

DESCRIPTION

METHOD FOR CHECKING THE PRESENCE OF A ROTATING ELEMENT IN A MACHINE TOOL

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Technical field

The present invention relates to a checking method and apparatus for checking the presence of a rotating element. The present invention can advantageously be applied to
10 check the presence of a rotating tool in a numerical control machine tool, to which reference will be explicitly made in the specification without loss of generality.

Background art

15 In a numerical control machine tool different types of tools can be mounted on the spindle. These tools are taken from and replaced in an automatic store and, in use, are rotated to machine a piece by removing material.

When it is necessary to change the tool, the spindle is
20 placed at the automatic store where it replaces the old tool and takes the new one.

As it can occur that the spindle does not take the new tool from the store, after a tool change it is necessary to check that the spindle has actually taken the new tool. In
25 other words, it has to be checked that the tool is actually present in the spindle.

Moreover, in the course of the use the tool could break (typically, but not only, when the tool is a drill bit with a small diameter) and thus it is necessary to check that
30 the tool carried by the spindle is entire (that is to say, it comprises its end portion, which is its tip).

In order to check that the spindle actually carries a tool (more specifically, a rotating tool, that is a tool rotated by the spindle) and that the tool is entire (that is, it
35 comprises its end portion) the numerical control machine can include a checking apparatus or device of the contact type (which can not be used, however, for checks while the

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tool is rotating) or contactless type. Contactless devices can, for example, detect the presence of the rotating tool by means of the interruption of a light beam (this solution often has problems of overall dimensions) or the
5 observation and the analysis of a radiation reflected by the tool itself.

A checking apparatus of the last type such as, for example, the one shown in US-A-5293048 includes an emitter of an electromagnetic radiation (typically, but not necessarily,
10 a laser beam) which is directed to the area in which the rotating tool should be positioned, and a receiver which is arranged next to the emitter and receives the electromagnetic radiation reflected by the rotating tool. A processing unit of the checking apparatus analyzes the
15 reflected electromagnetic radiation detected by the receiver and determines as a function of said analysis whether the rotating tool is actually present or not.

The analysis of the reflected electromagnetic radiation detected by the receiver is critical, since it must assure
20 a high reliability in determining the presence of the rotating tool. In particular, such analysis includes complex processing, so as to avoid both false positive errors (that is, to determine that the rotating tool is present when it is not really present) and false negative
25 errors (that is, to determine that the rotating tool is not present when it is really present).

The level of risk of false positive errors is quite high, because the receiver can detect noises which could be mistaken for a radiation reflected by the rotating tool.
30 For example, the noises can include the electromagnetic radiation emitted by the emitter and reflected by objects other than the rotating tool (for example, coolant which is sprayed towards the rotating tool, dust or swarfs caused by the machining, or other reflecting surfaces placed behind
35 the tool), or the noises can comprise the electromagnetic radiation emitted by other sources (for example fluorescent lamps providing the environmental lighting).

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There is also the risk of false negative errors. In fact, using strict criteria for the analysis of the electromagnetic radiation detected by the emitter in order to try to avoid the false positive errors, may imply, as a negative consequence, that an electromagnetic radiation which has been actually reflected by the rotating tool but accidentally includes noises is not recognized as a reflection of the rotating tool.

10 Disclosure of the invention

Object of the present invention is to provide a checking method and apparatus for checking the presence of a rotating element, said checking method and apparatus enabling to detect the presence of the rotating tool with increased reliability and, concurrently, being easily and cheaply implemented.

The present invention provides a checking method and apparatus for checking the presence of a rotating tool according to what is claimed in the attached claims.

20 Brief description of the drawings

The present invention is hereinafter described with reference to the attached sheets of drawings given by way of non-limiting examples, wherein:

- 25 - figure 1 is a simplified view, with some parts removed and other parts enlarged for the sake of clarity, of a numerical control machine tool with a checking apparatus for checking the presence of a rotating tool according to the present invention; and
- 30 - figures 2-5 show four diagrams showing data processed by the checking apparatus for checking the presence of the rotating tool.

Best mode for carrying out the invention

35 In figure 1, a numerical control machine tool 1 (for instance an automatic drilling machine) is very schematically illustrated and includes a spindle 2 carrying

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a rotating tool 3 (a drill bit in the particular case shown in figure 1) and a worktable 4 carrying a piece 5 being machined.

Moreover, the machine tool 1 includes a checking apparatus
5 6 which checks the presence (and thus indirectly the entirety) of the rotating tool 3. The entirety of the rotating tool 3 is detected by directing the checking apparatus 6 towards the end portion (that is, towards the tip) of the rotating tool 3: if the end portion of the
10 rotating tool 3 is actually present, it is assumed that the rotating tool 3 is present and is also entire. Obviously, the checking apparatus 6 could be used to check only the presence of the rotating tool 3 by directing the checking apparatus 6 towards a central portion of the rotating tool
15 3 itself.

The machine tool 1 can include a speed sensor 7 mechanically connected to the spindle 2 to measure a rotational frequency (that is, a speed of rotation), in particular a real rotational frequency RF, of the rotating
20 tool 3 and provide its own reading to a (digital or analog) input of the checking apparatus 6. According to an equivalent embodiment, the machine tool 1 doesn't include the speed sensor 7. In this case, the real rotational frequency RF of the rotating tool 3 is accurately estimated
25 on the basis of a nominal frequency, which is per se known as control parameter of an electric motor which puts the spindle 2 into rotation, by means of proper processing operations such as the ones hereinafter described with reference to figure 5.

30 The checking apparatus 6 includes an optical emitter 8 to direct a main electromagnetic radiation 9 towards the rotating tool 3. According to a preferred embodiment, the main electromagnetic radiation 9 is a pulsed laser beam (which corresponds to a periodically recurring alternation
35 of presence and absence of the laser beam) that oscillates (pulses) with a frequency of the order of 10-500 kHz. Moreover, the checking apparatus 6 includes an optical

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receiver 10 to receive a reflected electromagnetic radiation 11 which has been reflected by the rotating tool 3. In other words, the optical receiver 10 "catches" the reflection generated by the rotating tool 3 of the main electromagnetic radiation 9 emitted by the optical emitter 8.

The checking apparatus 6 includes a processing unit 12 that collects the reflected electromagnetic radiation 11 (that is, it collects the electric signals provided by the optical receiver 10 which is "hit" by the reflected electromagnetic radiation 11) to determine a rough signal S to analyze (shown in figure 2). According to a preferred embodiment, the collection of the reflected electromagnetic radiation 11 is carried out by means of a sample and hold circuit synchronized with the oscillation frequency of the main electromagnetic radiation 9.

Knowing the real rotational frequency RF of the rotating tool 3 (such frequency can be obtained in two different ways: provided by the speed sensor 7 to the processing unit 12 or processed, in the absence of any speed sensor, on the basis of a known nominal frequency), the processing unit 12 determines the length of the rough signal S as a function of the real rotational frequency RF so that the rough signal S includes at least two complete rotations of the rotating tool 3 and, preferably, includes at least three complete rotations of the rotating tool 3 (obviously, the rough signal S can include more than three complete rotations of the rotating tool 3, the important thing is that the rough signal S never includes less than two complete rotations of the rotating tool 3). It should be noted that the greater the number of complete rotations of the rotating tool 3 included in the rough signal S is, the simpler and more accurate the analysis of the rough signal S to determine the presence of the rotating tool 3 is, but, the longer the time required is. The processing operations hereinafter described enable to get very good results using

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a limited number of complete rotations of the tool and thus in a very short time.

In calculating the length of the rough signal S, the processing unit 12 takes account of the difference between the real rotational frequency RF and the known nominal rotational frequency and determines the length of the rough signal S in such a way that even in the worst case, that is in the case that the real rotational frequency RF is lower than the nominal one, with a maximal difference lying within a known variability range, the rough signal S includes at least two complete rotations of the rotating tool 3 (at least three complete rotations of the rotating tool 3 in the preferred embodiment).

In the example shown in figure 2, the dashed line represents the rough signal S which is composed by 1536 samples. Such rough signal S has been obtained by demodulating the reflected electromagnetic radiation 11 with a sampling frequency of 1.6 kHz and at a nominal rotational frequency of the rotating tool 3 equal to 200 RPM (that is, equal to $200/60=3,333$ Hz). If the real rotational frequency RF corresponded to the nominal one, sampling at 1.6 kHz a complete rotation of the rotating tool 3 would include 480 samples. It is necessary, however, to take into account that the real rotational frequency RF could generally vary with respect to the nominal one at which the electric motor putting the spindle 2 into rotation is driven. Typically, the variation lies within a variability range of ± 5 . This is generally true and doesn't affect the proper machining operations of the machine tool performed by means of the tool 3 in any way. Hence, in the worst case (that is, in the case that the real rotational frequency RF is 5% lower than the nominal frequency) a complete rotation of the rotating tool 3 includes 512 samples (that is, 480 samples + 5% + rounding off to have a "convenient" number to store, as 512 is a power of 2). Therefore, the rough signal S must be composed of 1536 (=512x3) samples to be certain that the rough signal S

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refers to at least three complete rotations of the rotating tool 3.

According to a possible embodiment, the reflected electromagnetic radiation is collected with a sampling
5 frequency that is varied as a function of the rotational frequency of the rotating tool 3 in such a way that the sampling frequency increases as the rotational frequency increases. For example, when the nominal rotational frequency of the rotating tool 3 is between 200RPM and 1000
10 RPM, the sampling frequency can be equal to 1.6 kHz, while when the nominal rotational frequency of the rotating tool 3 is between 1000 RPM and 5000 RPM the sampling frequency can be equal to 8 kHz. Since the sampling frequency increases as the rotational frequency of the rotating tool
15 3 increases, it is possible to keep the accuracy of the collection quite constant (that is to say, to have a more or less constant number of samples for each complete rotation of the rotating tool 3, and thus a number which is not too great when the rotating tool rotates slowly and/or
20 not too small when the rotating tool 3 rotates quickly).

According to a possible embodiment, the number of complete rotations of the rotating tool 3 included in the rough signal S is not constant but increases as the rotational frequency of the rotating tool 3 increases. In this way,
25 the length of the collection of the rough signal S is more or less constant (so that the time needed to check the presence of the rotating tool 3 can be kept more or less constant).

According to a preferred embodiment, the processing unit 12
30 applies in advance (that is, before further processing operations hereinafter described) to the rough signal S a low-pass software filtering. Moreover, according to a preferred embodiment, the processing unit 12 applies in advance (that is, before further processing operations
35 hereinafter described) to the rough signal S a time scaling of the values by subtracting a constant value equal to the minimum value of the rough signal S. In figure 2, the

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dashed line represents the rough signal S which is not filtered and not time scaled, while the continuous line represents the rough signal S filtered and time scaled.

In the preferred embodiment, in which the real rotational
5 frequency RF is not provided by the speed sensor 7, the processing unit 12 firstly processes the filtered and time scaled rough signal S to determine the exact period of rotation of the rough signal S (thus of the rotating tool 3) by means of an analysis in the time domain. Then, after
10 the exact period of rotation of the rough signal S is determined, the processing unit 12 cuts a part of the rough signal as a function of the exact period of rotation of the rough signal S in such a way that the cut rough signal S exactly includes a whole number of complete rotations of
15 the rotating tool 3. In other words, normally the rough signal S includes a fractional number of complete rotations of the rotating tool 3 and thus the rough signal S is cut (that is to say, a part of the samples included in the rough signal S is cut) in such a way that, after the cut-
20 off, the cut rough signal S exactly includes a whole number of complete rotations of the rotating tool 3 (for example, exactly three complete rotations of the rotating tool 3 as in the embodiment shown in figures 2-5). The cut-off of the rough signal S can take place only at the initial portion
25 of the rough signal S, only at the end portion of the rough signal S, or at both the initial portion and the end portion of the rough signal S.

The processing unit 12 determines the exact period of rotation of the rough signal S by means of an analysis in
30 the time domain performed with a pitch detection algorithm enabling to estimate the period of the fundamental frequency of a quasiperiodic and virtually periodic signal. Preferably, the processing unit 12 uses the autocorrelation function AMDF ("Average Magnitude Difference Function")
35 which is based on the following equation:

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$$AMDF(k) = \sum_{M=k}^{N-1} |S(m) - S(m-k)|$$

Figure 3 shows the value of the AMDF of the samples of the rough signal S represented in figure 2.

The autocorrelation function AS MDF ("Average Squared Mean Difference Function") or another autocorrelation function could be used instead of the autocorrelation function AMDF.

The processing unit 12 determines the exact period of rotation of the rough signal S (thus of the rotating tool 3) by identifying the lowest of the local minima of the AMDF function included in a search interval that is determined as a function of the nominal rotational frequency of the rotating tool 3 and as a function of the variability range of the real rotational frequency RF with respect to the nominal one. With reference to the embodiment shown in figures 2 and 3, the nominal rotational frequency of the rotating tool 3 is equal to 200 RPM (3.333 Hz) and if this was the value of the real rotational frequency RF, sampling at 1.6 kHz a complete rotation of the rotating tool 3 would include 480 samples. Taking account of the variability range of the real rotational frequency RF ($\pm 5\%$ of the nominal frequency) the search interval is centered on 480 samples and has a width of $\pm 5\%$ of 480 samples, that is equal to ± 24 samples. Hence, the search interval is between $480-24=456$ samples and $480+24=504$ samples. The exact rotational period of the rough signal S (and thus of the rotating tool 3) which corresponds to the real rotational frequency RF can thus be searched between the sample 456 and the sample 504. In the AMDF function the periodicity corresponds to the lowest of the local minima included between the sample 456 and the sample 504.

It should be noted that if any local minimum is not included in the search interval (between the 456th value and the 504th value of the AMDF function in the case of

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figure 3) the processing unit 13 determines that the rotating tool can not be recognized and thus is not present.

As previously stated, once the exact rotational period of the rough signal S is determined, the processing unit 12 cuts the rough signal S in such a way that the rough signal S exactly includes a whole number of complete rotations of the rotating tool 3 (for example, exactly three complete rotations of the rotating tool 3 as in the embodiment shown in figures 2-5).

After the cut-off of the rough signal S, the processing unit 12 decimates/expands, by applying a resampling for example by means of linear interpolation, the cut rough signal S in such a way that the cut rough signal S includes a number of samples equal to a power of the number 2 (for example 1024, that is 2^{10} , as in the embodiment shown in figures 2-5). A decimation/expansion of the cut rough signal S in order to have a number of samples equal to a power of number 2 is not strictly necessary but enables the application of the FFT ("Fast Fourier Transform") instead of a DFT ("Discrete Fourier Transform") which is less efficient from the computational point of view.

In figure 4, the continuous line represents the rough signal S which has been cut and, in this case, decimated (thus including 1024 samples), while the dashed line represents the rough signal S before the cut off and the decimation (that is, only filtered and time scaled).

After the decimation/expansion of the cut rough signal S, the processing unit 12 applies to the cut and decimated/expanded rough signal S the FFT to move from the time domain to the frequency domain and thus to perform an analysis in the frequency domain. Figure 5 shows the result of the application of the FFT to the cut and decimated rough signal S (represented with a continuous line in figure 4).

Once the FFT has been applied, the processing unit 12 analyzes the harmonics of the rough signal S to check

whether the rough signal S includes a periodicity with a frequency corresponding to (correlated with) the rotational frequency of the rotating tool 3, preferably to the real rotational frequency RF. Then, the processing unit 12
5 determines that the rotating tool 3 is actually present if the rough signal S includes a periodicity with a frequency corresponding to (correlated with) the rotational frequency of the rotating tool 3. It should be noted that the frequency of a periodicity of the rough signal S
10 corresponds to (is correlated with) the rotational frequency of the rotating tool 3 when it is an integral multiple of - or is equal to, when it is a multiple of order 1 - the rotational frequency of the rotating tool 3. In particular, the processing unit 12 analyzes the rough
15 signal S in the frequency domain and determines that the rough signal S includes a periodicity with a frequency corresponding to (correlated with) the real rotational frequency RF of the rotating tool 3 if the frequency content of the rough signal S has predominant components at
20 integral multiples of the real rotational frequency RF of the rotating tool 3.

According to a first approach, the processing unit 12 determines the amplitude and the order of the harmonic with the maximum amplitude (in figure 5 the harmonic with the
25 maximum amplitude is the third harmonic with an amplitude of about 170) and thus the processing unit 12 determines that the rotating tool 3 is actually present if the order of the harmonic with the maximum amplitude is an integral multiple of the whole number of complete rotations of the
30 rotating tool 3 included in the cut rough signal S (that is, an integral multiple of three in the example shown in figures 2-5). According to an alternative embodiment, the processing unit determines that the rotating tool is actually present if the order of the harmonic with the
35 maximum amplitude is an integral multiple of the whole number of complete rotations of the rotating tool 3 included in the cut rough signal S and if, at the same

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time, the maximum amplitude of the harmonic with the maximum amplitude is higher than a first threshold value. According to a different approach, the processing unit 12 calculates a signal-to-noise ratio as a function of the whole number of complete rotations of the rotating tool 3 included in the cut rough signal S (that is, as a function of the number three in the example shown in figures 2-5) and thus determines that the rotating tool 3 is actually present if the signal-to-noise ratio is higher than a second threshold value. In other words, in calculating the signal-to-noise ratio all the amplitudes of the harmonics the order of which is an integral multiple of the whole number of complete rotations of the rotating tool 3 included in the cut rough signal S are considered as useful signal, and all the amplitudes of the harmonics the order of which is not an integral multiple of the whole number of complete rotations of the rotating tool 3 included in the cut rough signal S are considered as noise. For example, according to a first method of calculating the signal-to-noise ratio, the signal-to-noise ratio is calculated as a fraction where the numerator is the sum (for example quadratic) of the amplitudes of the harmonics the order of which is an integral multiple of the whole number of complete rotations of the rotating tool 3 included in the cut rough signal, and the denominator is the sum (for example quadratic) of all the amplitudes of the harmonics the order of which is not an integral multiple of the whole number of complete rotations of the rotating tool 3 included in the cut rough signal S. According to another method of calculating the signal-to-noise ratio (which is perfectly equivalent to the first method above-described) the signal-to-noise ratio is calculated as a fraction where the numerator is the sum (for example quadratic) of the amplitudes of the harmonics the order of which is an integral multiple of the whole number of complete rotations of the rotating tool 3 included in the cut rough signal S,

and the denominator is the difference between the sum (for example quadratic) of all the amplitudes and the numerator. According to a different embodiment, the processing unit 12 doesn't determine the exact rotational period of the rough
5 signal S and thus doesn't cut the rough signal S. In this case, before the decimation/expansion is performed (and thus before the FFT is applied) the processing unit 12 can apply to the rough signal S a window function (for example a Hanning window) so as to avoid (or at least limit) the
10 spectral leakage phenomenon. The accuracy/reliability of this embodiment is fair but lower than that of the above-described preferred embodiment.

According to another embodiment, the processing unit 12 doesn't perform the decimation/expansion of the rough
15 signal S, and thus, rather than applying the FFT, it applies the DFT (that is, the traditional Fourier transform) to the rough signal S. The accuracy/reliability of this embodiment is not lower than that of the above-described preferred embodiment, but it requires a computing
20 power higher (or, if the computing power is the same, a computing time longer) than that of the above-described preferred embodiment.

The above-described checking method for checking the presence of a rotating element provides many advantages.
25 First of all, the above-described checking method enables to determine the presence or absence (breakage) of the rotating tool 3 in a quick and very reliable way.

Moreover, as the above-described method neither requires a high computing power nor uses a large amount of memory, it
30 can be easily and cheaply implemented.

In the embodiment described above and shown in the attached figures, the checking method is used to check the presence/breakage of the rotating tool 3. Obviously, it can be used to check the presence/breakage of any other type of
35 rotating element other than a rotating tool.

CLAIMS

1. Checking method for checking the presence of a rotating element (3), the checking method includes the steps of:

- obtaining a rotational frequency (RF) of the rotating element (3);
- directing a main electromagnetic radiation (9) towards the rotating element (3) by means of an emitter (8);
- receiving a reflected electromagnetic radiation (11) that has been reflected by the rotating element (3) by means of a receiver (10);
- collecting the reflected electromagnetic radiation (11) to determine a rough signal (S) to be analyzed;
- analyzing the rough signal (S) to verify whether the rough signal (S) includes a periodicity with a frequency corresponding to the rotational frequency (RF) of the rotating element (3); and
- determining that the rotating element (3) is actually present if the rough signal (S) includes a periodicity with a frequency corresponding to the rotational frequency (RF) of the rotating element (3);

the checking method is characterized in that it includes the further steps of:

- analyzing the rough signal (S) in the frequency domain; and
- determining that the rough signal (S) includes a periodicity with a frequency corresponding to the rotational frequency (RF) of the rotating element (3), if the frequency content of the rough signal (S) has predominant components at integral multiples of the rotational frequency (RF) of the rotating element (3).

2. Checking method according to claim 1 and including the further steps of:

- 5 - determining an exact rotational period of the rough signal (S) by means of an analysis in the time domain of the rough signal (S);
- cutting a part of the rough signal (S) as a function of the exact rotational period of the rough signal (S) in such a way that the cut rough signal (S) exactly includes a whole number of
10 complete rotations of the rotating element (3);
 and
- analyzing the cut rough signal (S) in the frequency domain.

15 3. Checking method according to claim 2 and including the further step of determining the exact rotational period of the rough signal (S) by means of an analysis in the time domain which is performed with a pitch detection algorithm.

20 4. Checking method according to claim 3 and including the further step of determining the exact rotational period of the rough signal (S) by means of an analysis in the time domain which is performed with a pitch
25 detection algorithm using the autocorrelation function AMDF (Average Magnitude Difference Function).

30 5. Checking method according to claim 2, 3 or 4 and including the further step of determining the exact rotational period of the rough signal (S) by searching for the exact rotational period within a search interval which is determined as a function of a nominal rotational frequency of the rotating element (3) and as a function of a variability range with
35 respect to the nominal rotational frequency.

- 5 6. Checking method according to claim 5 and including the further step of determining that the rotating element (3) can not be recognized and thus is not present if it is not possible to determine the exact rotational period of the rough signal (S) within the search interval.
- 10 7. Checking method according to any one of claims 2 to 6 and including the further step of decimating/expanding, by applying a resampling, the cut rough signal (S), before the analysis in the time domain is performed.
- 15 8. Checking method according to claim 7 and including the further step of decimating/expanding the rough signal (S) in such a way that the rough signal (S) includes a number of samples that is equal to a power of the number two.
- 20 9. Checking method according to any one of claims 1 to 8 and including the further step of applying a Fourier Transform to the rough signal (S) to move from the time domain to the frequency domain.
- 25 10. Checking method according to claim 9, wherein said Fourier Transform is a FFT (Fast Fourier Transform).
- 30 11. Checking method according to claim 9 or claim 10 and including the further steps of:
- determining the amplitude and the order of the harmonic with the highest amplitude; and
 - determining that the rotating element (3) is actually present if the order of the harmonic with the highest amplitude is an integral multiple of the whole number of complete rotations of the rotating element (3) included in
- 35 the rough signal (S).

12. Checking method according to claim 11 and including the further step of determining that the rotating element (3) is actually present if the order of the harmonic with the highest amplitude is an integral multiple of the whole number of complete rotations of the rotating element (3) included in the rough signal (S), and if, at the same time, the highest amplitude of the harmonic with the highest amplitude is higher than a first threshold value.
13. Checking method according to claim 9 or claim 10 and including the further steps of
- calculating a signal-to-noise ratio as a function of the whole number of complete rotations of the rotating element (3) included in the rough signal (S); and
 - determining that the rotating element (3) is actually present if the signal-to-noise ratio is higher than a second threshold value.
14. Checking method according to claim 13, wherein in calculating the signal-to-noise ratio all the amplitudes of the harmonics the order of which is an integral multiple of the whole number of complete rotations of the rotating element (3) included in the rough signal (S) are considered as useful signal, and all the amplitudes of the harmonics the order of which is not an integral multiple of the whole number of complete rotations of the rotating element (3) included in the rough signal (S) are considered as noise.
15. Checking method according to claim 13 or 14 and including the further step of calculating the signal-to-noise ratio as a fraction where the numerator is a sum of the amplitudes of the harmonics the order of

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which is an integral multiple of the whole number of complete rotations of the rotating element (3) included in the rough signal (S), and the denominator is a sum of all the amplitudes of the harmonics the order of which is not an integral multiple of the whole number of complete rotations of the rotating element (3) included in the rough signal (S).

16. Checking method according to claim 13 or 14 and including the further step of calculating the signal-to-noise ratio as a fraction where the numerator is a sum of the amplitudes of the harmonics the order of which is an integral multiple of the whole number of complete rotations of the rotating element (3) included in the rough signal (S), and the denominator is the difference between the sum of all the amplitudes and the numerator.

17. Checking method according to any one of claims 1 to 16 and including the further step of determining the length of the rough signal (S) as a function of the rotational frequency (RF) of the rotating element (3) in such a way that the rough signal (S) includes at least two complete rotations of the rotating element (3).

18. Checking method according to any one of claims 1 to 17 and including the further step of varying the sampling frequency of the reflected electromagnetic radiation (11) as a function of the rotational frequency (RF) of the rotating element (3) in such a way that the sampling frequency increases as the rotational frequency (RF) increases.

19. Checking method according to any one of claims 1 to 18 and including the further step of varying the number of complete rotations of the rotating element (3)

included in the rough signal (S) as a function of the rotational frequency (RF) of the rotating element (3) in such a way that the number of complete rotations of the rotating element (3) included in the rough signal (S) increases as the rotational frequency (RF) increases.

20. Checking apparatus for checking the presence of a rotating element (3) at a known or determinable rotational frequency (RF); the checking apparatus (6) comprises:

- an emitter (8) for directing a main electromagnetic radiation (9) towards the rotating element (3);
- a receiver (10) for receiving a reflected electromagnetic radiation (11) which has been reflected by the rotating element (3); and
- a processing unit (12) which samples the reflected electromagnetic radiation (11) to determine a rough signal (S) to be analyzed, analyzes the rough signal (S) to verify if the rough signal (S) includes a periodicity with a frequency corresponding to the rotational frequency (RF) of the rotating element (3), and determines that the rotating element (3) is actually present if the rough signal (S) includes a periodicity with a frequency corresponding to the rotational frequency (RF) of the rotating element (3);

the checking apparatus (6) is characterized in that

- the processing unit (12) analyzes the rough signal (S) in the frequency domain; and
- the processing unit (12) determines that the rough signal (S) includes a periodicity with a frequency corresponding to the rotational frequency (RF) of the rotating element (3) if the frequency content of the rough signal (S) has

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dominant components at integral multiples of the rotational frequency (RF) of the rotating element (3).

- 5 21. Checking apparatus according to claim 20, wherein said main electromagnetic radiation is a pulsed laser beam.