected to the system bus 523 via the serial port interface 546. In a networked environment, program modules depicted relative to the computer 520, or portions thereof, may be stored in the remote memory storage device. It will be appreciated that the network connections shown are exemplary and other means of establishing a communications link between the computers may be used.

[0027] Computer 520 may include a variety of computer readable storage media. Computer readable storage media can be any available media that can be accessed by computer 520 and includes both volatile and nonvolatile media, removable and non-removable media. By way of example, and not limitation, computer readable media may comprise computer storage media and communication media. Computer storage media include both volatile and nonvolatile, removable and non-removable media implemented in any method or technology for storage of information such as computer readable instructions, data structures, program modules or other data. Computer storage media include, but are not limited to, RAM, ROM, EEPROM, flash memory or other memory technology, CD-ROM, digital versatile disks (DVD) or other optical disk storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other medium which can be used to store the desired information and which can be accessed by computer 520. Combinations of any of the above should also be included within the scope of computer readable media that may be used to store source code for implementing the methods and systems described herein. Any combination of the features or elements disclosed herein may be used in one or more embodiments.

[0028] In describing preferred embodiments of the subject matter of the present disclosure, as illustrated in the Figures, specific terminology is employed for the sake of clarity. The claimed subject matter, however, is not intended to be limited to the specific terminology so selected, and it is to be understood that each specific element includes all technical equivalents that operate in a similar manner to accomplish a similar purpose.

[0029] This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

Claims

1. A method comprising:

determining an aft end cross sectional area (210) for a transition piece (200) of a gas turbine engine;
determining a forward end cross sectional area (205) for the transition piece;
and
fabricating the transition piece based on a constant slope of cross sectional area change between the aft end and the forward end.

2. The method of claim 1, wherein the transition piece is within +/- 3% of the constant slope of cross sectional area along the length of the transition piece.

3. The method of claim 1, wherein the transition piece is within an average +/-3% of the constant slope of cross sectional area along the length of the transition piece.

4. The method of any preceding claim, wherein the forward end cross sectional area is taken near the attachment point of the combustor liner and the transition piece.

5. The method of any preceding claim, wherein the aft end cross sectional area is taken near the aft frame.

6. A transition piece (200) for a gas turbine engine comprising a cross sectional area along the length of the transition piece that stays within +/- 3% of a constant slope cross sectional area, wherein the constant slope cross sectional area is based on an aft end cross sectional area measurement (210) and a corresponding forward end cross sectional area measurement (205) at a respective length.

7. The transition piece of claim 6, wherein the transition piece is within an average +/- 3% of the constant slope of cross sectional area along the length of the transition piece.

8. The transition piece of claim 6 or claim 7, wherein the forward end cross sectional area is taken near the attachment point of the combustor liner of the gas turbine engine and the transition piece.

9. The transition piece of any one of claims 6-8, wherein the aft end cross sectional area is taken near the aft frame of the gas turbine engine.

10. A system comprising:

a first processor adapted to execute computer-readable instructions; and
a first memory communicatively coupled to said first processor, said first memory having stored therein computer-readable instructions that, if executed by the first processor, cause the processor to perform operations comprising:
determining an aft end cross sectional area for a transition piece of a gas turbine engine;
determining a forward end cross sectional area based on the aft end cross sectional area for the transition piece;
determining the constant slope of cross sectional area change between the aft end and the forward end; and
creating the transition piece based on the constant slope of cross sectional area.

11. The system of claim 10, wherein the transition piece is within +/- 3% of the constant slope of cross sectional area along the length of the transition piece.

12. The system of claim 10, wherein the transition piece is within an average +/-3% of the constant slope of cross sectional area along the length of the transition piece.

13. The system of any one of claims 10-12, wherein the forward end cross sectional area is taken near the attachment point of the combustor liner and the transition piece.

14. The system of any one of claims 10-13, wherein the aft end cross sectional area is taken near the aft frame.

15. The system of any one of claims 10-14, wherein computer-readable instructions include taking a cross sectional area measurement of the transition piece at every one-tenth interval of the length of the transition piece.

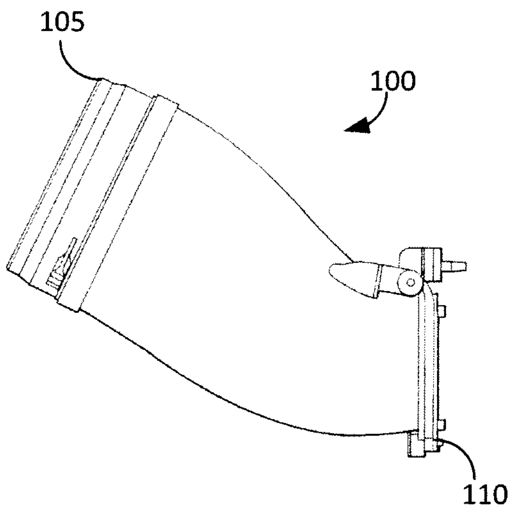


Figure 1

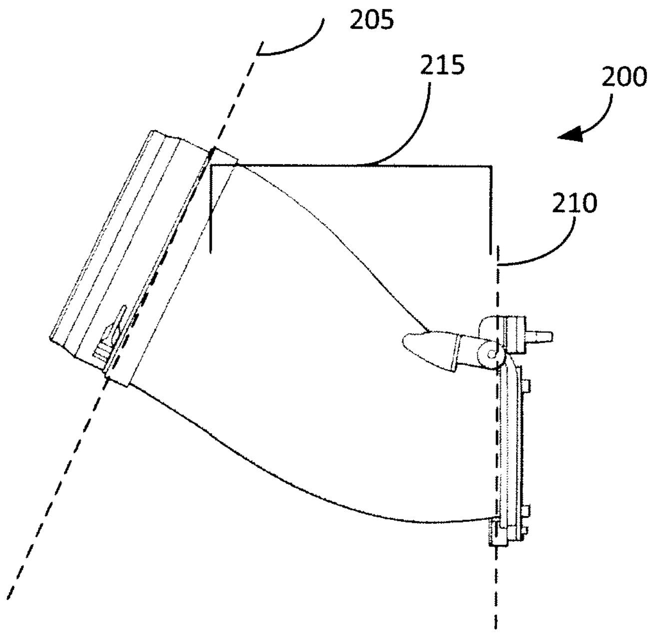
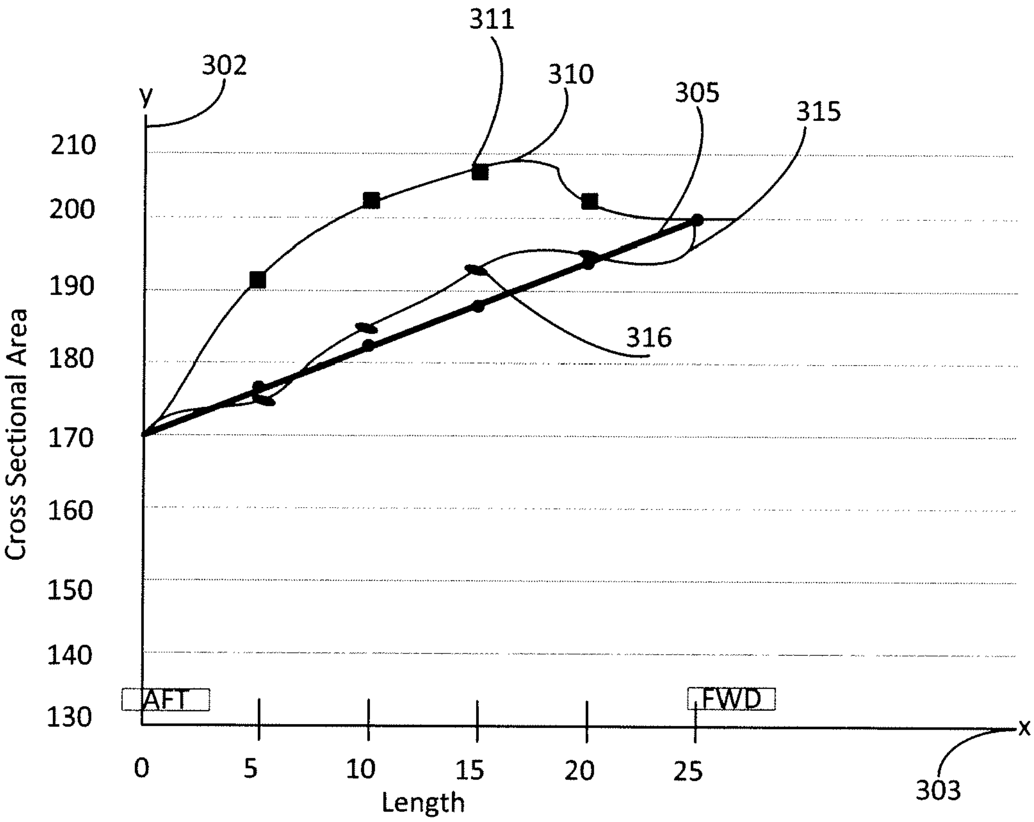


Figure 2



311
302
310
305
315
y
210
200
190
180
170
160
150
140
130
Cross Sectional Area
316
AFT
FWD
0
5
10
15
20
25
Length
x
303

Figure 3

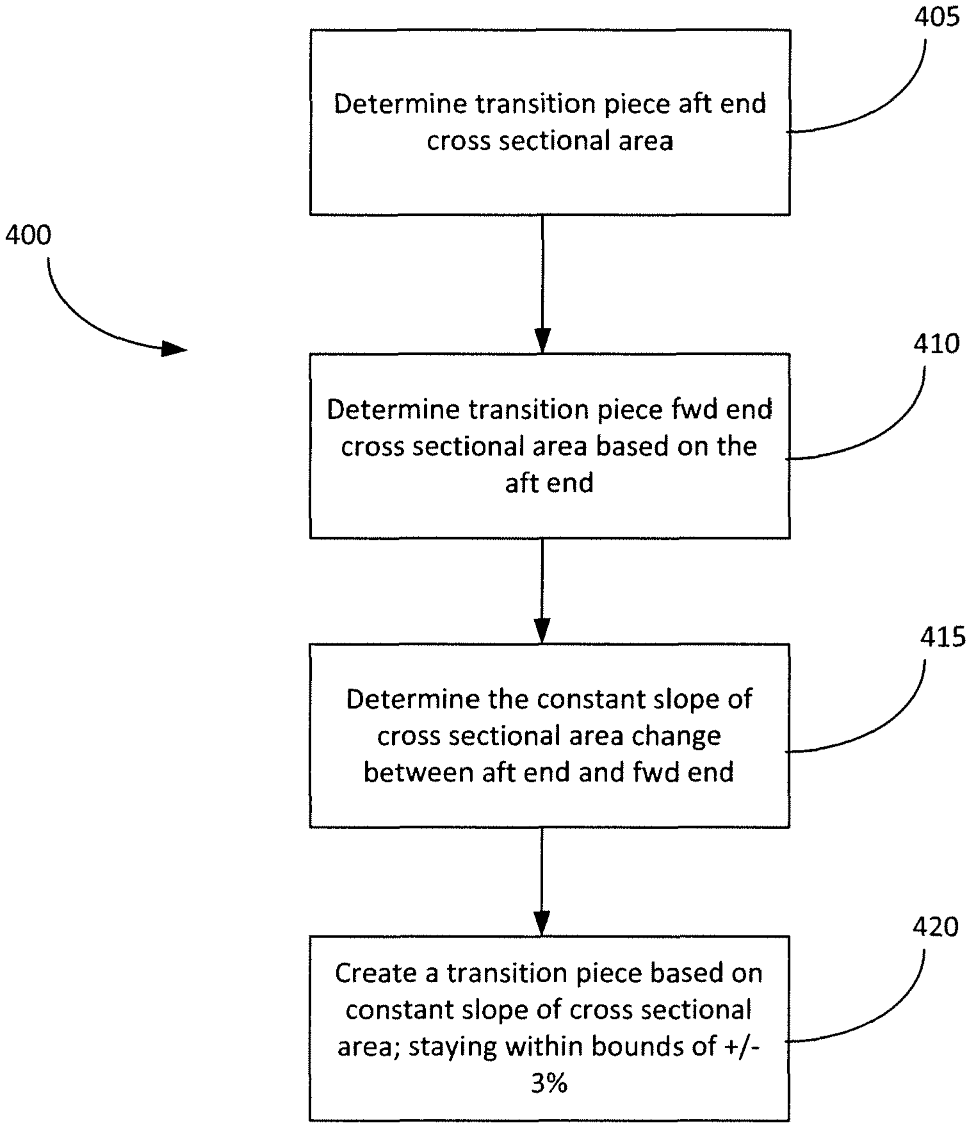

405
Determine transition piece aft end cross sectional area
400
410
Determine transition piece fwd end cross sectional area based on the aft end
415
Determine the constant slope of cross sectional area change between aft end and fwd end
420
Create a transition piece based on constant slope of cross sectional area; staying within bounds of +/- 3%

Figure 4

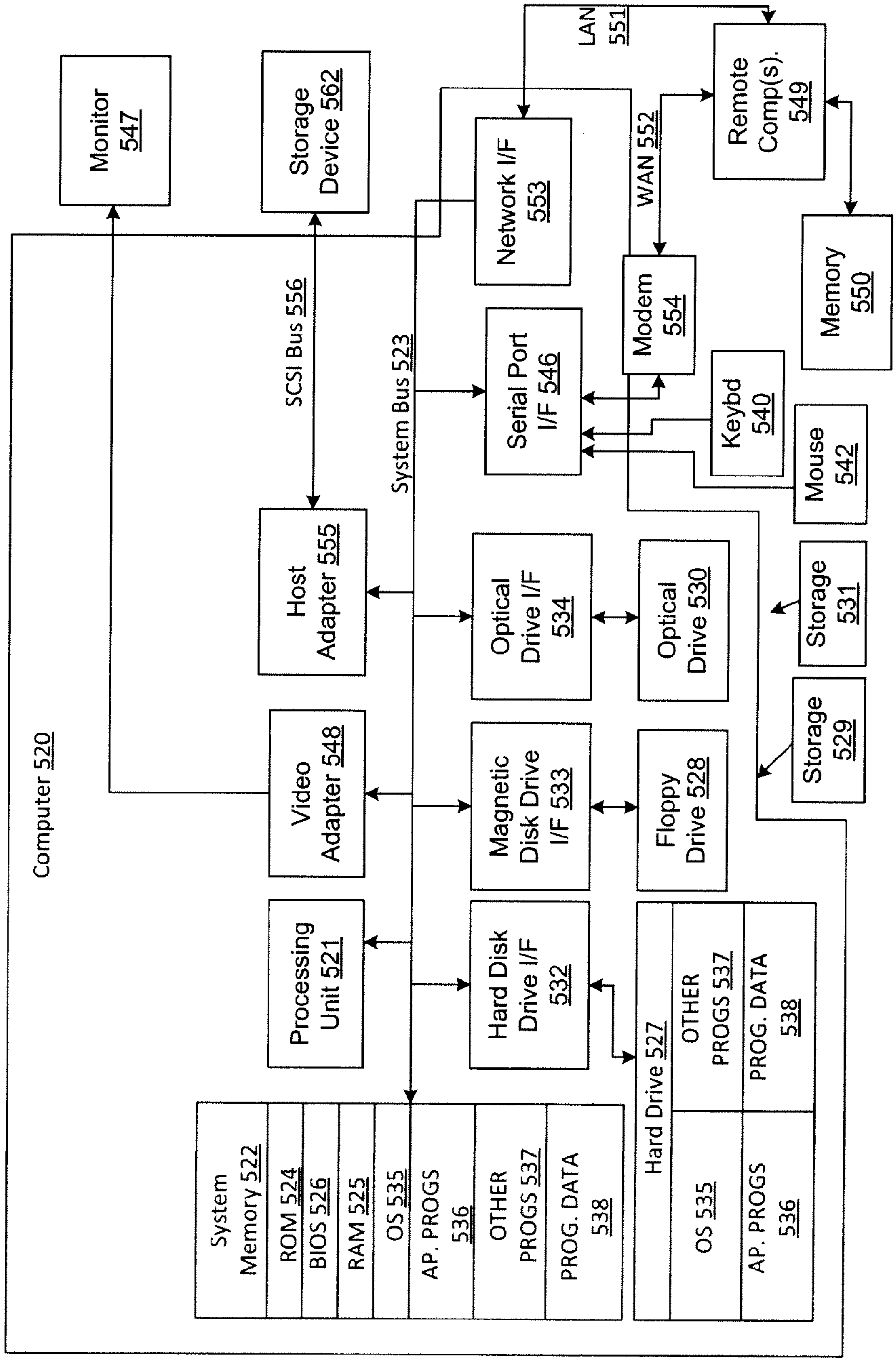

Computer 520
Monitor 547
Storage Device 562
SCSI Bus 556
System Bus 523
LAN 551
WAN 552
Remote Comp(s). 549
Memory 550
Network I/F 553
Modem 554
Serial Port I/F 546
Keybd 540
Mouse 542
Host Adapter 555
Optical Drive I/F 534
Optical Drive 530
Storage 531
Storage 529
Video Adapter 548
Magnetic Disk Drive I/F 533
Floppy Drive 528
Processing Unit 521
Hard Disk Drive I/F 532
Hard Drive 527
OTHER PROGS 537
PROG. DATA 538
OS 535
AP. PROGS 536
System Memory 522
ROM 524
BIOS 526
RAM 525
OS 535
AP. PROGS 536
OTHER PROGS 537
PROG. DATA 538

Figure 5