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| United States Patent Application Publication | 20250257626 |
| Kind Code | A1 |
| Publication Date | August 14, 2025 |
| Inventor(s) | KROESEN; Gerrit et al. |


## AUTOMATIC THRUST ACTIVATED MULTI-SPEED REDUCTION GEAR AND CLUTCH SYSTEM AND METHOD


### Abstract

A technique facilitates application of increased force in various well applications while limiting the overall time period of the operation by automatically utilizing two modes of operation. In some well applications, the technique automatically applies increased force to facilitate shearing of a tubular product in a timely manner. By way of example, the system may be utilized to rapidly advance rams to the point of contact with the tubular product extending through well equipment, e.g. through a blowout preventer (BOP), and then to automatically shift to a slower advance but higher force mode. The higher force mode facilitates shearing of a variety of tubular products in a variety of well applications.



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**Family ID:** **90608582**

**Appl. No.:** **19/111327**

**Filed (or PCT Filed):** **October 03, 2023**

**PCT No.:** **PCT/US2023/034343**


### Related U.S. Application Data

us-provisional-application US 63378567 20221006

### Publication Classification

**Int. Cl.:** **E21B33/06** (20060101)

**U.S. Cl.:**

CPC **E21B33/063** (20130101);

## Background/Summary

CROSS REFERENCE TO RELATED APPLICATION [0001] The present document is based on and claims priority to U.S. Provisional Patent Application No. 63/378,567, filed Oct. 6, 2022, which is incorporated herein by reference in its entirety.

BACKGROUND
[0002] In many oil and gas well applications, pressure control equipment is used to enable rapid and controlled shutdown of a well. For example, rams may be employed to enable shearing of a tubular product, e.g. a drill string, disposed through a blowout preventer so the blowout preventer may be sealed off above the well. Generally, the rams may be moved linearly against the tubular product with sufficient force to shear the tubular product, thus providing space for sealing off the primary blowout preventer passageway. However, some types of tubular products are becoming more difficult to shear. This is particularly true when the shearing is to be performed in a limited amount of time, such as an American Petroleum Institute (API) allotted time of, for example, 30-45 seconds.
SUMMARY
[0003] In general, a system and methodology provide an automatic, multi-speed technique which enhances the speed of an operation while enabling increased application of force. In a well related shearing operation, for example, the system and method enable an automatically increased force for shearing of a tubular product in a timely manner. By way of example, the system may be utilized to rapidly advance rams to the point of contact with the tubular product and then to automatically shift to a slower advance but higher force mode. The higher force mode enables shearing of a variety of tubular products, e.g. drill strings or other tubular products extending through a blowout preventer (BOP) or other well equipment. According to an embodiment, the technique employs a force enhancement system having a roller screw oriented to exert a linear force and a motor coupled to the roller screw via components which automatically shift between modes. The automatic shifting enables rapid engagement with the tubular product in a first mode followed by automatic shifting to a second mode able to provide a higher cutting force for shearing the tubular product.
[0004] However, many modifications are possible without materially departing from the teachings of this disclosure. Accordingly, such modifications are intended to be included within the scope of this disclosure as defined in the claims.

## Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0005] Certain embodiments of the disclosure will hereafter be described with reference to the accompanying drawings, wherein like reference numerals denote like elements. It should be understood, however, that the accompanying figures illustrate the various implementations described herein and are not meant to limit the scope of various technologies described herein, and:
[0006] FIG. **1** is a cross-sectional view of a shifting system, e.g. a ram shifting system, employed in a well application, according to an embodiment of the disclosure;
[0007] FIG. **2** is a cross-sectional view of a portion of the shifting system illustrated in FIG. **1** showing a clutch in an engaged position, according to an embodiment of the disclosure;
[0008] FIG. **3** is an orthogonal view of the shifting system illustrated in FIG. **1** and having a

portion cut away to illustrate various internal components, according to an embodiment of the disclosure;

[0009] FIG. **4** is a cross-sectional view similar to that of FIG. **1** but showing the shifting system in a different operational configuration with the clutch disengaged, according to an embodiment of the disclosure;

[0010] FIG. **5** is a cross-sectional view of a portion of the shifting system illustrated in FIG. **4** showing the clutch in the disengaged position, according to an embodiment of the disclosure;

[0011] FIG. **6** is a cross-sectional view of a portion of the shifting system to better show the disengaged clutch in which a pressure plate has been moved away from a corresponding friction plate, according to an embodiment of the disclosure;

[0012] FIG. **7** is a cross-sectional view of a portion of the shifting system to better show the planetary gear system which becomes operational when the clutch is disengaged, according to an embodiment of the disclosure;

[0013] FIG. **8** is an orthogonal view of the shifting system illustrated in FIG. **4** and having a portion cut away to illustrate various internal components, according to an embodiment of the disclosure;

[0014] FIG. **9** is an orthogonal view of another example of a clutch spring which may be used to bias the clutch toward an engaged position, according to an embodiment of the disclosure;

[0015] FIG. **10** is an orthogonal view of another example of a clutch spring which may be used to bias the clutch toward an engaged position, according to an embodiment of the disclosure; and

[0016] FIG. **11** is an orthogonal view of another example of a clutch spring which may be used to bias the clutch toward an engaged position, according to an embodiment of the disclosure.

## DETAILED DESCRIPTION

[0017] In the following description, numerous details are set forth to provide an understanding of some embodiments of the present disclosure. However, it will be understood by those of ordinary skill in the art that the system and/or methodology may be practiced without these details and that numerous variations or modifications from the described embodiments may be possible.

[0018] The disclosure herein generally involves a system and methodology which facilitate application of increased force, e.g. increased force to facilitate shearing of a tubular product used in a well application. Effectively, the technique makes multiple gear reduction ratios, e.g. two gear reduction ratios, available without employing an elaborate control system. The shifting of gear ratios is automatic, mechanical, and happens in response to increasing load on operating components of the system. In some embodiments, the system may be employed to advance rams used in shearing of tubular products in a well application. In this type of well application, the system enables rapid advance of the rams up to a point of contact with the tubular product and then automatically shifts to a lower gear ratio which effectively provides greater shear force for shearing the tubular product.

[0019] By way of specific example, the system may be used for rapidly advancing a ram to the point of contact with a drill string or other tubular product extending through a blowout preventer (BOP) or other well equipment. The system then automatically shifts to a slower advance but higher force mode based on thrust loading experienced due to contact with the tubular product. The higher force mode enables shearing of a wide variety of tubular products. According to an embodiment, the technique employs a force enhancement system having a roller screw oriented to exert a linear force. A motor is coupled to the roller screw via components, which convert the rotational motion of the motor into linear motion of the roller screw. The components also are arranged to automatically shift between modes. The automatic shifting enables rapid engagement with the tubular product in a first mode followed by automatic shifting to a second mode able to provide a higher cutting force for shearing the tubular product.

[0020] Referring generally to FIGS. **1-3**, an example of a shifting system **20** is illustrated. In this example, the shifting system **20** comprises an automatic thrust activated shear force enhancer **22**, which is an assembly of components arranged to enable shifting between modes, e.g. a higher speed lower force mode and a lower speed higher force mode.

[0021] For the purpose of explanation, the shifting system **20** is illustrated as coupled to a ram **24** constructed to shear a tubular product **26**, e.g. a drill string **28**, deployable in a well **30**. However, the shifting system may be used in a variety of other applications which benefit from the automatic shifting between modes as described in greater detail below. In some applications, a pair of the shifting systems **20** may be mounted to well equipment **32** as illustrated.

[0022] In the specific embodiment illustrated, two shifting systems **20** are mounted to a blowout preventer (BOP) **34**. By way of example, the shifting systems **20** may be mounted to a bonnet **36** of the BOP **34** and oriented generally perpendicularly with respect to the tubular product **26**. Tubular product **26** passes through the BOP **34** via a primary passage **38** extending through the BOP **34** to enable communication with well **30**. Each shifting system **20** may comprise a suitable mounting structure **40**, e.g. a flange type mounting structure, to enable appropriate connection to the BOP **34** or other type of well equipment **32**.

[0023] As illustrated, the automatic thrust activated shear force enhancer **22** comprises a roller screw **42** disposed within an outer housing **44**. The roller screw **42** is oriented for linear motion, as indicated by arrow **46**, within the outer housing **44** and along an interior passage **48** of mounting structure **40**. In the example illustrated, the roller screw **42** may be coupled to the ram **24** to control linear movement of ram **24** against and through tubular product **26**.

[0024] The shear force enhancer **22** further comprises a motor **50** operatively coupled to the roller screw **42** via a roller screw assembly **52** and additional components as described in greater detail below. The motor **50** causes relative rotation between the roller screw assembly **52** and the roller screw **42** which, in turn, drives the roller screw **42** linearly. In the specific example illustrated, the motor **50** causes the roller screw assembly **52** to rotate about the roller screw **42** to drive the linear movement of roller screw **42** and thus linear motion of the ram **24**. Various guide features may be used along ram **24** and/or roller screw **42** to prevent unwanted rotation of roller screw **42**/ram **24**.

[0025] In a first mode, the motor **50** is coupled to the roller screw assembly **52** via a clutch **54** while clutch **54** is operably engaged as further illustrated in FIGS. **2** and **3**. The clutch **54** may have various components and structures and may be located within a clutch housing **55**. In the illustrated example, clutch **54** comprises a clutch friction plate **56** connected to roller screw assembly **52** via a sun gear **58**. Additionally, clutch **54** has a clutch pressure drive plate **60** illustrated as biased into engagement with clutch friction plate **56** via a clutch spring **62**. The illustrated clutch spring **62** is in the form of a diaphragm spring **64**, but other types of clutch springs **62** may be employed as described in greater detail below.

[0026] With clutch **54** engaged in the first mode, the motor **50** is effectively coupled to the roller screw assembly **52** in a relatively higher gear ratio which drives the roller screw assembly **52** at a first, higher rotational speed. This first rotational speed causes the roller screw **42** to move at a corresponding higher linear speed, e.g. a higher linear speed in the direction of arrow **46**. According to an embodiment, the motor **50** may be connected to the roller screw assembly **52** in a 1:1 ratio so the roller screw assembly **52** effectively rotates at the same speed as motor **50**. However, other "high-speed" ratios may be selected. Although various types of motors **50** may be utilized, it should be noted the illustrated motor comprises a stator **66**, affixed within outer housing **44**, and a rotor **68** which rotates within stator **66** so as to provide rotational motion to roller screw assembly **52** in the direction indicated by arrow **69**. The roller screw assembly **52** may have threaded rollers which engage corresponding threads along the exterior of roller screw **42** so as to drive the roller screw **42** linearly as roller screw assembly **52** is rotated by motor **50**.

[0027] In the example illustrated, motor **50** is coupled to the roller screw assembly **52** via a series of components including a motor drive adapter **70** which may be connected, e.g. keyed, to rotor **68**. The motor drive adapter **70**, in turn, is connected to a gearbox drive adapter **72**, which is connected to an outer ring gear **74**. With clutch **54** engaged, the outer ring gear **74** is locked together with a planet gear carrier **76**, which is connected to clutch friction plate **56** so that these components rotate along with the sun gear **58** in a high speed ratio, e.g. a 1:1 ratio, with the motor **50** and motor drive adapter **70**. The sun gear **58** is bolted or otherwise connected to the roller screw assembly **52**. It should be noted that planet gears/rollers **78** are disposed between outer ring gear **74** and sun gear **58** but rotate along with them at the same speed when the clutch **54** is engaged. In other words, the planet gears **78** do not provide a speed reduction with respect to the roller screw assembly **52** (or a speed reduction with respect to linear movement of roller screw **42**) when in this first mode.

[0028] Referring generally to FIGS. **4-6**, when the ram **24** (or other attachment connected to roller screw **42**) engages an object, e.g. tubular product **26**, a thrust force begins to act on the ram **24** and thus on the roller screw **42**. Once the thrust acting on the roller screw reaches a level able to overcome clutch spring **62**, i.e. a shifting level, continued operation of motor **50** automatically causes the roller screw **42** to shift roller screw assembly **52**, sun gear **58**, and the attached clutch pressure drive plate **60** in a linear direction opposite to that of arrow **46** (see arrow **80** in FIGS. **4** and **7**). This shifting causes the clutch pressure drive plate **60** to disengage from clutch friction plate **56**, thus disengaging clutch **54** as further illustrated in FIG. **8**. Effectively, the shear force enhancer **22** has automatically shifted to a second mode of operation enabling a higher force, e.g. a higher shear force, to be applied via ram **24** or other feature. It should be noted that if tubular product **26** is able to be sheared without increased force, then the shear force enhancer **22** can continue to operate in the first mode throughout the shearing operation.

[0029] Once the clutch pressure drive plate **60** is disengaged from clutch friction plate **56**, the planet gears **78** are allowed to rotate. The motor **50** rotates motor drive adapter **70** and gearbox drive adapter **72** so as to rotate outer gear ring **74**. With clutch **54** disengaged, the outer gear ring **74** is able to rotate planet gears **78** which, in turn, rotate sun gear **58** and thus roller screw assembly **52**. However, this planet gear assembly is constructed to provide a gear reduction which lowers the rotational speed of roller screw assembly **52** without changing the speed of motor **50**.

[0030] Consequently, the roller screw assembly **52** is able to apply a greater torque which is thus converted to a higher force, e.g. a higher shear force, exerted linearly via roller screw **42** and ram **24**. Shifting from the first mode to the second mode occurs automatically and mechanically based on the linear force experienced by roller screw **42** as ram **24** is driven against tubular product **26**.

[0031] According to another embodiment, the same principle of operation may be employed by utilizing an electronic circuit. In this embodiment, the resultant force acting on roller screw **42** upon engagement with tubular product **26** can be used to shift components so as to close a circuit. Closure of the circuit may be used to energize an electromagnet which disengages the clutch and thus automatically changes the gear ratio in the planetary gear set containing planet gears **78**.

[0032] The mechanical clutch **54** is illustrated as using diaphragm spring **64** to bias pressure drive plate **60** into clutch friction plate **56**. However, various other types of springs may be used to provide this biasing force. By way of example, the clutch spring **62** may be in the form of a single coil spring **82**, as illustrated in FIG. **9**. In another example, the clutch spring **62** may utilize a plurality of coil springs **84** mounted between corresponding spring plates **86**, as illustrated in FIG. **10**. By way of further example, the clutch spring **62** may be in the form of an elastomeric spring **88**, as illustrated in FIG. **11**.

[0033] Depending on the specific well operation and well equipment, the automatic thrust activated shear force enhancer **22** may be used individually, in pairs, or in greater numbers. Additionally, the automatic thrust activated shear force enhancer **22** may be used in a variety of well applications to perform shearing of various tubular products **26** extending through a BOP **34** or other well structure. The automatic shifting between a rapid, lower force mode and a slower, higher force mode facilitates the shearing of a wider variety of tubular products in a wider variety of applications. It should be noted, however, the automatic thrust activated shear force enhancer **22** may be used in many other types of applications that can benefit from the automatic thrust activated multi-speed capability.

[0034] Additionally, the automatic thrust activated shear force enhancer **22** may have a variety of sizes and configurations. The shape, size, and configuration of various components may vary to accommodate the parameters of intended operations. For example, various types of clutches **54**, including various types of clutch springs **62**, may be employed. Numerous types of seals, bearings, springs, and other supporting features may be employed to help position components and to seal off certain regions of the automatic thrust activated shear force enhancer **22**. Different gear arrangements may be selected to enable automatic shifting between desired gear ratios. Also, gear arrangements may be employed to provide automatic transition between more than two gear ratios, e.g. three or more gear ratios.
[0035] Although a few embodiments of the disclosure have been described in detail above, those of ordinary skill in the art will readily appreciate that many modifications are possible without materially departing from the teachings of this disclosure. Accordingly, such modifications are intended to be included within the scope of this disclosure as defined in the claims.

## Claims

**1**. A system for use in a well operation, comprising: a ram constructed to shear a tubular product deployable in a well; and a ram shifting system having an automatic thrust activated shear force enhancer, the automatic thrust activated shear force enhancer comprising: a roller screw coupled to the ram; a motor coupled to the roller screw via a roller screw assembly, which is rotated about the roller screw to drive the roller screw and the ram in a linear direction; in a first mode, the motor being coupled to the roller screw assembly via a clutch, which is engaged to drive the roller screw assembly at a first rotational speed; and in a second mode, the clutch being forced to a disengaged position via thrust acting on the roller screw as the ram engages the tubular product, the disengaged position enabling the motor to drive the roller screw assembly via a gear assembly at a second rotational speed lower than the first rotational speed, thus creating increased torque on the roller screw assembly and enhanced shear force via the ram.
**2**. The system as recited in claim 1, further comprising a blowout preventer (BOP) having the tubular product extending through the BOP, the ram shifting system being mounted to the BOP.
**3**. The system as recited in claim 2, wherein the ram shifting system is mounted to a bonnet of the BOP.
**4**. The system as recited in claim 3, further comprising a second ram and a second ram shifting system mounted to the bonnet.
**5**. The system as recited in claim 1, wherein in the first mode, the motor is coupled to the roller screw assembly via a motor drive adapter, a gearbox drive adapter, an outer ring gear, and the clutch, which is biased to the engaged position via a clutch spring.
**6**. The system as recited in claim 1, wherein in the first mode, the motor is coupled to the roller screw assembly in 1:1 drive ratio.
**7**. The system as recited in claim 1, wherein in the second mode, the motor drives the roller screw assembly via a motor drive adapter, a gearbox drive adapter, an outer ring gear coupled with planet gears, and a sun gear driven by the planet gears while being coupled to the roller screw assembly to create a reduction in rotational speed of the roller screw assembly, thus increasing torque acting on the roller screw assembly and thereby increasing the linear force exerted on the ram by the roller screw.
**8**. The system as recited in claim 5, wherein the clutch spring comprises a diaphragm spring.
**9**. The system as recited in claim 5, wherein the clutch spring comprises a coil spring.
**10**. The system as recited in **5**, wherein the clutch spring comprises an elastomeric spring.
**11**. A system, comprising: a force enhancement system having: a roller screw oriented to exert a linear force; and a motor coupled to the roller screw via a roller screw assembly so that operation of the motor drives the roller screw in a linear direction, the motor being coupled to the roller screw

assembly through a mechanism that is automatically shifted between a first mode and a second mode when the linear force acting on the roller screw reaches a shifting level, the first mode having the motor causing linear movement of the roller screw through a clutch, which is engaged to drive the roller screw at a relatively rapid linear speed, the second mode having the clutch disengaged once the linear force acting on the roller screw reaches the shifting level so as to enable the motor to utilize a gear assembly in causing linear movement of the roller screw at a relatively slower linear speed but with greater force.

**12**. The system as recited in claim 11, further comprising a ram coupled to the roller screw.

**13**. The system as recited in claim 12, further comprising a BOP, the force enhancement system being mounted to the BOP.

**14**. The system as recited in claim 11, wherein when in the first mode, the motor rotates the roller screw assembly via a motor drive adapter, a gearbox drive adapter, an outer ring gear, and the clutch which is biased to the engaged position via a clutch spring.

**15**. The system as recited in claim 14, wherein when in the first mode, the motor is coupled to the roller screw assembly in a 1:1 drive ratio.

**16**. The system as recited in claim 11, wherein in the second mode, the motor drives the roller screw assembly via a motor drive adapter, a gearbox drive adapter, an outer ring gear coupled with planet gears, and a sun gear driven by the planet gears while coupled to the roller screw assembly to create a reduction in rotational speed of the roller screw assembly relative to the speed of the roller screw assembly in the first mode.

**17**. A method, comprising: coupling a ram to a ram shifting system having a roller screw driven by a motor; using the motor for selectively rotating the roller screw assembly to cause the roller screw and the ram to move in a linear direction; automatically shifting the ram shifting system from a first mode to a second higher torque mode when linear thrust acting on the roller screw reaches a certain thrust level; and continuing rotation of the roller screw assembly in the second higher torque mode so that a higher level of torque acts on the roller screw assembly to thus enhance the linear thrust exerted by the roller screw and the ram.

**18**. The method as recited in claim 17, further comprising mounting the ram shifting system to a BOP.

**19**. The method as recited in claim 18, wherein continuing rotation comprises forcing the ram to shear a tubular structure extending through the BOP.

**20**. The method as recited in claim 17, wherein automatically shifting comprises using the linear thrust acting on the roller screw to shift the roller screw in a manner which disengages a clutch.