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(54) **MILLING SYSTEM FOR FORMING A WINDOW IN THE WALL OF A TUBULAR**

FRÄSSYSTEM ZUM ERSTELLEN EINES FENSTERS IN EINEM ROHR

SYSTEME DE FRAISAGE PERMETTANT DE FORMER UNE FENETRE DANS LA PAROI D'UN  
TUBULAIRE

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## Description

**[0001]** The present invention relates to a system for milling a window in a casing arranged in a borehole formed in an earth formation according to the preamble of claim 1. Such a milling system is known from EP-A-0 791 722. In the technology of producing hydrocarbon fluid from a wellbore it has become practice to drill branch boreholes via corresponding openings formed in the casing of the main wellbore, such openings being generally referred to as windows. Conventionally a window is created by fixedly positioning a whipstock having a slanted guide-way, within the casing and guiding a milling tool along the guide-way during milling of the window. The downhole force required to progress the milling tool along the guide-way is supplied from surface via a pipe string connected to the milling tool. Fluid is pumped through the pipe string to operate the milling tool and to remove the milling cuttings from the borehole.

**[0002]** A problem of the conventional system for milling a window in a casing is that the downhole force required to progress the milling tool along the guide-way is insufficiently controllable. This is, for example, due to frictional forces which counter-act the downward force acting on the pipe string, and due to uncontrolled bending of the pipe string within the casing.

**[0003]** It is an object of the invention to provide an improved milling system which overcomes the problems of the conventional system.

**[0004]** In accordance with the invention there is provided a system for milling a window in a casing arranged in a borehole formed in an earth formation as specified in claim 1.

**[0005]** The thrust force necessary for progressing the milling tool during milling is provided from the guiding device rather than from surface. For example, the guiding device can be provided with a hydraulic motor or an electric motor receiving power from surface via a suitable control system. With the system of the invention it is achieved that the problems of the conventional system are eliminated as it is no longer required to provide the downward force via an elongate element (such as a pipe string) extending from surface through the casing.

**[0006]** It is to be understood that in the context of the present invention the term "casing" refers to any elongate hollow element which is arranged in the borehole and in which a window is to be milled, such as a cemented casing or a wellbore liner.

**[0007]** Suitably the guiding device is provided with a guide-way defining said selected path and with means for preventing movement of the milling tool transverse to the guide-way. In this manner it is achieved that undesired "walk" of the mill during milling is prevented and that an accurate shape of the window is obtained.

**[0008]** In a preferred embodiment of the system, the selected path extends substantially parallel to the longitudinal axis of the casing. In this manner another problem of the conventional system, namely that the shape of the

window deviates from the planned circular or oval shape, is solved. For example, in the conventional system whereby the milling tool is arranged at an inclination angle relative to the longitudinal axis of the casing, the upper window portion is milled by the upper side of the mill and the lower window portion by the lower side of the mill. As a result the upper window portion will be biased in one direction (depending on the direction of rotation of the mill) and the lower window portion in the other direction. By selecting the path of the milling tool to be substantially in longitudinal direction of the casing it is achieved that only one side of the mill contacts the casing during the entire milling procedure.

**[0009]** The invention will now be described in more detail and by way of example with reference to the accompanying drawing in which:

Fig'. 1 schematically shows an embodiment of the system according to the invention.

**[0010]** A borehole 1 has been formed in an earth formation 2 and provided with a steel casing 3. The embodiment 4 of the system according to the invention includes a retrievable downhole packer 5 fixedly positioned at a selected location in the casing 3 and provided with an upwardly extending latching element 7 adapted to receive and fixedly hold a support column 9 of a guiding device 11 in a selected orientation. The guiding device 11 includes a ramp element 14 rigidly connected to the support column 9 and provided with a secondary support element 16 which is radially extendible against the inner surface of the casing 3. The ramp element 14 extends inclined relative to the longitudinal axis of the casing 3 and defines inclined, opposite, directions 20, 22 of a path along which a milling tool 18 is movable, direction 20 being inclined downwardly and direction 22 being inclined upwardly. The ramp element 14 is internally provided with a thrust means in the form of a chain (not shown) movable in the directions 20, 22 and an electric motor (not shown) for driving the chain. The milling tool 18 has legs 24, 26 which are connected to the chain so that movement of the chain in directions 20, 22 results in corresponding movement of the milling tool 18. The milling tool is internally provided with a hydraulic motor (not shown) for driving a mill 27 of the milling tool, the hydraulic motor receiving hydraulic fluid via a coiled tubing 30 extending through the casing 3 to a hydraulic pump (not shown) at surface, the coiled tubing being connected to the hydraulic motor by means of a flexible hose 31. The mill 27 has a plurality of outlet nozzles (not shown) for hydraulic fluid from the motor. The coiled tubing is provided with a connector (not shown) for connecting the coiled tubing to the guiding device 11 so as to lower and retrieve the guiding device 11 and milling tool 18 through the wellbore 1.

**[0011]** An electric power supply cable 32 extends from a control unit (not shown) at surface, through the coiled tubing 30 and the hose 31, to the milling tool 18 and from

there via one of the legs 24, 26 to the electric motor of the ramp element 14. The control unit is provided with controls for selectively moving the chain in direction 20 or 22. Furthermore, the control unit includes a control for selectively extending or retracting the secondary support element 16 relative to the inner surface of the casing 3.

**[0012]** During normal use the packer 5 with the latching element connected thereto is fixedly positioned at a selected location in the casing 3 at an orientation corresponding to the desired orientation of the window to be milled. The guiding device 11 is connected to the coiled tubing 30 by means of the connector and the combined guiding device 11/milling tool 18 are then lowered by coiled tubing 30 through the casing 3 until the support column 9 latches into latching element 7. Subsequently the control unit at surface is operated to provide a control signal via power supply cable 32 to the guiding device so as to radially extend support element 16 against the casing 3.

**[0013]** Hydraulic fluid is then pumped through the coiled tubing 30 thereby driving the hydraulic motor so as to rotate the mill 27. Simultaneously the control unit at surface is operated so as to move the chain and the milling tool 18 in the direction 20 in order to mill the window. The cuttings resulting from the milling operation are entrained and transported away by the hydraulic fluid exiting through the nozzles of the mill 27. After milling of the window has been completed, the control unit is operated so as to move the milling tool 18 in direction 22 away from the casing 3 and to retract the support element 16. The combined guiding device 11/milling tool 18 are then retrieved to surface by means of the coiled tubing 30. The packer 5 and latching element 7 are subsequently retrieved to surface in any suitable manner.

**[0014]** Instead of applying the milling tool and the guiding device as separate units, these devices can be integrated into one tool, optionally also including the packer and latching element.

**[0015]** In an alternative embodiment of the system according to the invention the thrust means is one of a worm-gear having a spindle extending in the direction along which the milling tool is guided and a hydraulic piston/cylinder assembly extendible in said direction.

**[0016]** Furthermore, the milling device can be provided with measuring means for measuring parameters such as the torque delivered by the output shaft of the milling tool, the thrust force delivered by the thrust means, and the position of the milling tool along said path. Suitably the measuring means is in communication with a data receiving station at surface via a data transmission cable extending through a tubing, e.g. the coiled tubing referred to above.

### Claims

1. A system for milling a window in a casing arranged in a borehole formed in an earth formation, the sys-

tem comprising a milling tool (18) for milling such a window, a guiding device (11) for guiding the milling tool along a selected path within the casing during milling of such a window, the guiding device having means (5-9) for fixedly arranging the guiding device within the casing, wherein the guiding device is provided with thrust means for thrusting the milling tool along the selected path during milling of such a window, a motor being so arranged as to drive a mill (27) of the milling tool, **characterised in that** the motor and the thrust means are arranged such that operation of the thrust means causes both the motor and the milling tool to be thrust together along said selected path.

2. The system of claim 1, wherein the thrust means includes one of a chain movable in the direction of said path, a worm-gear having a spindle extending in the direction of said path, and a hydraulic piston/cylinder assembly extendible in the direction of said path.
3. The system of claim 1 or 2, wherein the guiding device (11) is provided with a guide-way defining said selected path and with means for preventing movement of the milling tool transverse to the guide-way.
4. The system of any one of claims 1-3, wherein the said selected path extends substantially parallel to the longitudinal axis of the casing.
5. The system of any one of claims 1-4, wherein the milling tool (18) has an output shaft driven by a hydraulic motor, the hydraulic motor being connected to a hydraulic fluid supply by tubing (31) extending through the casing to the surface and having an outlet opening for hydraulic fluid arranged so as to allow the hydraulic fluid to entrain cuttings resulting from milling the window.
6. The system of claim 5, wherein the thrust means is driven by an electric motor connected to an electric power supply cable (32) extending through said tubing.
7. The system of claim 5 or 6, wherein the tubing is a coiled tubing.
8. The system of any one of claims 1-7, wherein the milling device is provided with measuring means for measuring at least one of the torque delivered by an output shaft of the milling tool, the thrust force delivered by the thrust means, and the position of the milling tool along said path.
9. The system of claim 8 when dependent on claim 5, wherein the measuring means is in communication with a data receiving station at surface via a data

transmission cable extending through said tubing.

10. The system of any one of claims 1-9, further comprising an indexing device for orienting the milling tool in different orientations relative to the guiding device so as to allow the window to be milled in multiple passes of the milling tool, wherein each pass corresponds to one of said orientations of the milling tool relative to the guiding device.
11. The system of any one of claims 1-10, wherein the selected path extends substantially in longitudinal direction of the casing.

### Patentansprüche

1. System zum Fräsen eines Fensters in einer Auskleidung, die in einem Bohrloch angeordnet ist, das in einer Erdformation ausgebildet ist, mit einem Fräs-  
werkzeug (18) zum Fräsen eines solchen Fensters, einer Führungsvorrichtung (11) zum Führen des Fräs-  
werkzeuges entlang eines vorbestimmten Pfades innerhalb der Auskleidung während des Fräsens des  
Fensters, wobei die Führungsvorrichtung mit Mitteln (5-9) zum fixen Anordnen der Führungsvorrichtung  
innerhalb der Auskleidung versehen ist, wobei die Führungsvorrichtung mit Antriebsmitteln zum Beauf-  
schlagen des Fräswerkzeuges entlang des vorbestimmten Pfades während des Fräsens des Fen-  
sters ausgestattet ist, wobei ein Motor derart angeordnet ist, daß er einen Fräser (27) des Fräs-  
werkzeuges antreibt, **dadurch gekennzeichnet, daß** der Motor und die Antriebsmittel derart ausgebildet  
sind, daß die Betätigung der Antriebsmittel sowohl den Motor als auch das Fräswerkzeug gemeinsam  
entlang des vorbestimmten Pfades beaufschlagt.
2. System nach Anspruch 1, bei welchem die Antriebs-  
mittel eine Kette aufweisen, die in Richtung des Pfa-  
des bewegbar ist, ein Schneckengetriebe mit einer  
Spindel, die sich in Richtung des Pfades erstreckt,  
und eine hydraulische Kolben/Zylinderanordnung,  
die in Richtung des Pfades ausfahrbar ist.
3. System nach Anspruch 1 oder 2, bei welchem die  
Führungsvorrichtung (11) mit einer Führungsbahn  
versehen ist, welche den vorbestimmten Pfad defi-  
niert, und mit Mitteln zum Verhindern einer Bewe-  
gung des Fräswerkzeuges quer zur Führungsbahn.
4. System nach einem der Ansprüche 1-3, bei welchem  
sich der vorbestimmte Pfad im wesentlichen parallel  
zur Längsachse der Auskleidung erstreckt.
5. System nach einem Ansprüche 1-4, bei welchem  
das Fräswerkzeug (18) eine Ausgangswelle hat, die  
von einem Hydraulikmotor angetrieben ist, wobei der

Hydraulikmotor mit einer hydraulischen Fluidversor-  
gung über ein Rohr (31) verbunden ist, das sich  
durch die Auskleidung zur Oberfläche erstreckt und  
eine Auslaßöffnung für Hydraulikfluid aufweist, die  
so angeordnet ist, daß das Hydraulikfluid die vom  
Fräsen des Fensters resultierenden Späne mitrei-  
ßen kann.

6. System nach Anspruch 5, bei welchem die Antriebs-  
mittel von einem elektrischen Motor angetrieben  
sind, der mit einem elektrischen Energieversor-  
gungskabel (32) verbunden ist, das sich durch das  
Rohr erstreckt.
7. System nach Anspruch 5 oder 6, bei welchem das  
Rohr ein gewendeltetes Rohr ist.
8. System nach einem der Ansprüche 1-7, bei welchem  
die Fräsvorrichtung mit Meßmitteln zum Messen zu-  
mindest einer Größe aus Drehmoment, das von der  
Ausgangswelle des Fräswerkzeuges abgegeben  
wird, aus der von den Antriebsmitteln abgegebenen  
Antriebskraft und aus der Position des Fräs-  
werkzeuges entlang des Pfades ausgestattet ist.
9. System nach Anspruch 8, rückbezogen auf An-  
spruch 5, bei welchem die Meßmittel mit einer Da-  
tenempfangsstation an der Oberfläche über ein Da-  
tenübertragungskabel in Verbindung stehen, das  
sich durch das Rohr erstreckt.
10. System nach einem der Ansprüche 1-9, das ferner  
eine Fortschaltvorrichtung zum Orientieren des Frä-  
swerkzeuges in unterschiedlichen Orientierungen  
relativ zur Führungsvorrichtung aufweist, damit das  
Fenster in mehreren Durchgängen des Fräs-  
werkzeuges gefräst werden kann, wobei jeder Durch-  
gang einer dieser Orientierungen des Fräs-  
werkzeuges relativ zur Führungsvorrichtung entspricht.
11. System nach einem der Ansprüche 1-10, bei wel-  
chem sich der vorbestimmte Pfad im wesentlichen  
in Längsrichtung der Auskleidung erstreckt.

### Revendications

1. Système pour fraiser une fenêtre dans un cuvelage  
aménagé dans un trou de forage formé dans une  
formation terrestre, le système comprenant un outil  
de fraisage (18) pour fraiser cette fenêtre, un dispo-  
sitif de guidage (19) pour guider l'outil de fraisage le  
long d'un trajet choisi dans le cuvelage au cours du  
fraisage de cette fenêtre, le dispositif de guidage  
ayant des moyens (5 à 9) pour aménager de manière  
fixe le dispositif de guidage dans le cuvelage, dans  
lequel le dispositif de guidage est muni d'un moyen  
de poussée pour pousser l'outil de fraisage le long

- du trajet choisi au cours du fraisage de cette fenêtre, un moteur étant également aménagé de façon à entraîner une fraise (27) de l'outil de fraisage, **caractérisé en ce que** le moteur et le moyen de poussée sont aménagés de sorte que le fonctionnement du moyen de poussée amène à la fois le moteur et l'outil de fraisage à être poussés ensemble le long dudit trajet choisi.
2. Système selon la revendication 1, dans lequel le moyen de poussée comprend un moyen quelconque choisi parmi une chaîne mobile dans la direction dudit trajet, une transmission à vis sans fin ayant un axe s'étendant dans la direction dudit trajet et un assemblage hydraulique à piston/cylindre pouvant s'étendre dans la direction dudit trajet. 10
  3. Système selon la revendication 1 ou 2, dans lequel le dispositif de guidage (11) est pourvu d'une voie de guidage définissant ledit trajet choisi et de moyens pour empêcher un mouvement de l'outil de fraisage transversalement à la voie de guidage. 20
  4. Système selon l'une quelconque des revendications 1 à 3, dans lequel ledit trajet choisi s'étend sensiblement parallèlement à l'axe longitudinal du cuvelage. 25
  5. Système selon l'une quelconque des revendications 1 à 4, dans lequel l'outil de fraisage (18) a un arbre de sortie entraîné par un moteur hydraulique, le moteur hydraulique étant raccordé à une alimentation en fluide hydraulique par une ligne de tubes (31) s'étendant à travers le cuvelage vers la surface et ayant une ouverture de sortie pour le fluide hydraulique aménagée pour permettre au fluide hydraulique d'entraîner des débris provenant du fraisage de la fenêtre. 30  
35
  6. Système selon la revendication 5, dans lequel le moyen de poussée est entraîné par un moteur électrique connecté à un câble d'alimentation électrique (32) s'étendant à travers ladite ligne de tubes. 40
  7. Système selon la revendication 5 ou 6, dans lequel la ligne de tubes est une ligne de tubes enroulés. 45
  8. Système selon l'une quelconque des revendications 1 à 7, dans lequel le dispositif de fraisage est muni d'un moyen de mesure pour mesurer au moins un paramètre parmi le couple de torsion délivré par un arbre de sortie de l'outil de fraisage, la force de poussée délivrée par le moyen de poussée et la position de l'outil de fraisage le long dudit trajet. 50
  9. Système selon la revendication 8 lorsqu'elle dépend de la revendication 5, dans lequel le moyen de mesure est en communication avec un poste de réception de données en surface via un câble de transmission de données s'étendant à travers ladite ligne de tubes. 55
  10. Système selon l'une quelconque des revendications 1 à 9, comprenant en outre un dispositif de mouvement intermittent pour orienter l'outil de fraisage dans différentes orientations par rapport au dispositif de guidage de manière à permettre de fraiser la fenêtre en de multiples passes de l'outil de fraisage, chaque passe correspondant à l'une desdites orientations de l'outil de fraisage par rapport au dispositif de guidage.
  11. Système selon l'une quelconque des revendications 1 à 10, dans lequel le trajet choisi s'étend sensiblement dans la direction longitudinale du cuvelage.

Fig. 1.

