CLAIMS

1. A method for identifying a leakage in a conduit (C) in which a fluid (F) flows, where said conduit (C) has a longitudinal axis (A), said method comprising the following steps:

A) providing a cable (1) comprising inside at least one first optical fiber (111), where said cable (1) comprises an inner surface (11) and has a longitudinal axis (1A) and said first optical fiber (111) is integral with a portion of said inner surface (11) of said cable (1),

B) arranging said cable (1) tensioned inside said conduit (C) so that the longitudinal axis (1A) of said cable (1) is coincident or substantially coinciding or parallel or substantially parallel to the longitudinal axis (A) of said conduit (C), in such a way that, in use, said cable (1) is inside the fluid present in said conduit (C),

C) for each instant time t_K, with k=1,…,M where M is a positive integer and *k* is the index of the number of time instants, measuring by means of a logic control unit (U) the value of mechanical deformation at predetermined points P_i of said cable (1), with *i*=1,…,N where N is a positive integer and *i* is the index of the number of said predetermined points, so as to obtain a succession of values of mechanical deformation $(D_i)_k$ for each of said predetermined points P_i at each time instant t_K:

at the time instant t_1

$(D_1)_1, (D_2)_1 \ldots (D_N)_1$

at the time instant t_2

$(D_1)_2, (D_2)_2 \ldots (D_N)_2$

…

at the time instant t_M

$(D_1)_M, (D_2)_M \ldots (D_N)_M$

D) for each time instant t_K, calculating by means of said logic control unit (U) the difference between the value of mechanical deformation $(D_i)_k$ at a predetermined point P_i of said cable (1) and a respective predetermined reference value of mechanical deformation $D_{10}, D_{20} \ldots D_{N0}$ at the same predetermined point P_i, so as to obtain for each time instant t_k a respective first succession of difference values $(\Delta D_i)_k$:

at the time instant t_1

$(\Delta D_1)_1, (\Delta D_2)_1 \ldots (\Delta D_N)_1$

where

$(\Delta D_1)_1 = (D_1)_1 - D_{10}$

$(\Delta D_2)_1 = (D_2)_1 - D_{20}$

…

$(\Delta D_N)_1 = (D_N)_1 - D_{N0}$

at the time instant t_2

$(\Delta D_1)_2, (\Delta D_2)_2 \ldots (\Delta D_N)_2$

where

$(\Delta D_1)_2 = (D_1)_2 - D_{10}$

$(\Delta D_2)_2 = (D_2)_2 - D_{20}$

…

$(\Delta D_N)_2 = (D_N)_2 - D_{N0}$

…

at the time instant t_M

$(\Delta D_1)_2, (\Delta D_2)_2 \ldots (\Delta D_N)_2$

where

$(\Delta D_1)_M = (D_1)_M - D_{10}$

$(\Delta D_2)_M = (D_2)_M - D_{20}$

…

$(\Delta D_N)_M = D_{NM} - D_{N0}$

E) for each time instant t_K, comparing by means of said logic control unit (U) each difference value of a respective succession of difference values $(\Delta D_i)_k$ with the subsequent difference value $(\Delta D_{i+1})_k$ of said respective succession of difference values, so as to obtain a respective second succession of difference values $\{\Delta(\Delta D_i)_k\}$:

at the time instant t_1

$\{\Delta(\Delta D_1)_1\},\{\Delta(\Delta D_2)_1\} \ldots \{\Delta(\Delta D_N)_1\}$

where

$\{\Delta(\Delta D_1)_1\} = (\Delta D_1)_1 - (\Delta D_2)_1,$

$\{\Delta(\Delta D_2)_1\} = (\Delta D_2)_1 - (\Delta D_3)_1,$

$\{\Delta(\Delta D_3)_1\} = (\Delta D_3)_1 - (\Delta D_4)_1,$

…

$\{\Delta(\Delta D_N)_1\} = (\Delta D_{N-1})_1 - (\Delta D_N)_1$

at the time instant t_2

$\{\Delta(\Delta D_1)_2\},\{\Delta(\Delta D_2)_2\}\ldots\{\Delta(\Delta D_N)_2\}$

where

$\{\Delta(\Delta D_1)_2\} = (\Delta D_1)_2 - (\Delta D_2)_2,$

$\{\Delta(\Delta D_2)_2\} = (\Delta D_2)_2 - (\Delta D_3)_2$

$\{\Delta(\Delta D_3)_2\} = (\Delta D_3)_2 - (\Delta D_4)_2$

…

$\{\Delta(\Delta D_N)_2\} = (\Delta D_{N-1})_2 - (\Delta D_N)_2$

…

at the time instant t_M

$\{\Delta(\Delta D_1)_M\},\{\Delta(\Delta D_2)_M\}\ldots\{\Delta(\Delta D_N)_M\}$

where

$\{\Delta(\Delta D_1)_M\} = (\Delta D_1)_M - (\Delta D_2)_M$

$\{\Delta(\Delta D_2)_M\} = (\Delta D_2)_M - (\Delta D_3)_M$

$\{\Delta(\Delta D_3)_M\} = (\Delta D_3)_M - (\Delta D_4)_M,$

...

$\{\Delta(\Delta D_N)_M\} = (\Delta D_{N-1})_M - (\Delta D_N)_M$

F) for each time instant t_K, verifying by means of said logic control unit (U) if the difference value $\{\Delta(\Delta D_i)_K\}$ of each second succession of difference values is greater than 0 for determining if an amount of fluid (F) comes out from said conduit (C) between two predetermined points of said conduit (C),

G) for each couple of predetermined points of said cable (1) at the difference value $\{\Delta(\Delta D_i)_K\}$ of each second succession is greater than 0, in order to determine if said amount of fluid (F) comes out from said conduit (C) due to leakage, verifying by means of said logic control unit (U):

when the value of mechanical deformation $(\Delta D_i)_{k+1}$ at a time instant t_{K+1} is equal to the value of the mechanical deformation $(\Delta D_i)_k$ at the time instant t_K, if the value of difference between the difference value $\{\Delta(\Delta D_i)_K\}$ between two predetermined points at the time instant t_K and the difference value $\{\Delta(\Delta D_i)_{K+1}\}$ between the same predetermined points at the time instant t_{K+1} is less than or equal to 0,

when the value of mechanical deformation $(\Delta D_i)_{k+1}$ at a time instant t_{K+1} is

different from the value of mechanical deformation $(\Delta D_i)_k$ at the time instant t_K, if the value of the difference between the difference value $\{\Delta(\Delta D_i)_K$ between two predetermined points at the time instant K and the difference value $\{\Delta(\Delta D_i)_{K+1}\}$ between the same predetermined points at the time instant K+1 multiplied for the ratio between the value of mechanical deformation $(\Delta D_i)_k$ at the time t_K and the value of mechanical deformation $(\Delta D_i)_{k+1}$ at the time instant t_{K+1} is less than or equal to 0.

2. The method according to the previous claim, characterized in that said method comprises the following step:

H) calculating by means of said logic control unit (U) the distance between a couple of predetermined points of said cable (1) at the difference value $\{\Delta(\Delta D_i)_K\}$ is greater than 0 and a further couple of predetermined points of said cable (1) at the difference value $\{\Delta(\Delta D_i)_K\}$ is lower than or equal to 0, where said further couple of predetermined points is arranged in succession to said couple of predetermined points, in order to identify the position of said leakage with respect to the length of the conduit (C).

3. The method according to the previous claim, characterized in that said method comprises the following steps:

- for each time instant t_K, verifying by means of said logic control unit (U) if the difference value $\{\Delta(\Delta D_i)_K\}$ of each second succession of difference values is equal to 0,

- if the difference value $\{\Delta(\Delta D_i)_K$ is equal to 0, verifying by means of said logic control unit (U) if at different time instant t_k, the value of the difference between the difference value $(\Delta D_i)_K$ at a predetermined point P_i of the cable (1) at the time instant t_K and the difference value $(\Delta D_i)_{K+1}$ in correspondence to same predetermined point P_i at time instant t_{K+1} is different from 0, for determining the change of the speed of the fluid between two subsequent time instants referred to a predetermined point P_i of said conduit (C).

4. The method according to any one of claims 1-3, characterized in that, in order to obtain a better spatial resolution referred to the position of each predetermined point P_i of the cable (1), said cable (1) comprises inside a second optical fiber (112), where an end of said second optical fiber (112) is connected to an end of said first

optical fiber (111).

5. The method according to the previous claim, characterized in that

said second optical fiber (112) is arranged inside a hollow element (122), where said hollow element (122) is arranged inside said cable (1),

in that

said method comprises the following step:

- measuring the temperature at each of said predetermined point P_i.

6. The method according to any one of claims 1-3, characterized in that,

said cable (1) comprises inside a second optical fiber (112), arranged inside a hollow element (122),

in that

- measuring the temperature at each of said predetermined point P_i.

7. The method according to any one of the previous claims, characterized in that said fluid is water or oil or gas.

8. A system for identifying the leakage in a conduit (C) in which a fluid (F) flows, comprising:

- a cable (1) comprising inside at least one first optical fiber (111), where said cable (1) comprises an inner surface (11) and has a longitudinal axis (1A) and said first optical fiber (111) is integral with a portion of said inner surface (11) of said cable (1);

- an optical interrogator machine (M) for interrogating said at least one first optical fiber (111), where said optical interrogator machine (M) is provided with at least one input for receiving an end of said cable (1),

- a control logic unit (U) configured to perform the steps from C to G of the method according to any one of the previous claims,

- a first sealing device (21) having a longitudinal axis (AL_1) and shaped to be adapted to the conduit (C) in such a way that, in use, said first sealing device (21) is positioned around a first portion of said conduit (C) and its longitudinal axis (AL_1) is coincident or substantially coincident with the longitudinal axis (A) of said conduit (C),

- a second sealing device (22) having a longitudinal axis (AL_2) and shaped to be adapted to the conduit (C), in such a way that, in use, said second sealing device (22) is positioned around a second portion of said conduit (C), spaced from said first portion, and its longitudinal axis (AL_2) is coincident or substantially coincident with the longitudinal axis (A) of said conduit (C),

- a first positioning device (61) and a second positioning device (62) for positioning said cable (1) inside said conduit (C),

where

said first sealing device (21) comprises a first channel (21A) for the passage of at least a cable, said first channel (21A) having an inlet and an outlet and being arranged around a first axis (A1) inclined with respect to a first transverse plane of said first sealing device (21) in such a way that said first channel (21A) forms with the longitudinal axis (AL_1) of said first sealing device (21) a first angle (α) between 5° and 45°, preferably 30°,

said second sealing device (22) comprises a further first channel (22A) for the passage of at least a cable, said further first channel (22A) having an inlet and an outlet and being arranged around a further first axis (A1') inclined with respect to a second transverse plane of said second sealing device (22), different from said first transverse plane, in such a way that said further first channel (22A) forms with the longitudinal axis (AL_2) of said second sealing device (21) a further first angle (β) between 5° and 45°, preferably 30°,

said first channel (21A) and said further first channel (22A) have an inclination equal or substantially equal and opposite with respect to a transverse plane of said conduit (C),

each positioning device (61,62) comprises:

a respective body (611,621) having a respective part configured to be coupled respectively to the inlet of the first channel (21A) of the first sealing device (21) and to the inlet of the further first channel (22A) of the second sealing device (22),

a respective sealing element (612,622) arranged on the respective body (611,621),

a hollow element (613,623) arranged at least partially inside the respective body (611,621) and sliding with respect to said body,

where

the hollow element (613) of the first positioning device (61) has a length such that, in use, substantially extends from the inlet of the first channel (21A) of the first sealing device (21) inside the conduit (C), up to an axis being coincident or substantially coincident with or parallel or substantially parallel to the longitudinal axis (A) of said conduit (C), and the hollow element (623) of the second positioning device

(62) has a length such that, in use, substantially extends from the inlet of the further first channel (22A) of the second sealing device (22) inside the conduit (C), up to an axis coincident or substantially coincident or parallel or substantially parallel to the axis longitudinal (A) of said conduit (C).

9. The system according to the previous claim, characterized in that said control logic unit (U) is configured to perform the step H of the method according to any one of claims 2-7.

10. The system according to any one of claims 8-9, characterized in that

said first sealing device (21) comprises a second channel (21B), where said second channel (21B) has an inlet and an outlet and is arranged around a second axis (A2) perpendicular or substantially perpendicular to the longitudinal axis (AL_1) of the first sealing device (21) and forms with said first axis (A1) of said first channel (21A) a second angle (θ) between 45° and 85°, preferably 60°,

said second sealing device (22) comprises a further second channel (22B), where said further second channel (22B) has an inlet and an outlet and is arranged around a further second axis (A2') perpendicular or substantially perpendicular to the longitudinal axis (AL_2) of the second sealing device (22) and forms with said second axis (A2) of said second channel (22A) a third angle (δ) between 45° and 85°, preferably 60°.

11. The system according to any one of claims 8-10, characterized in that said first sealing device (21) and said second sealing device (22) comprise a respective first part (211; 221) and a respective second part (212; 222), couplable with said first part (211; 221).

12. The system according to any of the claims 8-11, characterized in that

said first sealing device (21) is provided with first clamping means (210) for clamping said first sealing device (21) on the conduit (C),

in that

said second sealing device (22) is provided with second clamping means (220) for clamping said second sealing device (22) on the conduit (C).

13. The system according to any one of previous claims 8-12, characterized in that said system comprises:

a first blocking device (31) for preventing the cable (1) from sliding with respect to the sealing element (612) of the first positioning device (61), where said first blocking device (31) is dimensioned and shaped in a such a way to abut to the first positioning

device (61), and/or

a second blocking device (32) for preventing the cable (1) from sliding with respect to the sealing element (622) of the second positioning device (62), where said second blocking device (32) is dimensioned and shaped in a such a way to abut against the second positioning device (62).

14. The system according to any one of claims 8-13, characterized in that said cable (1) comprises inside a second optical fiber (112) having an end connected to an end of said first optical fiber (111).

15. The system according to the previous claim, characterized in that said second optical fiber (112) is arranged inside a hollow element (122).

16. The system according to any one of claims 8-13, characterized in that said cable (1) comprises inside a second optical fiber (112), arranged inside a hollow element (122).