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[Continued on next page]

(54) Title: METHOD OF DETECTING A WORN LINK IN A CHAIN, AND A HOIST ARRANGEMENT

(57) **Abstract:** The invention concerns a method for detecting a worn link (12, 14) in a chain (10) of a hoist arrangement by measuring a first signal (11) while the hoist operates. The invention also concerns a hoist arrangement and use of a signal (11) for detecting a worn link (12, 14) in a chain (10).

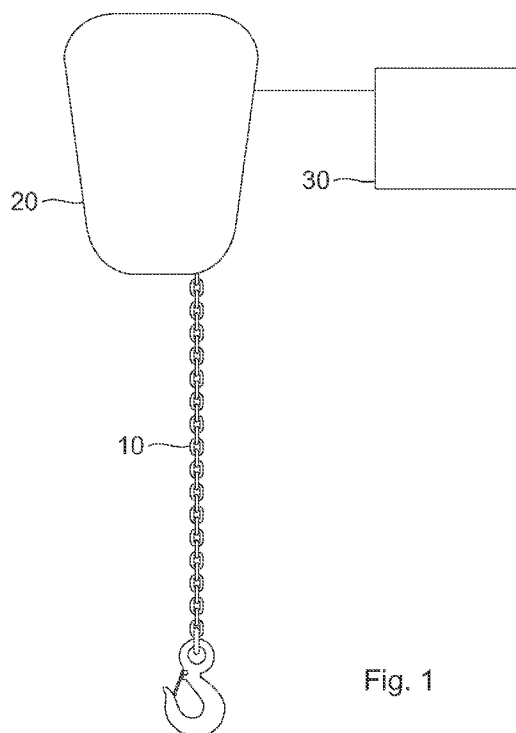


Fig. 1



SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ,
GW, KM, ML, MR, NE, SN, TD, TG).

— of inventorship (Rule 4.17(iv))

Declarations under Rule 4.17:

Published:

— as to applicant's entitlement to apply for and be granted
a patent (Rule 4.17(ii))

— with international search report (Art. 21(3))

METHOD OF DETECTING A WORN LINK IN A CHAIN, AND A HOIST ARRANGEMENT

FIELD OF THE INVENTION

The present invention relates to a method and arrangement of
5 detecting wearing of a chain, and more particularly to detecting wearing of
individual links of a chain in a hoist arrangement.

BACKGROUND OF THE INVENTION

Chains are used in hoists to raise or lower payloads using wheels,
pulleys or other actuators driven with an electric drive system. The chain of the
10 hoist arrangement has to be inspected regularly in addition to full scale
maintenance of the system. A worn out chain causes jamming of the drive and
in worst case the worn out chain may break which may cause a serious
accident. The chain can be inspected visually or by manual measurements but
it takes a long time to inspect each link of the chain on a regular basis so its
15 negative effect on productivity is substantial.

JP2013010634 discloses a lifetime judgement apparatus of a chain
which comprises a rotation-detection unit which detects the rotation speed of
arbitrary rotating shafts. The length of the chain is detected from pulses from
the rotation-detection unit and compared to a predetermined length of a novel
20 chain. A 5 % elongation in the overall length of the chain is disclosed as a limit
for alert.

One of the problems associated with the above arrangement is that
the elongation in the overall length is not a good indicator of the condition of
the chain. Hoists are not typically driven between their extreme points all the
25 time so the chain does not wear evenly. The chain experiences most wear in
the part which has the most interaction with the actuator moving the chain.
One worn out link is enough to cause a malfunction or an accident even
though all the remaining links would be intact. This kind of wearing would
remain undetected if only elongation of the chain is measured.

BRIEF DESCRIPTION OF THE INVENTION

An object of the present invention is thus to provide a method and
an arrangement for implementing the method so as to alleviate the above
disadvantages. The objects of the invention are achieved by a method and an
arrangement which are characterized by what is stated in the independent

claims. The preferred embodiments of the invention are disclosed in the dependent claims.

The invention is based on the idea based on the realization that wear and tear of the chain affects the electric drive system of the hoist arrangement. Deviations in the chain can be detected by measuring quantities, such as load, speed or electric current of the electric drive system, of the electric drive system while the hoist is operated. An intact chain can be seen as relatively constant load when it is reeled in but the electric drive system experiences a distinct load peak when a damaged link is reeled in. So the damaged link causes an impulse that can be detected within the electric drive system, i.e. on motor side from an actuator. No changes, alterations or sensors on the opposite side, i.e. load side from the actuator, are needed.

An advantage of the method and arrangement of the invention is that a single damaged link in the chain can be detected in an otherwise intact chain. Even the exact position of the damaged link(s) can be extracted if the measured data is combined with position measurement data. These measurements can be performed while the hoist is operated normally so unnecessary stoppage can be avoided. Preferably the needed measurement data can be produced without any additional hardware using existing sensors.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following the invention will be described in greater detail by means of preferred embodiments with reference to the accompanying drawings, in which

Figure 1 illustrates a general hoist arrangement; and

Figure 2a and 2b illustrate an example of a chain with damages and corresponding measurement results of the chain;

DETAILED DESCRIPTION OF THE INVENTION

Figure 1 shows a hoist arrangement which comprises an electrically driven actuator 20 which is controlled with a control system 30. The actuator 20 reels in and out a chain 10 for raising or lowering a payload fastened to the chain with e.g. a hook. The actuator 20 comprises or is driven by an electric motor which is operated with the control system 30. The electric motor operates one or more sprockets, wheels, pulleys or other actuators which interact with the chain such that the rotating motion of a shaft of the electric motor reels in and out the chain as needed. The electric motor is

preferably frequency-converter-driven. In an embodiment the hoist arrangement comprises a contactor drive. In the embodiment of contactor drive, the system preferably comprises a data processing unit for performing measurements and analysis. The electric drive system of the hoist arrangement comprises the electrically driven actuator 20, the electric drive and the control system 30.

Drive-related quantities of the electric motor can be measured with sensors from the electric motor, the frequency converter and/or the control system. Useful signals for detecting deviations in the chain include load signal and speed signal but other signals may also be possible to use for that purpose. In the following, an example of load signal measurements is presented, but also other suitable signals, e.g. speed signal, could be used similarly. When a payload, e.g. a crate, hanging from the chain 10 is reeled in with the actuator, the electric motor experiences a load which consists of the force of gravity on the crate, drag of the chain 10 within the actuator's gearing mechanism, friction and other losses. If the crate is reeled in, i.e. lifted, with constant speed, all the other components of the load that the electric motor experiences can be approximated to be constant except the drag of the chain 10 within the actuator's gearing mechanism in case the chain 10 is damaged. In an embodiment the load signal is measured between the actuator of the hoist arrangement (sprocket, wheel, pulley or the like) and the electric drive of the hoist arrangement. In an embodiment the load signal is measured from the electric drive side of the actuator of the hoist arrangement.

An aspect of the invention is a hoist arrangement which comprises a chain 10, an actuator 20 having an electric motor interacting with the chain for lifting and lowering a payload, and a control system 30 for controlling the electric motor. The control system 30 comprises means for measuring and outputting of a first signal for indicating a worn link in the chain. Such means can comprise for example one or more sensors for measuring one or more quantities and one or more computing devices or processors for input and output of said measured quantities. In an embodiment the measured first signal is a load signal or a speed signal. In an embodiment the control system further comprises means for measuring position signal while driving the hoist and combining the measured position signal with the measured first signal for indicating a worn link in the chain and its position in the chain. In an embodiment the drive system calculates the position signal by measuring

internally the number and/or fraction of revolutions and multiplies that with a factor which depends on the circumference of the sprocket. In an embodiment the position is derived by using a sensor which measures pulses from the sprocket's shaft and multiplies that with a factor which depends on the
5 circumference of the sprocket.

For example a transformation in a shape of a link of the chain may prevent the chain to fit properly in the gearing mechanism which increases the drag within the gearing mechanism and some additional power is momentarily needed from the electric motor to overcome this increased drag. In another
10 example a deformed link may drag against a surface within the actuator which causes increased friction i.e. drag which again has to be compensated by momentary addition of power to the electric motor. These changes can be measured from the electric motor, the frequency converter and/or the control system of the hoist arrangement. The changes or deviations can be seen by
15 inspecting the measurement results or the control system may analyse the measurement results and produce an alert if a peak above or below a certain threshold level is detected.

In an embodiment a position signal indicating the position of the chain is measured in addition to the first signal which aims to detect deviations
20 in the chain. The position of the chain is measured in many hoists arrangements for other purposes, such as for controlling the lifted payload, so the same signal can be used for indicating the part of the chain which currently affects the measurement of the first signal, such as the load signal or the speed signal. By combining the results of the measurements the first signal
25 can be presented as a function of position of the chain, for example load is presented as a function of position of the chain in the example of Figure 2b. Without the information from the position signal, the first signal (e.g. load) has to be presented as a function of e.g. time or some other quantity which does not directly indicate the position in the chain so search for the indicated damaged
30 link is more difficult. In an embodiment one or more measurements are performed with a frequency converter of an electric drive of the hoist. In an embodiment one or more measurements are performed with a control system of an electric drive of the hoist.

In an embodiment a load signal is produced with a strain gauge
35 measurement. The strain gauge measurement can be realized with a strain gauge sensor mounted in the proximity of bearings of a payload-bearing shaft

of the drive system. The sensor could also be mounted in the proximity of bearings of a drive shaft of the actuator. In an embodiment the strain gauge sensor is mounted onto bearing frame of a shaft, next to the bearings of the shaft of the actuator 20.

5 The load measurement can be based on the fact that the dimensions of a worn link of the chain have changed during the wearing of the link. This can be seen especially in the inside ends of the worn link. This causes additional friction (compared to an intact chain) and minor deformations in the chain when the damaged part of the chain is reeled through the actuator.

10 In practice the worn link travels a slightly different route in the actuator than an intact link thus rubbing itself against other links, sprockets and chain guides around sprockets in a different way than an intact link. This deviation leads to an increased resistance to motion and/or increased friction (compared to an intact link) which can be seen as an increased load, e.g. at the strain gauge

15 sensor, when the worn link is handled.

 An aspect of the invention is a method of detecting worn link in a chain 10 of a hoist arrangement. The worn link is detected by measuring a first signal 11 of the hoist arrangement while driving the hoist and detecting peaks 13, 15 crossing of a certain threshold level 19 in the measured first signal 11.

20 The peaks 13, 15 in the measured first signal 11 represent a worn link (12, 14) in the chain 10. The peaks can be positive and/or negative peaks in the measured signal so the threshold level can be above and/or under the normal operating range which an intact chain produces. In an embodiment the measured first signal 11 is a load signal of the hoist and peaks 13, 15 above a

25 certain threshold level 19 are detected. In an embodiment the measured first signal 11 is a load signal of the hoist and peaks 13, 15 above and under a certain threshold level 19 are detected. In an embodiment the measured first signal is a speed signal of the hoist and peaks crossing a certain threshold level are detected.

30 Figure 2a illustrates an example of a part of chain 10 that has two worn/damaged links 12 and 14. The first worn/damaged link 12 has a more pronounced damage and the second link 14 has experienced a minor transformation in its shape. Figure 2b illustrates an exemplary graph 11 of what could be the measurement result for the chain of Figure 2a. The figures

35 are aligned such that the graph 11 of Figure 2b shows in each point the measurement result of that of the chain 10 of Figure 2a which is directly above

the graph 11. In Figure 2b, a threshold level 19 is indicated with a horizontal line and a measurement result above that line indicates damage in a link of the chain 10. A suitable threshold level 19 may vary between different hoist arrangements. A good starting point for the threshold level is slightly above the level which is received from measurement of a new and intact chain.

When following the graph 11 of Figure 2b from left to right, small jitter or noise can be seen in the intact part of the chain before the first damaged link 12. The jitter or noise is typically caused by the angular type of movement of a chain in a sprocket. The graph 11 nevertheless lies below the threshold level until the first damaged link 12 enters the actuator's gearing mechanism. The first damaged link 12 has experienced major damage and it produces a distinct peak 13 to the graph 11. Between the damaged links 12 and 14 again some jitter or noise may exist but it is below the threshold level 19. The second damaged link 14 has experienced minor damage and it produces clear but less distinct peak 15 compared to the first damaged link 12. After the second damaged link 14 the rest of the chain is more or less intact and only small jitter or noise can be seen but again it stays below the threshold level. In some cases another threshold level under the normal range of operation can be used to detect momentary decreases in load. Similar behaviour can also be seen in other measurements of drive-related quantities, such as speed measurements. Depending on the measured quantity, the deviation can reach higher or lower levels but the described principle still applies.

In an embodiment position signal is measured while driving the hoist. The position signal can be combined with the measured first signal, such as load signal, for extracting a position of a worn link in the chain from the measured signals. This is illustrated in Figure 2b in which locations of the peaks, i.e. damaged links, are directly comparable to the positions of the damaged links in the actual chain. The horizontal axis can represent for example position in millimetres from the outer or inner end of the chain.

In an embodiment the measuring is performed while driving the hoist. In most cases the deviations in the measurement results become clearer when a payload is lifted with the hoist, compared to driving the hoist without a payload. In an embodiment the measuring is performed while driving the hoist having a payload. The threshold 19 may change depending on the mass of the payload that is lifted. In an embodiment the measuring is performed with rated

load or rated payload of the hoist which gives clear and comparable results and a fixed threshold can be used.

5 An aspect of the invention is the use of a speed signal or a load signal 11 of a hoist arrangement for detecting a worn link 12, 14 in a chain 10 of the hoist arrangement.

It will be obvious to a person skilled in the art that, as the technology advances, the inventive concept can be implemented in various ways. The invention and its embodiments are not limited to the examples described above but may vary within the scope of the claims.

CLAIMS

1. A method of detecting a worn link in a chain (10) of a hoist arrangement operated with an electric drive system, **characterized** by measuring a first signal (11) of the electric drive system of the hoist arrangement while driving the hoist and detecting peaks (13, 15) crossing of a certain threshold level (19) in the measured first signal (11), which peaks (13, 15) in the measured first signal (11) represent a worn link (12, 14) in the chain (10).
2. A method according to claim 1, **characterized** in that the measured first signal (11) is a load signal of the electric drive system of the hoist and peaks (13, 15) above a certain threshold level (19) are detected.
3. A method according to claim 1, **characterized** in that the measured first signal is a speed signal of the electric drive system of the hoist and peaks crossing a certain threshold level are detected.
4. A method according to any one of claims 1 to 3, **characterized** by measuring position signal of the electric drive system while driving the hoist and combining the measured position signal with the measured first signal for extracting a position of a worn link in the chain from the measured signals.
5. A method according to any one of claims 1 to 4, **characterized** in that the measuring is performed while driving the hoist with rated load of the hoist.
6. A method according to any one of claims 1 to 5, **characterized** in that one or more measurements are performed with a frequency converter of the electric drive of the hoist.
7. A method according to any one of claims 1 to 5, **characterized** in that one or more measurements are performed with a control system of the electric drive of the hoist.
8. A method according to any one of claims 1 to 7, **characterized** in that one or more measurements are performed using a strain gauge sensor located at a bearing frame of a shaft of the hoist arrangement.
9. A hoist arrangement comprising a chain (10), an actuator (20) having an electric motor interacting with the chain for lifting and lowering a payload, and a control system (30) for controlling the electric motor,

characterized in that the control system (30) comprises means for measuring and outputting of a first signal for indicating a worn link in the chain.

10. A hoist arrangement as claimed in claim 9,
characterized in that the measured first signal is a load signal or a
5 speed signal.

11. A hoist arrangement according to claim 9 or 10,
characterized in that the control system further comprises means for
measuring position signal while driving the hoist and combining the measured
position signal with the measured first signal for indicating a worn link in the
10 chain and its position in the chain.

12. A hoist arrangement according to any one of claims 9 to 11,
characterized in that the first signal is measured with a strain gauge
sensor.

13. A hoist arrangement according to claim 12,
15 **characterized** in that the strain gauge sensor is mounted onto the
periphery of a bearing frame of a shaft of the actuator (20).

14. Use of a load signal (11) of a hoist arrangement for detecting a
worn link (12, 14) in a chain (10) of the hoist arrangement.

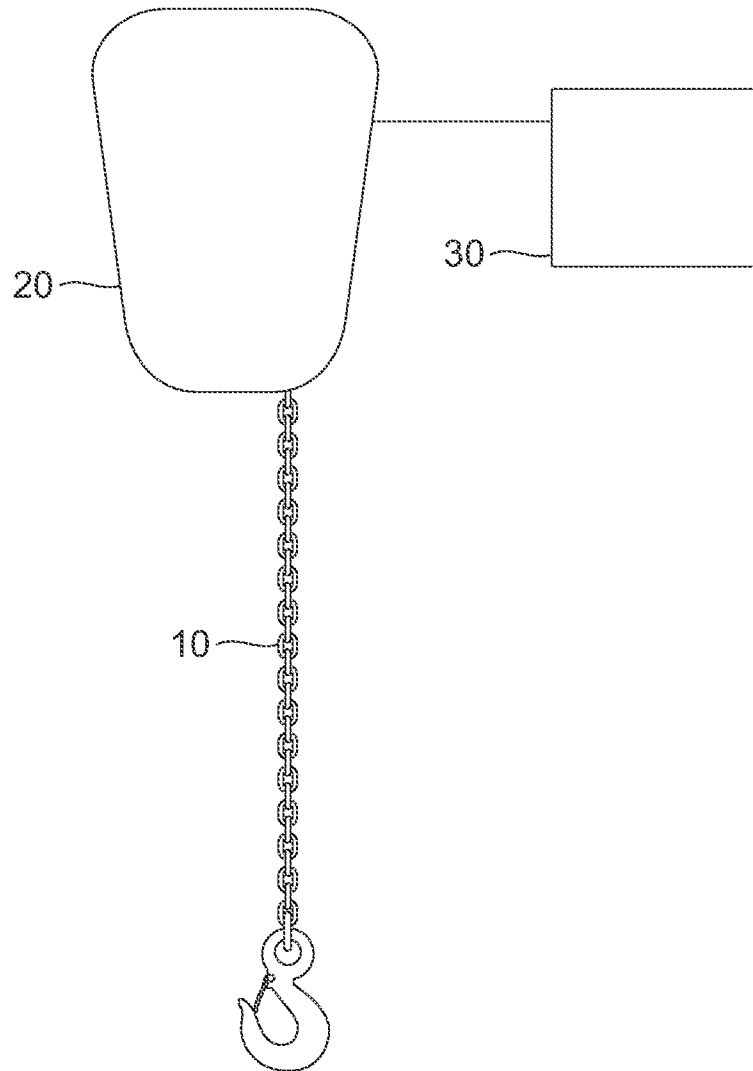


Fig. 1

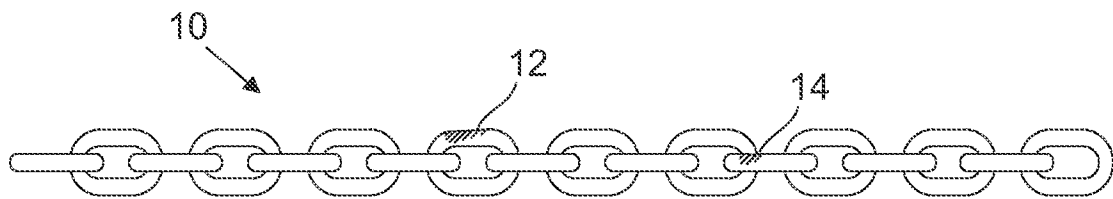


Fig. 2a

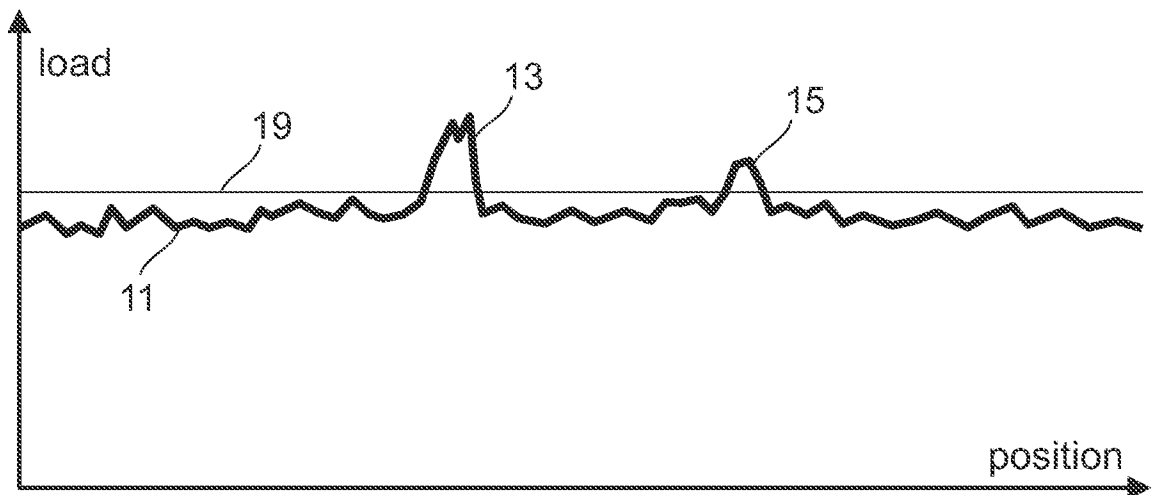


Fig. 2b

INTERNATIONAL SEARCH REPORT

International application No.

PCT/FI2015/050515

A. CLASSIFICATION OF SUBJECT MATTER

See extra sheet

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: B66D, B65G, B66B, G01L, H02P

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
FI, SE, NO, DK

Electronic data base consulted during the international search (name of data base, and, where practicable, search terms used)

EPO-Internal, WPIAP

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 29504180 U1 (RUD KETTEN RIEGER & DIETZ [DE]) 27 June 1996 (27.06.1996) the whole document, especially page 2, 2nd paragraph; page 4, 4th paragraph; figure 6	1, 5, 7-9, 12, 13
A	US 3998317 A (STINNETT ARVIL L) 21 December 1976 (21.12.1976) the whole document, especially abstract; figures 1-3	1-14
A	US 2012325021 A1 (NISHIKAWA KAZUHIRO [JP]) 27 December 2012 (27.12.2012) the whole document, especially paragraph [0043]; figure 11	1-14
A	WO 2012080570 A1 (KONECRANES PLC [FI]) 21 June 2012 (21.06.2012) the whole document, especially paragraphs [0002] and [0012]-[0014]; figures 1 and 2	1-14

☐ Further documents are listed in the continuation of Box C.
☒ See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier application or patent but published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

19 October 2015 (19.10.2015)

Date of mailing of the international search report

29 October 2015 (29.10.2015)

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/FI2015/050515

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

Invention 1: Claims 1-13 are directed to measuring a first signal for indicating a worn link in a chain.

Invention 2: Claim 14 is directed to use of a load signal for detecting a worn link in a chain.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT
Information on Patent Family Members

International application No.
PCT/FI2015/050515

Patent document cited in search report	Publication date	Patent family members(s)	Publication date
DE 29504180 U1	27/06/1996	None	
.....			
US 3998317 A	21/12/1976	None	
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		FI 124566 B	15/10/2014
.....			

INTERNATIONAL SEARCH REPORT

International application No.

PCT/FI2015/050515

CLASSIFICATION OF SUBJECT MATTER

IPC

B66D 3/20 (2006.01)

B66D 1/20 (2006.01)

B66D 1/58 (2006.01)

G01L 5/00 (2006.01)