but it is typically at the end of the stroke that a great deal of force is required to finish the closing stroke, particularly to cut the cable if present.

Summary of the Invention

According to a first aspect of the present invention there is provided a valve actuator comprising:

a movable control element moveable in a longitudinal direction;

a propulsion device for moving said movable control element, the propulsion device comprising a moveable portion moveable in a longitudinal direction having a stroke extending from a first position to a second position;

a resilient element, having a stroke extending in a longitudinal direction from a first relatively unloaded position to a second relatively loaded position; and

a transmission mechanism;

the resilient element being loaded in a longitudinal direction under the action of the propulsion device via the transmission mechanism and being configured to urge the moveable portion of the propulsion device in a longitudinal direction towards the first position via the transmission mechanism when loaded;

wherein the transmission mechanism provides a gearing ratio between the moveable portion of the propulsion device and the resilient element; wherein the transmission mechanism is configured to vary the gearing ratio between the moveable portion of the propulsion device and the resilient element within the stroke of the moveable portion of the propulsion device; wherein the transmission mechanism is characterised by: a pivotable lever arm having one end pivotally coupled around a pivot point to an outer structure of the valve actuator and another end, and further comprising a surface which engages with the moveable portion; and an arm linkage which is pivotally coupled to the lever arm at a separate point on the lever arm between the said one end and the other end where said separate point is spaced apart from the said pivot point; wherein the movement of the moveable portion in the longitudinal direction causes the lever arm to pivot around the said pivot point which causes the arm linkage to move in the longitudinal direction and which is translated to smaller longitudinal movement of the resilient element.

The resilient element is normally loaded under the action of the propulsion device when the propulsion device moves from the first position to the second position. "Loaded" includes partially loaded, that is before the resilient element's stroke has reached the relatively unloaded position.

The gearing ratio may be a gearing increase or a gearing decrease, but is preferably a gearing ratio decrease, that is, a gearing reduction ratio from the moveable portion of the propulsion device to the resilient element.

volume between the piston and cylinder sleeve. Thus preferably the moveable portion of the propulsion device is the cylinder.

Preferably the resilient element is attached to a first plate at its first end and a second plate at its second end, more preferably said first plate is moveable and said second plate is fixed.

Preferably said piston and cylinder sleeve may be selectively decoupled to allow for selective relative movement of the two.

In one embodiment~~aspect~~, the propulsion device acts upon the resilient element through the transmission mechanism which comprises a lever.

The lever and moveable portion of the propulsion device can engage by any suitable means e.g. pads. In preferred embodiments however, a roller is provided to interface between these components and is normally provided on the moveable portion of the propulsion device which engages the lever.

In order to vary the gearing ratio between the moveable portion of the propulsion device and the resilient element, and especially to reduce the gearing reduction ratio, the lever is preferably specially shaped, and the moveable portion of the propulsion device follows this shape to transmit additional movement/force at a particular point in the stroke of the moveable portion of the propulsion device. In particular a notch and/or shoulder (preferably both) may be provided on the lever so that a relatively steep gradient exists on the surface of the lever which will, in use, increase the force or movement transmitted from the resilient element to the moveable portion of the propulsion device at a particular point of the stroke of the moveable portion of the propulsion device.

For certain embodiments, one side of said lever is in contact with said first plate, and preferably the opposite side (through a fulcrum) of said lever is in contact with a moveable part of said piston and cylinder arrangement. Thus as the cylinder moves down the spring stack is compressed by being pushed up, and vice versa.

In alternative embodiments, the lever is arranged to move an attached bearing ring in the same direction as that of the cylinder, and thus compresses the resilient element from an opposite end. Normally a spindle is provided to connect the lever to the bearing ring. Thus as the cylinder moves down the spring stack is compressed from above by downward movement.

In an embodiment, ~~second aspect~~ the transmission device comprises a rack and pinion mechanism.

The rack is normally connected to or provided on the movable portion of the propulsion device. A second, normally static, rack may also be provided to engage with the pinion. Normally an axle extends through the pinion and also engages with said first plate connected to the resilient element. Thus for such embodiments, as the moveable portion of the propulsion device moves, the rack thereon engages and rotates the pinion, which via the axle engaging with the first plate, loads (and strokes) the resilient element.

In order to vary the gearing ratio between the moveable portion of the propulsion device and the resilient element, and especially to reduce the gearing reduction ratio, the axle is preferably provided in the pinion in an off-centre position. Thus in use it will rotate and, depending on its start

and finishing position, either increase or decrease the movement/force afforded to the moveable portion of the propulsion device as the pinion rotates through the rack.

Normally the transmission mechanism is configured such that compared to the starting position of the axle, the gearing reduction ratio is reduced at a point close to the first relatively unloaded position of the resilient element; that is, more than 70% of the distance towards the relatively unloaded position, often more than 80% and optionally more than 90%. Thus the axle is normally provided in the pinion such that rotation of the pinion at least 70% of the distance towards the relatively unloaded position, often more than 80% optionally more than 90%, increases the force of the stroke of the resilient element compared to its force at other positions.

The actuators according to embodiments of the present invention are preferably relatively compact compared to known actuators for equivalent output ratings. For actuators designed to couple to larger valves, larger actuators will be required.

Typically actuators according to embodiments of the present invention are more than 600mm in height, often more than 800mm. Typically they are less than 1400mm in height, often less than 1100mm.

Preferably the actuators in embodiments of the present invention comprise~~ing~~ a transmission mechanism based on a lever are 600 – 1000 mm in height, preferably 800 – 900mm in height.

Actuators requiring increased output, such as for larger valves, are preferably based on having a transmission mechanism based on a rack

and pinion mechanism. Such embodiments preferably have a height of 700 to 1400mm, more preferably 850 to 1100mm.

The moveable control element is normally connected to the moveable portion of the propulsion device. For certain embodiments they may be provided as a single piece.

According to a second~~further~~ aspect of the present invention, there is provided a valve including a valve actuator according to the first aspect of the present invention.

According to a third~~yet further~~ aspect of the present invention, there is provided a pipeline including at least one valve according to the second aspect of the present invention.

~~According to a further aspect of the present invention t~~There is also disclosed~~provided~~ a valve actuator comprising:

a movable control element;

a propulsion device for moving said movable control element, the propulsion device comprising a moveable portion having a stroke extending from a first position to a second position;

a resilient element, having a stroke extending from a first relatively unloaded position to a second relatively loaded position; and

a transmission mechanism;

the resilient element being loaded under the action of the propulsion device via the transmission mechanism and being configured to urge the moveable portion of the propulsion device towards the first position via the transmission mechanism when loaded;

wherein the transmission mechanism comprises a rack and pinion mechanism.

The rack and pinion mechanism is preferably the rack and pinion mechanism as described herein.

~~According to a further aspect of the present invention t~~There is also disclosed~~provided~~ a valve actuator comprising:

a movable control element;

a propulsion device for moving said movable control element, the propulsion device comprising a moveable portion having a stroke extending from a first position to a second position;

a resilient element, having a stroke extending from a first relatively unloaded position to a second relatively loaded position; and

a transmission mechanism;

the resilient element being loaded under the action of the propulsion device via the transmission mechanism and being configured to urge the moveable portion of the propulsion device towards the first position via the transmission mechanism when loaded;

wherein the transmission mechanism is adapted to vary a gearing ratio between the moveable portion of the propulsion device and the resilient element within the stroke of the moveable portion of the propulsion device and the resilient element.

~~According to a further aspect of the present invention t~~There is also disclosed~~provided~~ a valve actuator for a gate valve comprising:

a movable control element;

a propulsion device for moving said movable control element, the propulsion device comprising a moveable portion having a stroke extending from a first position to a second position;

a resilient element, having a stroke extending from a first relatively unloaded position to a second relatively loaded position; and

a transmission mechanism;

the resilient element being loaded under the action of the propulsion device via the transmission mechanism and being configured to urge the moveable portion of the propulsion device towards the first position via the transmission mechanism when loaded;

wherein the resilient element comprises a plurality of disc springs.

The disc springs are preferably the disc springs described herein. Such embodiments are especially useful when used with a gate valve.

~~According to a further aspect of the present invention t~~There is also disclosed~~provided~~ a transmission mechanism apparatus comprising:

a movable control element;

a propulsion device for moving said movable control element, the propulsion device comprising a moveable portion having a stroke extending from a first position to a second position;

a plurality of disc springs, having a stroke extending from a first relatively unloaded position to a second relatively loaded position; and

a transmission mechanism;

the plurality of disc springs being loaded under the action of the propulsion device via the transmission mechanism and being configured to urge the moveable portion of the propulsion device towards the first position via the transmission mechanism when loaded;

wherein the transmission mechanism provides a gearing ratio between the moveable portion of the propulsion device and the resilient element.

Thus such embodiments can be used as a transmission mechanism for different purpose not limited to actuators for gate valves.