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Inventor(s)	Boswell; Mark Jason et al.

Exhaust gas recirculation valve assembly

Abstract

An exhaust gas recirculation (EGR) valve assembly includes a valve housing with a wall defining a flow passage. The valve housing defines a bore communicating with the flow passage. A shaft is supported in the bore and extends into the flow passage. A flap is supported on the shaft in the flow passage. The flap is movable relative to the flow passage between a closed position and an open position. A sealing member projects from the wall into the flow path. The sealing member has a sealing surface that interacts with the flap in the closed position to inhibit gas flow through the flow passage, an opposite surface tapering toward the wall, and a circumferential end surface proximate and tapered away from the bore. The flap is coined against the sealing surface. A spider assembly is positioned between the shaft and a drive shaft of an actuator assembly.

Inventors: **Boswell; Mark Jason (Corning, IA), House; Timothy Garritt (Urbandale, IA)**

Applicant: **Power Packer North America, Inc.** (Westfield, WI)

Family ID: **1000008765318**

Assignee: **Power Packer North America, Inc. (Westfield, WI)**

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Primary Examiner: Low; Lindsay M

Assistant Examiner: Morales; Omar

Attorney, Agent or Firm: Michael Best & Friedrich LLP

Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS (1) This application claims priority to U.S. Provisional Patent Application No. 63/485,725 filed on Feb. 17, 2023, the entire contents of which is incorporated herein by reference.

FIELD
(1) The present disclosure generally relates to valve assemblies and, more particularly, to exhaust gas recirculation (EGR) valve assemblies.
BACKGROUND
(2) In general, EGR valve assemblies are used to control the recirculation of exhaust gases through combustion chambers within internal combustion engines. Exhaust gas recirculation that is improperly controlled may result in air/fuel mixtures that are too rich or too lean for efficient combustion.
SUMMARY
(3) In one independent aspect, a valve assembly, such as an EGR valve assembly, may generally include a valve housing including a body with a wall defining a flow passage along a flow path between an inlet and an outlet, the valve housing further defining a bore communicating with the flow passage and extending transverse to the flow path; a shaft supported in the bore and extending into the flow passage; a flap supported on the shaft in the flow passage, the flap being movable relative to the flow passage between a closed position and an open position; and a sealing member projecting from the wall into the flow path, the sealing member having a sealing surface configured to interact with the flap in the closed position to inhibit gas flow through the flow passage, an opposite surface facing away from the sealing surface and tapering toward the wall, and a circumferential end surface proximate the bore, the end surface being tapered away from the bore.
(4) In another independent aspect, a method of manufacturing a valve assembly, such as an EGR valve assembly, may be provided. The valve assembly may include a valve housing with a body having a wall defining a flow passage along a flow path between an inlet and an outlet, a flap supported in the flow passage for movement between a closed position and an open position, a first sealing member projecting from the wall into the flow path, the first sealing member having a first sealing surface configured to interact with a first portion of the flap in the closed position to inhibit gas flow through the flow passage, and a second sealing member projecting from the wall into the flow path, the second sealing member having a second sealing surface configured to interact with a second portion of the flap in the closed position to inhibit gas flow through the flow passage. The method may generally include supporting the flap in the flow passage with the first portion of the flap engaging the first sealing surface and the second portion of the flap engaging the second sealing surface; engaging, through the inlet, a first ram against a side of the first portion of the flap opposite the first sealing surface; engaging, through the outlet, a second ram against a side of the second portion of the flap opposite the second sealing surface; and simultaneously applying, with the first ram and the second ram, force to the flap to coin the first portion of the flap against the first sealing surface and to coin the second portion of the flap against the second sealing surface.
(5) In yet another independent aspect, a valve assembly, such as an EGR valve assembly, may generally include a valve housing including a body with a wall defining a flow passage along a flow path between an inlet and an outlet; a shaft supported by the valve housing and extending into the flow passage, the shaft extending along and being pivotable about a shaft axis; a flap supported

on the shaft in the flow passage, the flap being movable relative to the flow passage between a closed position, in which flow of gas through the flow passage is inhibited, and an open position; an actuator assembly including a drive shaft extending along and pivotable about a drive axis; and a spider assembly configured to drivingly connect the drive shaft and the shaft. The spider assembly may include a spider member defining a first slot facing toward the drive shaft and extending along a first slot axis and a second slot facing toward the shaft and extending along second slot axis, the second slot axis being transverse to the first slot axis, a first sliding member connectable to the drive shaft and positionable in the first slot, the first sliding member being configured to slide in the first slot and along the first slot axis, and a second sliding member connectable to the shaft and positionable in the second slot, the second sliding member being configured to slide in the second slot and along the second slot axis.
(6) Other independent aspects of the disclosure may become apparent by consideration of the detailed description, claims and accompanying drawings.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) FIG. **1** is a perspective view of a valve assembly, such as an EGR valve assembly.
(2) FIG. **2** is a front elevation view of the valve assembly of FIG. **1**.
(3) FIG. **3** is a rear elevation view of the valve assembly of FIG. **1**, opposite the view of FIG. **2**.
(4) FIG. **4** is a side view of the valve assembly of FIG. **1**.
(5) FIG. **5** is an opposite side view of the valve assembly of FIG. **1**.
(6) FIG. **6** is a bottom view of the valve assembly of FIG. **1**.
(7) FIG. **7** is a top view of the valve assembly of FIG. **1**.
(8) FIG. **8** is a front cross-sectional view of the valve assembly of FIG. **1**, taken generally along the line A-A in FIG. **7**.
(9) FIG. **9** is a side cross-sectional view of the valve assembly of FIG. **1**, taken generally along the line B-B in FIG. **7**.
(10) FIG. **10** is a top cross-sectional view of the valve assembly of FIG. **1**, taken generally along the line C-C in FIG. **2**.
(11) FIG. **11**A is an enlarged perspective view of a portion of the valve assembly of FIG. **1**, illustrating a tapered end of a sealing member.
(12) FIG. **11**B is an enlarged perspective view of another portion of the valve assembly of FIG. **1**, illustrating an opposite tapered end of a sealing member shown in FIG. **11**A.
(13) FIG. **12**A is an enlarged perspective view of another portion of the valve assembly of FIG. **1**, illustrating a tapered end of a sealing member.
(14) FIG. **12**B is an enlarged perspective view of another portion of the valve assembly of FIG. **1**, illustrating an opposite tapered end of a sealing member shown in FIG. **12**A.
(15) FIG. **13** is a schematic diagram of a method of manufacturing a valve assembly, such as the valve assembly of FIG. **1**, illustrating a coining process.
(16) FIG. **14** is a perspective view of a portion of the valve assembly of FIG. **1**, illustrating a spider assembly, a driven shaft, and a flap.
(17) FIG. **15** is an exploded view of the portion of the valve assembly shown in FIG. **14**.
(18) FIG. **16** is a top view of the spider assembly shown in FIG. **14**.
(19) FIG. **17** is a side view of the spider assembly and the driven shaft shown in FIG. **14**, with a torsion spring removed.
(20) FIG. **18** is a side view of the spider assembly and the driven shaft shown in FIG. **14**, with the spring and the spider member removed.
(21) FIG. **19** is another side view of the portion of the spider assembly and the driven shaft as

shown in FIG. **18**.
(22) FIG. **20** is a side view of the spider member and a drive bowtie shown in FIG. **15**.
(23) FIG. **21** is a side view of the spider member, a driven bowtie, and a plate shown in FIG. **15**.
(24) FIG. **22** is a bottom view of the spider member shown in FIG. **15**.
(25) FIG. **23** is a top view of the spider member shown in FIG. **15**.
(26) FIG. **24** is a bottom view of the spider, the drive bowtie, and the plate shown in FIG. **21**.
(27) FIG. **25** is a perspective view of a valve housing portion of the valve assembly of FIG. **1**.
(28) FIG. **26** is a top cross-sectional view of the valve assembly of FIG. **1**, taken generally along the line D-D in FIG. **9**.
(29) FIG. **27** is a top cross-sectional view of the valve assembly of FIG. **1**, taken generally along the line E-E in FIG. **9**.
(30) FIG. **28** is a partial cross-sectional view of the valve assembly of FIG. **1**, taken generally along the line F-F in FIG. **7**.
(31) FIG. **29** is a perspective view of a spring holder shown in FIG. **15**.
(32) FIG. **30** is a bottom perspective view of the valve assembly of FIG. **1**, illustrated with the valve housing portion removed.

DETAILED DESCRIPTION

(33) Before any independent embodiments are explained in detail, it is to be understood that the disclosure is not limited in its application to the details of construction and the arrangement of components set forth in the following description or illustrated in the following drawings. The disclosure is capable of other independent embodiments and of being practiced or of being carried out in various ways. Also, it is to be understood that the phraseology and terminology used herein is for the purpose of description and should not be regarded as limiting.
(34) Use of “including” and “comprising” and variations thereof as used herein is meant to encompass the items listed thereafter and equivalents thereof as well as additional items. Use of “consisting of” and variations thereof as used herein is meant to encompass only the items listed thereafter and equivalents thereof. Unless specified or limited otherwise, the terms “mounted,” “connected,” “supported,” and “coupled” and variations thereof are used broadly and encompass both direct and indirect mountings, connections, supports, and couplings.
(35) Relative terminology, such as, for example, “about”, “approximately”, “substantially”, etc., used in connection with a quantity or condition would be understood by those of ordinary skill to be inclusive of the stated value and has the meaning dictated by the context (for example, the term includes at least the degree of error associated with the measurement of, tolerances (e.g., manufacturing, assembly, use, etc.) associated with the particular value, etc.). Such terminology should also be considered as disclosing the range defined by the absolute values of the two endpoints. For example, the expression “from about 2 to about 4” also discloses the range “from 2 to 4”. The relative terminology may refer to plus or minus a percentage (e.g., 1%, 5%, 10% or more) of an indicated value.
(36) Also, the functionality described herein as being performed by one component may be performed by multiple components in a distributed manner. Likewise, functionality performed by multiple components may be consolidated and performed by a single component. Similarly, a component described as performing particular functionality may also perform additional functionality not described herein. For example, a device or structure that is “configured” in a certain way is configured in at least that way but may also be configured in ways that are not listed.
(37) The embodiment(s) described below and illustrated in the figures are presented by way of example only and are not intended as a limitation upon the concepts and principles of the present disclosure. As such, it will be appreciated that variations and modifications to the elements and their configuration and/or arrangement exist within the spirit and scope of one or more independent aspects as described.
(38) FIGS. **1-7** illustrate a valve assembly **10**, such as an exhaust gas recirculation (EGR) valve

assembly and, specifically, a cold-side EGR valve assembly, operable to control exhaust flow to the engine intake (not shown), thereby controlling the air-to-fuel ratio and reducing engine emissions. In other constructions (not shown), the valve assembly **10** may be another type of valve assembly, for example, an exhaust brake valve assembly.

(39) The valve assembly **10** includes a valve housing portion **14** defining a flow passage **18** through which gas flows along a flow path. A butterfly flap **22** is supported on a driven shaft **26** (at a flap end **27**) for pivoting movement therewith between an open position, a closed position, in which gas flow is inhibited, and a plurality of intermediate flow positions. An opposite transmission end **28** of the driven shaft **26** (see FIG. **8**) extends towards an actuator housing portion **30** in which a drive or actuator assembly **34** is housed.

(40) With continued reference to FIGS. **1-7**, the valve housing portion **14** includes a body **38** having a wall **42**. The wall **42** defines the flow passage **18** which extends along a passage axis A1. A plurality of bosses **46** (three shown), each having an opening **50**, are circumferentially spaced apart on the body **38**. The illustrated openings **50** are provided on a common circle and receive respective fasteners (not shown) for mounting the Valve assembly **10** to an engine component such as an intake or exhaust manifold (not shown).

(41) As shown in FIG. **8**, a bore **62**, with portions **62***a*, **62***b* on opposite sides of the flow passage **18**, is defined in the valve housing portion **14** in a direction transverse to the wall **42**. The driven shaft **26**, extending along a driven shaft axis A2, is pivotably supported in the bore **62**.

(42) FIGS. **9-10** illustrate an inner surface **66** of the wall **42** shaped to direct the flow of exhaust gases between opposite ports (e.g., an inlet **70** and an outlet **74**). An entrance surface **78** slopes inwardly from the inlet **70** toward the flap **22** and the driven shaft **26**, and an exit surface **82** slopes outwardly from the flap **22** and the driven shaft **26** to the outlet **74**. In other constructions (not shown), the inner surface **66** may be at least partially cylindrical along the passage axis A1.

(43) Additionally, the inner surface **66** provides a surface against which the flap **22** is able to seal. With continued reference to FIGS. **9-10**, the inner surface **66** includes an annular first sealing ridge **86** closer to the inlet **70** and an annular second sealing ridge **90** closer to the outlet **74**. The first sealing ridge **86** has a sealing surface **94** shaped to sealingly mate with a first portion of the flap **22**, a radially-inner flat surface **98** and an opposite surface **102** sloped away from the flap **22** and the driven shaft **26**. The first sealing surface **94** has an annular seal face area.

(44) With continued reference to FIGS. **9-10**, the second sealing ridge **90** includes a sealing surface **106** shaped to sealingly mate with a second portion of the flap **22**, a radially-inner flat surface **110** and an opposite surface **114** sloped away from the flap **22** and the driven shaft **26**. The sealing surface **106** has an annular seal face area. The sealing ridges **86**, **90**, along with the sealing surfaces **94**, **106**, the flat surfaces **98**, **110**, and the opposite surfaces **102**, **114**, curve about the passage axis A1.

(45) With reference to FIGS. **11**A-**12**B, each sealing ridge **86**, **90** terminates in opposite tapered ends **115**, **116**, respectively. In the illustrated construction, the tapered ends **115**, **116** are identical. Each tapered end **115**, **116** includes a sloped end **118**, **122**, a pointed end **120**, **124**, and a terminal end **121**, **125**, each being angled away from the bore **62**.

(46) With continued reference to FIG. **10**, a first chamfered surface **126** transitions the surface **102** into the inlet surface **78**, and a second chamfered surface **130** transitions the surface **114** into the outlet surface **82**. A radially-outer flat surface **134** is positioned adjacent to the first sealing ridge **86** and surrounds a portion of the flap **22** when the flap **22** is in the closed position, and a radially-outer flat surface **138** is positioned adjacent to the second sealing ridge **90** and surrounds an opposite portion of the flap **22** when the flap **22** is in the closed position. A third chamfered surface **142** transitions the flat surface **134** to the outlet surface **82**, and a fourth chamfered surface **146** transitions the flat surface **138** to the inlet surface **78**.

(47) In operation, exhaust gases flow through the inlet **70**, along the flow passage **18**, and through the outlet **74**. When the flap **22** is in the open position and, more particularly, in a fully open

position, the flow is at a maximum. The exhaust gases flow over the sealing ridges **86**, **90**, and flow around the flap **22** and around the driven shaft **26**. When the flap **22** is in the closed position, the flap **22** engages the sealing surfaces **94**, **106** to at least substantially block and prevent the flow of exhaust gases through the flow passage **18**.

(48) The exhaust gases may contain water vapor, particles, and other impurities. As exhaust gases flow through the flow passage **18**, deposits, such as condensate, "coke", "gunk", soot, and other matter may form on the inner surface **66**. If deposits form on the sealing ridges **86**, **90**, the flap **22**, the driven shaft **26**, the bore **62**, etc., sealing efficiency and movement of the flap **22** and the shaft **26** may be inhibited. Sloped surfaces within the flow passage **18** (e.g., the opposite surfaces **102**, **114**, the tapered ends **115**, **116**, etc.) cause deposits to flow away from locations (e.g., the sealing surfaces **94**, **106**, the bore **62**) where deposits may inhibit sealing efficiency.

(49) FIG. **13** schematically illustrates a process for coining the flap **22** and the sealing surfaces **94**, **106** of the valve assembly **10**. Coining may provide a valve assembly **10** with a flap **22** having a precise, "custom" fit with the sealing surfaces **94**, **106** as they have been formed in the valve housing portion **14** and vice versa.

(50) In the manufacturing process, the flap **22** is supported on the shaft **26** in the flow passage **18** and engaged with the sealing surfaces **94**, **106**. A first ram **147** is inserted into the inlet **70** and pressed against a first side **150** of the flap **22** opposite the sealing surface **94**, while a second ram **148** is inserted into the outlet **74** and pressed against a second side **154** of the flap **22** opposite the sealing surface **106**. The rams **147**, **148** apply force **155**, **156** to the opposite sides **150**, **154** of the flap **22** (e.g., on opposite sides of a driven shaft **26**) to coin or cold forge the flap **22** against the first sealing surface **94** and against the second sealing surface **106**. As a result, the flap **22** conforms to contours of the sealing surfaces **94**, **106**, and vice versa.

(51) With continued reference to FIG. **13**, the first ram **147** has a first ram area, and the first sealing surface **94** defines a first seal face area. The second ram **148** has a second ram area, and the second sealing surface **106** defines a second seal face area. In the illustrated construction, the first ram area is greater than the first seal face area, and the second ram area is greater than the second seal face area.

(52) Each force **155**, **156** is greater than about 4,000 pound-force (lbf) and up to about 12,000 lbf. More particularly, each force is greater than about 7,000 lbf and up to about 9,000 lbf (e.g., about 8,000 lbf). In the illustrated process, the forces **155**, **156** are substantially equal and are applied simultaneously. The forces **155**, **156** are applied for at least one second (s) and up to about 20 s (e.g., in the illustrated embodiment, about 5 s).

(53) With reference to FIGS. **1** and **8-9**, the actuator housing portion **30** is mounted to the valve housing portion **14** by screws **158**. The actuator assembly **34** includes an electric motor **162** (schematically illustrated; e.g., a brushless DC motor) positioned within the actuator housing portion **30**. An electrical connector **166** provides electrical power and communication signals to the motor **162**. Electrical and control components (not shown), such as, for example, a controller (including an electronic processor), a motor controller, a printed circuit board, one or more sensors, etc., are also housed in the actuator housing portion **30**.

(54) The electric motor **162** includes a pivoting drive shaft **170** defining a drive shaft axis A3. In some embodiments, the drive shaft axis A3 not be collinear with the driven shaft axis A2. A spider assembly **174** (see FIGS. **8** and **14-15**) drivingly connects the drive shaft **170** to the driven shaft **26** and may accommodate misalignment between the axes A2, A3. The spider assembly **174** generally includes (see FIGS. **14-15**) a drive bowtie **178**, a driven bowtie **182**, a plate **186**, a spider member **190**, a torsion spring **194**, and a spring holder **196**.

(55) As shown in FIGS. **14-19**, the drive bowtie **178** defines an opening **198** proximate its center for coupling to the drive shaft **170**. The driven bowtie **182** defines an opening **202** proximate its center for coupling to the driven shaft **26**. In other constructions (not shown), the bowties **178**, **182** may be integrally formed with or coupled to the shafts **170**, **26** via other methods.

(56) With reference to FIGS. **14-24**, the spider member **190** defines a first slot **206** configured to receive and allow sliding movement of the drive bowtie **178** along the slot **206** while restraining transverse movement of the bowtie **178**. Similarly, the spider member **190** defines a second slot **210** configured and allow sliding movement of the driven bowtie **182** along the slot **210** while restraining transverse movement of the bowtie **182**. In the illustrated construction, the slots **206**, **210** are oriented transverse (e.g., substantially perpendicular) to each other such that the bowtie **178**, **182** are slidable transverse (e.g., substantially perpendicular) to each other. The misalignment of the axes A2, A3 is accommodated by sliding movement of the bowties **178**, **182** and the respective shafts **170**, **26**.
(57) As shown in FIG. **21**, opposed slots **214***a*, **214***b*, defined on opposite sides of the second slot **210**, are configured to receive the plate **186** and retain the driven bowtie **182** in the slot **210**. The plate **186** defines an opening receiving the driven shaft **26**. The spider member **190** defines an axial opening **218** at least roughly aligned with shafts **170**, **26**.
(58) As shown in FIG. **22**, the spider member **190** includes circumferentially-spaced protrusions **222**, **226**, **230** on a side of the spider member **190** near the first slot **206**. The protrusion **222** defines a notch **234** facing toward the driven shaft **26**.
(59) With reference to FIGS. **25-28**, the valve housing portion **14** defines a first recess **238** and a second recess **242** spaced circumferentially with respect to the driven shaft axis A2. The first recess **238** has a depth D1 (FIG. **28**) and a width W1 (FIG. **26**) and subtends an angle α**1** (FIG. **27**). The angle α**1** may be greater than about 45° and less than about 135° and, more particularly, approximately equal to a quarter-turn (e.g., about 70°, as shown). The second recess **242** is a notch having a depth D2 (FIG. **28**) and a width W2 (FIG. **26**; e.g., about 6 millimeters (mm)) sufficient to constrain the end **258** of the spring **194**, as discussed below.
(60) A spring bearing surface **246** is defined on an interior side of the second recess **242** (e.g., on a clockwise side of the second recess **242** when viewed in FIGS. **26-27**). A ledge **250** circumferentially surrounds the bore **62** and faces towards the actuator housing portion **30**.
(61) The spring **194** interfaces between the spider member **190** and the valve housing portion **14** in order to pivotably bias the spider assembly **174** and, more specifically, the spider member **190**, the driven bowtie **182**, and the driven shaft **26**, in a direction corresponding to the closed position of the flap **22**. As shown in FIG. **27**, a first end **254** of the spring **194** engages the spider member **190** (e.g., engaging within the notch **234** in the first protrusion **222**), and a second end **258** engages the valve housing portion **14** (e.g., within the second recess **242**, bearing against the spring bearing surface **246**). The spring **194** biases the spider member **190** and, therefore, the spider assembly **174**, in a counterclockwise direction (when viewed in FIG. **27**). The spring **194** is configured to bias the flap **22** into the closed position (as mentioned above) and to take up (that is, inhibit or eliminate) lash in the spider assembly **174**.
(62) With reference to FIGS. **8** and **26**, the spring holder **196** is positioned between the ledge **250** and the spring **194**. The illustrated spring holder **196** is formed of austenitic steel, which may provide, for example, friction reduction, reduced debris creation, compatibility with material of the spring **194**, etc.
(63) The spring holder **196** includes (see FIG. **29**) a generally flat and circumferential flange **266** from which centering projections **270***a*, **270***b*, **270***c* protrude. The centering projections **270***a*, **270***b*, **270***c* are oriented at approximately 90° relative to the flange **266** and extend into the bore **62** when the spring holder **196** is positioned in the valve housing portion **14**.
(64) A spring positioning projection **274** protrudes from the flange **266** in a direction opposite to the centering projections **270***a*, **270***b*, **270***c*. The spring positioning projection **274** is oriented at approximately 90° relative to the flange **266** and engages an inner surface of the spring **194** when the spring holder **196** is in position in the spider assembly **174** to position the spring **194** relative to the spring holder **196** and relative to the valve housing portion **14**. An orienting projection **278** extends radially from the flange **266** and, as illustrated, is configured (e.g., sized, shaped, etc.) to fit

within the second recess **242** of the valve housing portion **14** to orient the spring holder **196** relative to the valve housing portion **14**.

(65) With reference to FIGS. **8-9** and **30**, a seal **282** is positioned between the valve housing portion **14** and the actuator housing portion **30**. The illustrated seal **282** is an O-ring and fits within respective grooves **286***a*, **286***b* defined in the valve housing portion **14** and in the actuator housing portion **30**. The seal **282** is configured to inhibit the ingress of dust, dirt, debris, gas, and other material.

(66) In operation of the valve assembly **10**, control signals are provided (e.g., to the controller) to control the actuator assembly **34** to position the flap **22** in a desired position in the flow passage **18** for a desired flow of gas through the flow passage **18**. The motor **162** pivots the drive shaft **170**, causing pivoting movement of the drive bowtie **178** and the spider member **190** against the biasing force of the spring **194**. Pivoting movement of the spider member **190** causes pivoting movement of the driven bowtie **182**, the driven shaft **26**, and the flap **22**. The range of motion of the flap **22** is limited by the extent of the angle α**1** and a width of the first protrusion **222**.

(67) As mentioned above, the driven shaft axis A2 and the drive shaft axis A3 may be misaligned. The spider assembly **174** is configured to transmit torque from the drive shaft **170** to the flap **22** despite a misalignment between the axes A2, A3. If the axes, A2, A3 are misaligned, as the drive bowtie **178** pivots, the drive bowtie **178** may simultaneously slide along the first slot **206**. Similarly, as the spider member **190** pivots with the drive bowtie **178**, the driven bowtie **182** pivots and may also simultaneously slide along the second slot **210**. The sliding movement of the bowties **178**, **182** may accommodate axial misalignment of the shafts **170**, **26**.

(68) Manufacturing tolerances may exist between the drive and driven components. As a result, a certain amount of lash could exist within the spider assembly **174**, which could inhibit shafts **170**, **26** from rotating on a one-to-one basis at all times and at all rotational angles. In the illustrated construction, the spring **194** biases the components (e.g., to a position corresponding to the closed position of the flap **22**) to compensate for the lash. In other constructions (not shown), the spider assembly **174** may be used in other shaft arrangements (e.g., between a different type of drive shaft and driven shaft) to, for example, accommodate misalignment of the shafts, take up lash, etc.

(69) Although the invention has been described in detail with reference to certain preferred embodiments, variations and modifications exist within the scope and spirit of one or more independent aspects of the invention as described above. The embodiment(s) described above and illustrated in the figures are presented by way of example only and are not intended as a limitation upon the concepts and principles of the present disclosure. As such, it will be appreciated that variations and modifications to the elements and their configuration and/or arrangement exist within the spirit and scope of one or more independent aspects as described.

(70) One or more independent features and/or independent advantages of the invention may be set forth in the claims.

Claims

1. An exhaust gas recirculation (EGR) valve assembly comprising: a valve housing including a body with a wall defining a flow passage along a flow path between an inlet and an outlet, the valve housing further defining a bore communicating with the flow passage and extending transverse to the flow path; a shaft supported in the bore and extending into the flow passage, the shaft including a first end proximate an actuator and a second end distal from the actuator; a first bearing assembly supporting the shaft at the first end of the shaft, the first bearing assembly spaced apart from the flow passage; a second bearing assembly supporting the shaft at the second end of the shaft, the second bearing assembly spaced apart from the flow passage; a flap supported on the shaft in the flow passage, the flap being movable relative to the flow passage between a closed position and an open position, the flap positioned between the first bearing assembly and the

second bearing assembly in a direction along a length of the shaft; and a sealing member connected to and projecting from the wall into the flow path, the sealing member having a sealing surface configured to interact with the flap in the closed position to inhibit gas flow through the flow passage, an opposite surface facing away from the sealing surface and tapering toward the wall, and a circumferential end surface proximate the bore, the end surface being tapered away from the bore.

2. The exhaust gas recirculation (EGR) valve assembly of claim 1, wherein the sealing member is a first sealing member, the sealing surface is a first sealing surface configured to interact with a first portion of the flap, the opposite surface is a first opposite surface, and the end surface is a first sealing member end surface, and wherein the exhaust gas recirculation (EGR) valve assembly further comprises a second sealing member positioned between the inlet and the outlet, the second sealing member having a second sealing surface configured to interact with a second portion of the flap in the closed position to inhibit gas flow through the flow passage, a second opposite surface facing away from the second sealing surface and tapering toward the wall, and a circumferential second sealing member end surface proximate the bore, the second sealing member end surface being tapered away from the bore.

3. The exhaust gas recirculation (EGR) valve assembly of claim 2, wherein the bore is a first bore, wherein the valve housing defines a second bore spaced from the first bore, the shaft being supported in the first bore and the second bore, wherein the first sealing member has opposite first sealing member end surfaces, one opposite first sealing member end surface being proximate and tapering away from the first bore, and another opposite first sealing member end surface being proximate and tapering away from the second bore, and wherein the second sealing member has opposite second sealing member end surfaces, one opposite second sealing member end surface being proximate and tapering away from the first bore, and another opposite second sealing member end surface being proximate and tapering away from the second bore.

4. The exhaust gas recirculation (EGR) valve assembly of claim 3, wherein the first opposite surface extends between the opposite first sealing member end surfaces, and wherein the second opposite surface extends between the opposite second sealing member end surfaces.

5. The exhaust gas recirculation (EGR) valve assembly of claim 3, wherein the first portion of the flap is coined against the first sealing surface, and wherein the second portion of the flap is coined against the second sealing surface.

6. The exhaust gas recirculation (EGR) valve assembly of claim 3, wherein the first bore directly contacts the shaft, and wherein the second bore directly contacts the shaft.

7. The exhaust gas recirculation (EGR) valve assembly of claim 3, wherein: a single first sealing interface surrounds the shaft on a first side of the flap, the single first sealing interface including a first contact interface between the shaft and the wall to inhibit gas leakage between the shaft and the wall, and a single second sealing interface surrounds the shaft on a second side of the flap, the single second sealing interface including a second contact area between the shaft and the wall to inhibit gas leakage between the shaft and the wall.

8. The exhaust gas recirculation (EGR) valve assembly of claim 7, wherein: the first contact interface includes a first circumferential length equal to a circumference of the shaft at a first axial position along the shaft adjacent the first contact interface, and the second contact interface includes a second circumferential length equal to the circumference of the shaft at a second axial position along the shaft adjacent the second contact interface.

9. The exhaust gas recirculation (EGR) valve assembly of claim 1, wherein the bore is a first bore, wherein the valve housing defines a second bore spaced from the first bore, the shaft being supported in the first bore and the second bore, wherein the sealing member has opposite end surfaces, one opposite end surface being proximate and tapering away from the first bore, and another opposite end surface being proximate and tapering away from the second bore.

10. The exhaust gas recirculation (EGR) valve assembly of claim 9, wherein the opposite surface

extends between the opposite end surfaces.
11. The exhaust gas recirculation (EGR) valve assembly of claim 1, wherein the flap is coined against the sealing surface with a force greater than about 4,000 pound-force (lbf).
12. The exhaust gas recirculation (EGR) valve assembly of claim 1, further comprising an actuator assembly including a drive shaft extending along and pivotable about a drive axis, wherein a spider assembly is configured to drivingly connect the drive shaft to the shaft, the spider assembly including: a spider member defining a first slot facing toward the drive shaft and extending along a first slot axis and a second slot facing toward the shaft and extending along a second slot axis, the second slot axis being transverse to the first slot axis, a first sliding member connectable to the drive shaft and positionable in the first slot, the first sliding member being configured to slide in the first slot and along the first slot axis, and a second sliding member connectable to the shaft and positionable in the second slot, the second sliding member being configured to slide in the second slot and along the second slot axis.
13. The exhaust gas recirculation (EGR) valve assembly of claim 1, wherein the shaft directly contacts an edge of the circumferential end surface tapering away from the bore.
14. The exhaust gas recirculation (EGR) valve assembly of claim 1, wherein no bushing is positioned between the shaft and the circumferential end surface tapering away from the bore.
15. The exhaust gas recirculation (EGR) valve assembly of claim 1, wherein: the wall contacts the shaft to form a single first contact interface, the single first contact interface surrounding the shaft, the first contact interface is positioned between the flap and the first bearing assembly, a single second contact interface between the wall and the shaft surrounds the shaft, and the second contact interface is positioned between the flap and the second bearing assembly.
16. The exhaust gas recirculation (EGR) valve assembly of claim 1, wherein the first bearing assembly includes a ball bearing, and wherein the second bearing assembly includes a needle bearing.
17. The exhaust gas recirculation (EGR) valve assembly of claim 1, wherein the first bearing assembly is isolated from the flow passage, and wherein the second bearing assembly is isolated from the flow passage.
18. An exhaust gas recirculation (EGR) valve assembly comprising: a valve housing including a body with a wall defining a flow passage along a flow path between an inlet and an outlet; a shaft supported by the valve housing and extending into the flow passage, the shaft extending along and being pivotable about a shaft axis; a flap supported on the shaft in the flow passage, the flap being movable relative to the flow passage between a closed position, in which flow of gas through the flow passage is inhibited, and an open position; an actuator assembly including a drive shaft extending along and pivotable about a drive axis; and a spider assembly configured to drivingly connect the drive shaft and the shaft, the spider assembly including: a spider member defining a first slot facing toward the drive shaft and extending along a first slot axis and a second slot facing toward the shaft and extending along a second slot axis, the second slot axis being transverse to the first slot axis, a first sliding member connectable to the drive shaft and positionable in the first slot, the first sliding member being configured to slide in the first slot and along the first slot axis, the first slot restraining movement of the first sliding member in a direction perpendicular to the first slot axis, and a second sliding member connectable to the shaft and positionable in the second slot, the second sliding member being configured to slide in the second slot and along the second slot axis, the second slot restraining movement of the second sliding member in a direction perpendicular to the second slot axis.
19. The exhaust gas recirculation (EGR) valve assembly of claim 18, further comprising a torsion spring engageable between the valve housing and the spider member and configured to bias the flap toward the closed position.
20. The exhaust gas recirculation (EGR) valve assembly of claim 19, wherein the spider member includes a protrusion defining a notch, the torsion spring having an end engaging the notch.

21. The exhaust gas recirculation (EGR) valve assembly of claim 20, wherein the valve housing defines a first recess and a second recess, wherein the protrusion extends into the first recess, and wherein the end of the torsion spring is a first end, and the torsion spring has a second end extending into the second recess.
22. The exhaust gas recirculation (EGR) valve assembly of claim 19, wherein the valve housing defines a bore and has an annular ledge extending about at least a portion of the bore and facing towards the spider member, wherein the shaft is positioned in the bore, and wherein the exhaust gas recirculation (EGR) valve assembly further comprises a spring holder positioned between the ledge and the torsion spring.
23. The exhaust gas recirculation (EGR) valve assembly of claim 22, wherein the spring holder defines an opening, the shaft extending through the opening.
24. The exhaust gas recirculation (EGR) valve assembly of claim 22, wherein the spring holder has a flange positioned between the ledge and the torsion spring, the spring holder also having, extending from the flange, a radially-extending orienting projection engaging a recess defined by the valve housing, an axially-extending centering projection positioned in the bore, and an axially-extending spring positioning projection engaging the torsion spring.
25. The exhaust gas recirculation (EGR) valve assembly of claim 18, further comprising: a bore, wherein the shaft is positioned in the bore; and a sealing member projecting from the wall into the flow path, the sealing member having a sealing surface configured to interact with the flap in the closed position to inhibit gas flow through the flow passage, an opposite surface facing away from the sealing surface and tapering toward the wall, and a circumferential end surface proximate the bore, the end surface being tapered away from the bore.
26. The exhaust gas recirculation (EGR) valve assembly of claim 25, wherein the flap is coined against the sealing surface with a force greater than about 4,000 lbf.
27. The exhaust gas recirculation (EGR) valve assembly of claim 18, wherein the first slot axis and the second slot axis lie in parallel planes, and wherein the first slot axis is perpendicular to the second slot axis.
28. The exhaust gas recirculation (EGR) valve assembly of claim 18, wherein: in a first plane perpendicular to the drive axis, the first slot includes a centerline extending between open ends of the first slot; the first slot axis is oriented along the centerline of the first slot; in a second plane perpendicular to the shaft axis, the second slot includes a centerline extending between open ends of the second slot; and the second slot axis is oriented along the centerline of the second slot.