**Title:** A METHOD AND SYSTEM FOR MONITORING THE STATUS OF A TRANSMISSION MECHANISM

**FIG 1**

**Abstract:** The present invention discloses a method for monitoring the status of a transmission mechanism, comprising: generating a status monitoring curve using direct position information and indirect position information; identifying the current status of the transmission mechanism based on said status monitoring curve. In addition, the present invention also provides a system for monitoring the status of a transmission mechanism, comprising: a status monitoring curve generation module for using direct position information and indirect position information to generate a status monitoring curve; a status analysis module used to identify the current status of the transmission mechanism based on said status monitoring curve obtained by said status monitoring curve generation module. The technical solution provided by the present invention saves the cost for status monitoring and requires no additional installation space, eliminating any potential safety problems incidental to installation of sensors.
Description

A Method and System for Monitoring the Status of a Transmission Mechanism

Field of Invention

The present invention relates to the field of mechanical maintenance, and more particularly, to a method and system for monitoring the status of a transmission mechanism.

Background Technology

The transmission mechanism is a critical part of a machining tool such as a numerically controlled machine tool, especially the feeding system, including ball leading screw, guide, bearing connector and driving motors, which will have direct impacts on the machining precision of the machine tool. Any problem arising therewith such as wear, clearance and assembly error may lead to unacceptable products and unexpected mechanical damage, or even disastrous damage to the machine tool, thus incurring unnecessary additional costs. Therefore, it is very important to monitor the status of the transmission mechanism in a machine tool.

In the existing technologies, typical methods for monitoring the transmission mechanisms in machining equipment such as a machine tool rely on the added sensors such as vibration sensors, ultrasonic sensors, temperature sensors and oil quality analysis sensors, but these monitoring methods require additional sensor costs and space for installing the sensors. In addition, installation of sensors may cause damage to the structure of a machine tool.

Obviously, the status monitoring methods used in the existing technologies not only require additional costs but also entail safety concerns.
Description of Invention

The present invention provides a method for monitoring the status of a transmission mechanism on the one hand, and a system for monitoring the status of the transmission mechanism on the other hand for the purpose of saving costs.

The method for monitoring the status of a transmission mechanism of the present invention comprises:

- generating a status monitoring curve using direct position information and indirect position information;
- identifying the current status of the transmission mechanism based on said status monitoring curve.

Said identification of current status of the transmission mechanism based on the status monitoring curve is: comparing said status monitoring curve with the pre-generated status monitoring curve in normal status.

Said status monitoring curve is: a backlash distribution curve.

Said generation of a status monitoring curve using direct position information and indirect position information is:

- using the direct position information measured in turn at different distribution points in the course of movement of the transmission mechanism as the independent variables;
- using the difference between two lots of indirect position information, which corresponds to the same direction position information and is measured in two reserve motion directions in the course of movement of the transmission mechanism, as the function value corresponding to said direct position information;
using all independent variables and their corresponding function values to generate a backlash distribution curve.

Or, said generation of a status monitoring curve using direct position information and indirect position information is:

using the indirect position information measured in turn at different distribution points in the course of movement of the transmission mechanism as the independent variables;

using the difference between two lots of direct position information, which corresponds to the same indirect position information and is measured in two reserve motion directions in the course of movement of the transmission mechanism, as the function value corresponding to said indirect position information;

using all independent variables and their corresponding function values to generate a backlash distribution curve.

Said current status of the transmission mechanism comprises wear, erosion and break-off status of the engaging part of the transmission mechanism and/or status of a loose connection pair.

Said status monitoring curve is: a transfer function curve.

Said generation of a transfer function curve using direct position information and indirect position information is:

predefining the transfer functions of direct position information and indirect position information;

using the direct position information measured in turn at different distribution points in the course of movement of the transmission mechanism as the independent variables, or using the indirect position information measured in turn at different distribution points in the course of movement of
the transmission mechanism as the independent variables;

using all independent variables and their corresponding transfer function values to generate a transfer function curve.

Preferably, the method further comprises: using a signal processing method to separate the characteristic curve of the transmission mechanism from said monitoring curve;

executing said operation of identifying current status of the transmission mechanism based on said characteristic curve of the transmission mechanism.

Said signal processing method comprises: statistical analysis method, time sequence analysis method, fast Fourier transfer method, wavelet analysis method or empirical mode decomposition method.

Said current status of the transmission mechanism comprises any or any combination of manufacturing error status, assembly status, and wear, erosion and break-off status of the transmission mechanism.

The system for monitoring the status of a transmission mechanism of the present invention comprises:

a status monitoring curve generation module, which is used to generate a status monitoring curve by using the direct position information and indirect position information;

a status analysis module, which is used to identify the current status of the transmission mechanism based on said status monitoring curve obtained by said status monitoring curve generation module.

Said status monitoring curve generation module comprises:
a direct position information recording module, which is used to record direct position information measured in turn at different distribution points in the course of the movement of the transmission mechanism;

an indirect position information recording module, which is used to record the two lots of indirect position information, which is measured in two opposite directions in the course of movement of the transmission mechanism for each lot of direct position information and corresponds to the same direct position information;

a backlash calculation module, which is used to calculate the difference between said two lots of indirect position information corresponding to the same direct position information to obtain the backlash value corresponding to the direct position information;

a backlash curve generation module, which is used to generate a backlash distribution curve based on all direct position information and its corresponding backlash values and use said backlash distribution curve as the status monitoring curve of the transmission mechanism.

Or, said status monitoring curve generation module comprises:

an indirect position information recording module, which is used to record indirect position information measured in turn at different distribution points in the course of the movement of the transmission mechanism;

a direct position information recording module, which is used to record the two direct position information, which is measured in two opposite directions in the course of movement of the transmission mechanism for each lot of indirect position information and corresponds to the same indirect position information;

a backlash calculation module, which is used to calculate the
difference between said two direct position information corresponding to the same indirect position information to obtain the backlash value corresponding to the indirect position information;

a backlash curve generation module, which is used to generate a backlash distribution curve based on all indirect position information and its corresponding backlash values and use said backlash distribution curve as the status monitoring curve of the transmission mechanism.

Or, said status monitoring curve generation module comprises:

a direct position information recording module, which is used to record direct position information measured in turn at different distribution points in the course of the movement of the transmission mechanism;

an indirect position information recording module, which is used to record indirect position information which is measured in turn in the course of the movement of the transmission mechanism and corresponds to said direct position information;

a transfer function value calculation module, which is used to calculate the transfer function value corresponding to each direct position information or indirect position information based on the predefined transfer functions of direct position information and indirect position information respectively;

a transfer function curve generation module, which is used to generate the transfer function curve based on all direct position information and its corresponding transfer function values, or to generate the transfer function curve based on all indirect position information and its corresponding transfer function values, and use said transfer function curve as the status monitoring curve of the transmission
mechanism.

Preferably, between said status monitoring curve generation module and said status analysis module, the system further comprises: a characteristic curve extraction module used to separate the characteristic curve of the transmission mechanism from said status monitoring curve;

The status analysis module further identifies the current status of the transmission mechanism based on said characteristic curve of the transmission mechanism obtained by said characteristic curve extraction module.

From the solution described above, it is clear that the present invention generates a status monitoring curve by using direct position information measured by a direct measuring system and indirect position information measured by an indirect measuring system, and identifies the current status of the transmission mechanism based on the generated status monitoring curve. No sensors are required, thus saving costs for status monitoring, and no additional installation space is needed, eliminating any safety concerns incidental to installation of sensors.

Description of Drawings

The following will describe in detail the exemplary embodiments of the present invention with reference to the attached figures so that those of ordinary skill in the art will more clearly understand the above-described and other features and advantages of the present invention. In the attached Figures:

Figure 1 is an exemplary flow chart of the status monitoring method for a transmission mechanism in an embodiment of the present invention;

Figure 2 is a schematic diagram of a method for generating the backlash distribution curve in an embodiment of the
present invention;

Figure 3 (a) shows the backlash distribution curve of a transmission mechanism in normal status in an embodiment of the invention;

Figure 3 (b) shows the backlash distribution curve when the connection pair of the transmission mechanism shown in Figure 3 (a) is loose;

Figure 3 (c) is the backlash distribution curve when the transmission mechanism shown in Figure 3 (a) has a local wear;

Figure 4 (a) is a transfer function curve of a transmission mechanism with a major manufacturing error in an embodiment of the present invention;

Figure 4 (b) shows a transfer function curve of a transmission mechanism with a minor manufacturing error in an embodiment of the present invention;

Figure 5 (a) shows a transfer function curve of a transmission mechanism with a normal assembly in an embodiment of the present invention;

Figure 5 (b) shows a characteristic curve of a transmission mechanism separated from the transfer function curve shown in Figure 5 (a);

Figure 6 (a) is a transfer function curve of a transmission mechanism shown in Figure 5 (a) when eccentrically assembled;

Figure 6 (b) shows a characteristic curve of a transmission mechanism separated from the transfer function curve shown in Figure 6 (a);

Figure 7 is an exemplary diagram showing the structure
of the status monitoring system for a transmission mechanism in an embodiment of the present invention;

Figure 8 shows an internal structure of the status monitoring curve generation module in the system shown in Figure 7;

Figure 9 shows another internal structure of the status monitoring curve generation module in the system shown in Figure 7;

Figure 10 shows still another internal structure of the status monitoring curve generation module in the system shown in Figure 7.

Embodiments

In the embodiments of the present invention, monitoring is carried out without additional sensors by using position information of the transmission mechanism measured by the position measuring system in a numeric controlled machine tool.

In the machining equipment such as numeric controlled machine tools, a direct measuring system (DMS) and indirect measuring system (IMS) are a standard configuration. The IMS is usually installed at the starting position of a transmission chain, for example, for recording the transmission location information of the driving motor; the DMS is usually installed at the ending position of a transmission chain, for example, for recording the actual movement position information of the work table.

As a matter of fact, the position information measured by these two measuring systems contains a lot of status information of the transmission mechanism; therefore, if the position information measured by the direct measuring system is referred to as direct position information, and the position information measured by the indirect measuring system is re-
ferred to as indirect position information, a status monitoring curve can be generated with the direct position information measured by the direct measuring system and indirect position information measured by the indirect measuring system, and then the current status of the transmission mechanism is identified based on the generated status monitoring curve.

In order to make more apparent the purposes, technical solution and advantages of the present invention, the following further describes the present invention by referring to the drawings.

Figure 1 is an exemplary flow chart of the status monitoring method for a transmission mechanism in an embodiment of the present invention. As shown in Figure 1, the flow comprises the following steps:

Step 101, in which the status monitoring curve is generated using direct position information measured by the direct measuring system and indirect position information measured by the indirect measuring system.

This step can be embodied in multiple ways, and only two ways are illustrated below:

First method: backlash distribution curve.

In this method, in view of the fact that in a transmission mechanism, the position information measured in two opposite directions at the same point usually varies, i.e. there is a backlash, and the values of the backlash at different points (for example, different positions in the course of movement of the work table) are different, for example, when there is local wear in the transmission mechanism, the backlash measured corresponding to that local wear may be significant; furthermore, when the connection between the leading screw nut of the transmission mechanism and the work table is loose, the backlash value measured may also increase. There-
fore, in this step, a backlash distribution curve can be generated using direct position information measured by the DMS and indirect position information measured by the IMS and generated backlash distribution curve can be used as the status monitoring curve.

In an embodiment, the method of generating the backlash distribution curve may be: using the direct position information measured in turn by the DMS at different distribution points in the course of movement of the transmission mechanism as the independent variables; using the difference between two lots of indirect position information, which is measured in two reverse motion directions respectively in the course of movement of the transmission mechanism and corresponds to the same direct position information, as the function value corresponding to the direct position information; generating the backlash distribution curve by using all independent variables and their corresponding function values.

Or, the method of generating the backlash distribution curve may also be: using the indirect position information measured in turn by the IMS at different distribution points in the course of movement of the transmission mechanism as the independent variables; using the difference between two direct position information, which is measured by the DMS in two reverse motion directions respectively in the course of movement of the transmission mechanism and corresponds to the same indirect position information, as the function value corresponding to the indirect position information; generating the backlash distribution curve by using all independent variables and their corresponding function values.

As shown in Figure 2, Figure 2 is a schematic diagram of a method for generating the backlash distribution curve. In Figure 2, the direct position information measured by the DMS is used as a ruler, and a series of reference points are predefined on the ruler, such as Rk in Figure 2, wherein k=1,2,3,...,n. When the work table is moving in two opposite di-
rections, corresponding to a defined DMS reference point Rk, the IMS measures the indirect position information when the DMS measurement arrives at the defined reference point Rk. \( I_p,k \) shown in Figure 2 refers to the indirect position information measured by the IMS when the work table moves rightward (→) as shown in Figure 2, and \( I_m,k \) refers to the indirect position information measured by the IMS when the work table moves leftward (←) as shown in Figure 2. The difference between \( I_p,k \) and \( I_m,k \) measured corresponding to the same DMS reference point Rk, that is, the backlash value corresponding to that DMS reference point Rk, such as backlash 1, backlash 2, ..., backlash n shown in Figure 2.

Afterwards, the DMS reference point Rk can be used as the horizontal coordinates and the backlash value corresponding to the DMS reference point Rk can be used as the vertical coordinates to generate the backlash distribution curve. That is, the DMS reference point Rk is used as an independent variable and the backlash value of the corresponding DMS reference point Rk is used as the function value corresponding to the independent variable, and all the independent variables and their corresponding function values are used to generate the backlash distribution curve.

Second method: transfer function curve.

In this method, in view of the fact that there is a certain corresponding relation between the direction position information and indirect position information (for example, the rotation of the driving motor in the transmission mechanism is ultimately converted into movement of the work table), in this embodiment, a transfer function between the direct position information and indirect position information can be predefined. In this step, a transfer function curve is generated by using direct position information measured by the DMS and indirect position information measured by the IMS, and the generated transfer function curve is used as the status monitoring curve.
In an embodiment, a transfer function of direct position information measured by the DMS and indirect position information measured by the IMS can be predefined; the direct position information measured in turn by the DMS at different distribution points in the course of movement of the transmission mechanism or the indirect position information measured in turn by the IMS at different distribution points in the course of movement of the transmission mechanism is used as the independent variables; all independent variables and their corresponding transfer function values are used to generate the transfer function curve.

Wherein, the transfer function can be set based on requirements or experience, for example, the difference between direct position information measured by the DMS and indirect position information measured by the IMS, or the ratio or weighted calculation of the two can be used as the transfer function between the direct position information and indirect position information.

To plot the transfer function curve, the direct position information measured in turn by the DMS at different distribution points in the course of movement of the transmission mechanism or indirect position information measured in turn by the IMS at different distribution points in the course of movement of the transmission mechanism can be used as a ruler, and a series of reference points are predefined on that ruler. When the work table is moving at a constant speed in a direction, corresponding to the defined reference points, the transfer function values of the corresponding reference points are calculated sequentially. Next, the transfer function curve is generated with the reference points as the horizontal coordinates and the transfer function values of the corresponding reference points as the vertical coordinates. That is, the reference points are used as the independent variables and the transfer function values of the corresponding reference points are used as the function values for the corresponding independent variables, and all
the independent variables and their corresponding function values are used to generate the transfer function curve.

In addition, certain abnormal conditions of the transmission mechanism will cause significant changes in some signal components of the backlash curve or transfer function curve, for example, abnormal responses in certain frequency bands. With a signal processing method, these signal components relating to the abnormal status of the transmission mechanism can be extracted from the backlash curve or transfer function curve to form the characteristic curve.

By monitoring the changes of the characteristic curve, it is determined whether the transmission mechanism is in an abnormal state. Furthermore, the above two methods can also separate the characteristic curve of the transmission mechanism from the backlash curve or transfer function curve using a signal processing method, and identify the current status of the transmission mechanism based on the characteristic curve of the transmission mechanism. There are many signal processing methods including statistical analysis, time sequence analysis, fast Fourier transfer, wavelet analysis or empirical mode decomposition.

Step 102, which identifies the current status of the transmission mechanism based on the generated status monitoring curve.

In this step, considering the status monitoring curve being a backlash distribution curve, to identify the current status of the transmission mechanism, the wear, erosion, break-off status of the transmission mechanism and/or loose connection pair status are checked.

For example, Figures 3(a) to 3(c) are schematic diagrams of three backlash distribution curves of the same transmission mechanism. In Figures 3(a) to 3(c), the DMS positions (that is, direct position information measured by the DMS) are the
horizontal coordinates and backlash values corresponding to the DMS position points are the vertical coordinates.

Figure 3 (a) shows a backlash distribution curve of the transmission mechanism when in normal status; Figure 3 (b) shows a backlash distribution curve when the connection pair between the ball leading screw nut of the transmission and the work table is loose; Figure 3 (c) shows a backlash distribution curve when the transmission mechanism has a local wear.

By comparing Figure 3 (a) and Figure 3 (b), it is clear that overall the backlash values in Figure 3 (b) are bigger than those in Figure 3 (a). In Figure 3 (a), the mean value of backlash is around 0.0015mm, and the mean value of backlash in Figure 3 (b) is around 0.063mm. It is evident that the mean value of backlash is increased greatly, which means the connection pair of the transmission mechanism is loose. Therefore, in this case it is possible to check whether the connection pair is loose based on the backlash distribution curve.

By comparing Figure 3 (a) and Figure 3 (c), it is clear that the backlash distribution curve in Figure 3 (c) experiences a local abnormal fluctuation, and the backlash value in that part suddenly increases, but the fluctuation of the backlash distribution curve in Figure 3 (a) is smoother, which means the transmission mechanism shown in Figure 3 (c) has a local wear. Therefore, in this case it is possible to check whether there is a local wear based on the backlash distribution curve.

When the backlash distribution curve obtained has both of the conditions shown in Figure 3 (b) and Figure 3 (c), the transmission mechanism has both local wear and loose connection pair. Therefore, in this case it is possible to check whether there is a local wear and loose connection pair based on the backlash distribution curve.
In addition, considering the status monitoring curve being a transfer function curve, the current status of the transmission mechanism, for example, any or any combination of manufacturing error status, assembly status, wear, erosion and break-off status can be checked.

For example, Figures 4(a) to 4(b) are schematic diagrams of two transfer function curves of two transmission mechanisms respectively. In Figures 4(a) and 4(b), the DMS positions (that is, direct position information measured by the DMS) are the horizontal coordinates and the differences (transfer function) between the DMS position and IMS position corresponding to the DMS position points are the vertical coordinates.

Figure 4(a) shows a transfer function curve of the transmission mechanism with a major manufacturing error; Figure 4(b) shows a transfer function curve of the transmission mechanism with a minor manufacturing error.

By comparing Figure 4(a) and Figure 4(b), it is clear that, overall, the fluctuation of the transfer function curve shown in Figure 4(a) is bigger than that shown in Figure 4(b), wherein the fluctuation of the transfer function curve in Figure 4(a) is around 3.7µm, and the fluctuation shown in Figure 4(b) is around 2.0µm. It is apparent that the fluctuation of the transfer function curve shown in Figure 4(a) is significantly greater than that shown in Figure 4(b), which means the transmission mechanism has a manufacturing error. Therefore, in this case it is possible to check whether the manufacturing error of the transmission mechanism is acceptable based on the transfer function curve.

In addition, Figure 5(a) and Figure 6(a) are schematic diagrams of two transfer function curves of the same transmission mechanism respectively. In Figures 5(a) and 6(a), the DMS positions (that is, direct position information measured by the DMS) are the horizontal coordinates and the differ-
ences (transfer function) between the DMS position and IMS position corresponding to the DMS position points are the vertical coordinates.

Figure 5 (a) shows a transfer function curve of the transmission mechanism with a normal assembly; Figure 6 (a) shows a transfer function curve of the transmission mechanism eccentrically assembled.

By comparing Figure 5 (a) and Figure 6 (a), it is clear that, overall, the fluctuation of the transfer function curve shown in Figure 6 (a) is greater than that shown in Figure 5 (a). To make a further judgment, a signal processing method such as wavelet analysis may be used to separate the characteristic curve of the transmission mechanism from the transfer function curve shown in Figure 5 (a) and Figure 5 (b), as shown in Figure 5 (b) and Figure 6 (b), wherein Figure 5 (b) shows a characteristic curve of the transmission mechanism separated from the transfer function curve shown in Figure 5 (a); Figure 6 (b) shows a characteristic curve of the transmission mechanism separated from the transfer function curve shown in Figure 5 (a).

By comparing Figure 5 (b) and Figure 6 (b), it is clear that the fluctuation of the characteristic curve of the transmission mechanism shown in Figure 6 (b) is significantly greater than that shown in Figure 5 (b), which means the transmission mechanism is eccentrically assembled. Therefore, in this case it is possible to check whether the assembly of the transmission mechanism meets the requirements based on the transfer function curve or the characteristic curve separated therefrom.

In addition, if local abnormal fluctuation occurs in the transfer function curve or in the characteristic curve separated from the transfer function curve, it is possible to check the local wear status of the transmission mechanism based on the transfer function curve or the characteristic
curve separated therefrom.

If any two or three of the above situations occur, it is possible to check the respective failure as the case may be.

Further, in addition to the failure states illustrated above, other current states of the transmission mechanism can be checked based on the status monitoring curve, which is not further described herein.

Figure 7 is diagram showing an exemplary structure of the status monitoring system in a transmission mechanism in an embodiment of the present invention. Consulting Figure 7, the system comprises a status monitoring curve generation module 701 and a status analysis module 702.

The status monitoring curve generation module 701 generates a status monitoring curve using direct position information measured by the DMS and indirect position information measured by the IMS.

The status analysis module 702 is used to identify the current status of the transmission mechanism based on said status monitoring curve obtained by said status monitoring curve generation module.

In an embodiment, the status monitoring curve generation module 701 can be implemented in several ways. Several embodiments of the status monitoring curve generation module 701 are described below.

Corresponding to the first method described in Step 101 as shown in Figure 1, the status monitoring curve generation module 701 in the system can comprise, as shown by the real lines in Figure 8, a direct position information recording module 801, an indirect position information recording module 802, a backlash calculation module 803 and a backlash curve generation module 804.
The direct position information recording module 801 is used to record direct position information measured in turn by the DMS at different distribution points in the course of movement of the transmission mechanism.

The indirect position information recording module 802 is used to record two lots of indirect position information, which are measured by the IMS in two opposite movement directions in the course of movement of the transmission mechanism for each direct position information at different distribution points and is in correspondence with the same direct position information.

The backlash calculation module 803 is used to calculate the difference between said two lots of indirect position information, which is recorded by the indirect position information recording module 802 and is in correspondence with the same indirect position information, to obtain the backlash value corresponding to the direct position information.

The backlash curve generation module 804 is used to generate a backlash distribution curve based on all direct position information recorded by the direct position information recording module 801 and its corresponding backlash value calculated by the backlash calculation module 803, and use the generated backlash distribution curve as the status monitoring curve of the transmission mechanism.

Further, as shown by the dotted lines, between the status monitoring curve generation module 701 and the status analysis module 702, there is a characteristic curve extraction module 805, which is used to separate the characteristic curve of the transmission mechanism from the backlash curve generated by the backlash curve generation module 804. The status analysis module 702 further identifies the current status of the transmission mechanism based on said characteristic curve of the transmission mechanism obtained by the characteristic curve extraction module 805.
Or, as shown by the real lines in Figure 9, the status monitoring curve generation module 701 in the system can comprise: a direct position information recording module 901, an indirect position information recording module 902, a backlash calculation module 903 and a backlash curve generation module 904.

The indirect position information recording module 901 is used to record indirect position information measured in turn by the IMS at different distribution points in the course of movement of the transmission mechanism.

The direct position information recording module 902 is used to record two direct position information, which are measured by the DMS in two opposite directions in the course of movement of the transmission mechanism for each indirect position information at different distribution points and is in correspondence with the same indirect position information.

The backlash calculation module 903 is used to calculate the difference between said two direct position information, which is recorded by the direct position information recording module 902 and is in correspondence with the same indirect position information, to obtain the backlash value corresponding to the indirect position information.

The backlash curve generation module 904 is used to generate a backlash distribution curve based on all indirect position information recorded by the indirect position information recording module 901 and the backlash values which is calculated by the backlash calculation module 903 and corresponds to the indirect position information, and uses the generated backlash distribution curve as the status monitoring curve of the transmission mechanism.

Further, as shown by the dotted line, between the status monitoring curve generation module 701 and the status analy-
sis module 702, there is a characteristic curve extraction module 905, which is used to separate the characteristic curve of the transmission mechanism from the backlash curve generated by the backlash curve generation module 904. The status analysis module 702 further identifies the current status of the transmission mechanism based on said characteristic curve of the transmission mechanism obtained by the characteristic curve extraction module 905.

Corresponding to the second method described in Step 101 as shown in Figure 1, the status monitoring curve generation module 701 in the system can comprise, as shown by the real lines in Figure 10, a direct position information recording module 1001, an indirect position information recording module 1002, a transfer function value calculation module 1003 and a transfer function curve generation module 1004.

The direct position information recording module 1001 is used to record direct position information measured in turn by the DMS at different distribution points in the course of movement of the transmission mechanism.

The indirect position information recording module 1002 is used to record indirect position information corresponding to direct location information at different distribution points as measured in turn by the IMS during the movement of the transmission mechanism;

The transfer function value calculation module 1003 is used to calculate the transfer function values corresponding to each direct position information or indirect position information based on the predefined transfer functions of direct position information and indirect position information.

The transfer function curve generation module 1004 is used to generate a transfer function curve based on all direct position information measured by the direct position information recording module 1001 and the transfer function values, which
are calculated by the transfer function value calculation module 1003 and are in correspondence with the direct position information, or generate a transfer function curve based on all indirect position information measured by the indirect position information recording module 1002 and the transfer function values, which are calculated by the transfer function value calculation module 1003 and are in correspondence with the indirect position information, and use the generated transfer function curve as the status monitoring curve of the transmission mechanism.

In addition, as shown by the dotted line, between the status monitoring curve generation module 701 and the status analysis module 702 shown in Figure 10, there is a characteristic curve extraction module 1005, which is used to separate the characteristic curve of the transmission mechanism from the transfer function curve generated by the transfer function curve generation module 1004. The status analysis module 702 further identifies the current status of the transmission mechanism based on said characteristic curve of the transmission mechanism obtained by the characteristic curve extraction module 1005.

The specific implementation of the modules in the abovementioned systems can be identical to the steps of the method and flow shown in Figure 1 and is not further described herein.

With the above embodiments, it is clear that the technical solution of the present invention has the following advantages:

In the present invention, the current status of the transmission mechanism is identified using a status monitoring curve formed by status monitoring points along the entire length of the transmission shaft of the transmission mechanism (backlash value or transfer function value), enabling the curve to have characteristics that cannot be reflected by a single
status monitoring point and further use these characteristics to identify the current status of the transmission mechanism. Unlike the traditional monitoring methods, the present invention requires no sensors, saving costs of status monitoring, and does not need additional installation space, eliminating the safety concerns incidental to installation of sensors.

In specific implementation, this can be done by a status monitoring curve such as a backlash curve and a transfer function curve, wherein the backlash curve can reflect the failure of different parts on the transmission shaft of the transmission mechanism such as wear, erosion and break-off, or failure of the entire transmission mechanism such as a loose connection pair; the transfer function curve can reflect various ways of failure of the transmission mechanism such as eccentric installation and manufacturing error, and the backlash curve and its characteristic curve as well as the characteristic curve of the transfer function curve will not be affected by environmental factors such as temperature, hence the application is reliable.

In addition, since the technical solution of the present invention can reflect failure of different parts on the transmission shaft of the transmission mechanism and the traditional monitoring methods are not able to monitor failure of different parts on the transmission shaft of the transmission mechanism, the technical solution of the present invention can detect failure that cannot be detected by the traditional monitoring methods, for example, monitoring the severity of wear.

The above are only preferred embodiments of the present invention and are not intended to limit the protection scope of the present invention. Any modification, equivalent substitution and improvements falling within the spirit and principle of the present invention shall be covered by the protection of the present invention.
Claims

1. A method for monitoring the status of a transmission mechanism, wherein said method comprises:

   generating a status monitoring curve using direct position information and indirect position information;

   identifying the current status of the transmission mechanism based on said status monitoring curve.

2. The method as claimed in claim 1, wherein said identification of current status of the transmission mechanism based on the status monitoring curve is: comparing said status monitoring curve with the pre-generated status monitoring curve in normal status.

3. The method as claimed in claim 1, wherein said status monitoring curve is: a backlash distribution curve.

4. The method as claimed in claim 3, wherein said generation of a status monitoring curve using direct position information and indirect position information is:

   using the direct position information measured in turn at different distribution points in the course of movement of the transmission mechanism as the independent variables;

   using the difference between two lots of indirect position information, which corresponds to the same direction position information and is measured in two reserve motion directions in the course of movement of the transmission mechanism, as the function value corresponding to said direct position information;

   using all independent variables and their corresponding function value to generate a backlash distribution curve.
5. The method as claimed in claim 3, wherein said generation of a status monitoring curve using direct position information and indirect position information is:

using the indirect position information measured in turn at different distribution points in the course of movement of the transmission mechanism as the independent variables;

using the difference between two direct position information, which corresponds to the same indirect position information and is measured in two reserve motion directions in the course of movement of the transmission mechanism, as the function value corresponding to said indirect position information;

using all independent variables and their corresponding function values to generate a backlash distribution curve.

6. The method as claimed in any of claims 1-5, wherein said current status of the transmission mechanism comprises the status of wear, erosion, break-off and/or loose connection pair of the transmission mechanism.

7. The method as claimed in claim 1, wherein said status monitoring curve is: a transfer function curve.

8. The method as claimed in claim 7, wherein said generation of a status monitoring curve using direct position information and indirect position information is:

predefining the transfer functions of direct position information and indirect position information;

using the direct position information measured in turn at different distribution points in the course of movement of the transmission mechanism as the independent variables, or using the indirect position information measured in turn at...
different distribution points in the course of movement of the transmission mechanism as the independent variables; using all independent variables and their corresponding transfer function values to generate a transfer function curve.

9. The method as claimed in claim 3 or claim 7, wherein the method further comprises: using a signal processing method to separate the characteristic curve of the transmission mechanism from said status monitoring curve; executing said operation of identifying current status of the transmission mechanism based on said characteristic curve of the transmission mechanism.

10. The method as claimed in claim 9, wherein said signal processing method comprises: statistical analysis method, time sequence analysis method, fast Fourier transfer method, wavelet analysis method or empirical mode decomposition method.

11. The method as claimed in any of claims 1, 7, 8 and 10, wherein said current status of the transmission mechanism comprises: any one or any combination of manufacturing error status, assembly status, and wear, erosion and break-off status.

12. A system for monitoring the status of a transmission mechanism, wherein the system comprises:

a status monitoring curve generation module (701), which is used to generate a status monitoring curve by using the direct position information and indirect position information curves;

a status analysis module (702), which is used to identify the current status of the transmission mechanism based on said status monitoring curve obtained by said status monitoring curve generation module (701).
13. The system as claimed in claim 12, wherein said status monitoring curve generation module (701) comprises:

5 a direct position information recording module (801), which is used to record direct position information measured in turn at different distribution points in the course of the movement of the transmission mechanism;

10 an indirect position information recording module (802), which is used to record the two lots of indirect position information, which are measured in two opposite directions in the course of movement of the transmission mechanism for each direct position information and correspond to the same direct position information;

15 a backlash calculation module (803), which is used to calculate the difference between said two lots of indirect position information corresponding to the same direct position information to obtain the backlash value corresponding to the direct position information;

20 a backlash curve generation module (804), which is used to generate a backlash distribution curve based on all direct position information and its corresponding backlash values and use said backlash distribution curve as the status monitoring curve of the transmission mechanism.

14. The system as claimed in claim 12, wherein said status monitoring curve generation module (701) comprises:

30 an indirect position information recording module (901), which is used to record indirect position information measured in turn at different distribution points in the course of the movement of the transmission mechanism;

35 a direct position information recording module (902), which is used to record the two direct position information, which
is measured in two opposite directions in the course of movement of the transmission mechanism for each indirect position information and corresponds to the same indirect position information;

5 a backlash calculation module (903), which is used to calculate the difference between said two direct position information corresponding to the same indirect position information to obtain the backlash value corresponding to the indirect position information;

10 a backlash curve generation module (904), which is used to generate a backlash distribution curve based on all indirect position information and its corresponding backlash values and use said backlash distribution curve as the status monitoring curve of the transmission mechanism.

15. The system as claimed in claim 12, wherein said status monitoring curve generation module (701) comprises:

20 a direct position information recording module (1001), which is used to record direct position information measured in turn at different distribution points in the course of the movement of the transmission mechanism;

25 an indirect position information recording module (1002), which is used to record indirect position information which is measured in turn in the course of the movement of the transmission mechanism and corresponds to said direct position information;

30 a transfer function value calculation module (1003), which is used to calculate the transfer function value corresponding to each direct position information or indirect position information based on the predefined transfer functions of direct position information and indirect position information respectively;
a transfer function curve generation module (1004), which is used to generate the transfer function curve based on all direct position information and its corresponding transfer function values, or to generate the transfer function curve based on all indirect position information and its corresponding transfer function values, and use said transfer function curve as the status monitoring curve of the transmission mechanism.

16. The system as claimed in any of claims 13-15, wherein between said status monitoring curve generation module (701) and said status analysis module (702), the system further comprises: characteristic curve extraction modules (805, 905, 1005) used to separate the characteristic curve of the transmission mechanism from said status monitoring curve;

The status analysis module (702) further identifies the current status of the transmission mechanism based on said characteristic curve of the transmission mechanism obtained by said characteristic curve extraction modules (805, 905, 1005).
FIG 1

Generate a status monitoring curve using direct position information measured by the DMS and indirect position information measured by the IMS.

Use the generated status monitoring curve to identify the current status of the transmission mechanism.

FIG 2

DMS

<table>
<thead>
<tr>
<th>R1</th>
<th>R2</th>
<th>R3</th>
<th>Rn-1</th>
<th>Rn</th>
</tr>
</thead>
</table>

\[ \text{Reference points on the DMS} \]

\[ \text{\(\nabla\) Position of IMS in movement direction} \]

\[ \text{\(\Delta\) Position of IMS in movement direction} \]

IMS

\[ \text{Im1, Im2, Im3, Imn-1, Imn} \]

| Backlash 1 | Backlash 2 | Backlash 3 | Backlash n-1 | Backlash n |

\[ \text{Backlash in movement direction} \]
FIG 6A

Difference (mm)

FIG 6B

Difference (mm)

DMS position (mm)
FIG 7

701 Status monitoring curve generation module → Status analysis module 702

FIG 8

801 Direct position information recording module → 804 Backlash curve generation module → 805 Characteristic curve extraction module

802 Indirect position information recording module → 803 Backlash calculation module

FIG 9

901 Direct position information recording module → 904 Backlash curve generation module → 905 Characteristic curve extraction module

902 Direct position information recording module → 903 Backlash calculation module

FIG 10

1001 Direct position information recording module → 1005 Characteristic curve extraction module

1002 Characteristic curve extract module → 1003 Transmission function value calculation module → 1004 Transmission function curve generation module