CORPORATE CONDITION DIAGNOSTIC SYSTEMS FOR MACHINES AND EQUIPMENT

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Introduction.

High rates of maintenance and repair costs increase for machines and equipment stimulate rapid development of modern methods for design and production of unserviceable equipment and its parts as well as main equipment condition based maintenance technologies. Each of these technologies pays special attention to condition monitoring and long term condition prediction without disassembly of the equipment. A new direction formed recently in the science and technology "Machine Condition Monitoring and Diagnostics" (MCM&D) which deals with current condition monitoring, diagnostics, long term condition prognosis for machine's safe operation period, defects correction and specialized maintenance in field. Special solutions for the above tasks, special recommendations and international standards are being developed within this direction.

The standards recommend operating machines and equipment condition monitoring and prediction by processes values measured by integrated measurement instrumentation and by secondary processes parameters, for example, vibration, temperature, that are available for external measurement instrumentation. Besides a lot machines condition information can be obtained during its maintenance and certain non-destructive monitoring operations and during non destructive tests.

For a number of industrial plants condition based maintenance means is one of the main ways of costs decrease. To do this a condition monitoring and prediction should be conducted for all machinery and equipment within common technological process or a chain of linked processes. It can be done in formed and continuously developed united diagnostic system for the enterprise or corporation. The task for such a system is diagnostic information collection and generalizing as well as issuing standard reports on current and predicted condition for each machinery unit for the enterprise asset management (EAM) system.

Condition based maintenance technologies development goes in two opposite directions. The first one includes improving of CM features for newly designed equipment by embedding of sensors for working and secondary processes as well as integration of current condition estimation modules and algorithms in the automatic control and protection systems.

The second direction incorporates external diagnostic data collection and analysis systems development. Such data are collected from both embedded and external transducers as well as from other information sources of direct or indirect information on the monitored object condition. Corporate systems for condition monitoring and prediction are designed within this direction. All initial information, means and results of its analysis, current predicted condition estimation for the monitored equipment are gathered in this system.

Twenty years of Association VAST experience in development of methods and means for rotation equipment condition diagnostics by the vibration and drive motor current analysis shows that it is not economically efficient to integrate modern means of all processes measurement in the old equipment built in the previous century that had worked out most of its service life up to date. Detailed condition diagnostics for reliable long term condition prediction can be achieved by deeper analysis of the secondary processes in particular vibration and those working processes, for example, drive motor current, that can be monitored with external measurement devices.

Experience in functional diagnostics of machines that worked out most of its service resources and recommendation from ISO MCM&D standards became the basis of the new generation of measurement means and diagnostics software that can form a united enterprise condition monitoring and diagnostic system. Such a system structure being within the general provision and requirements of international standards, slightly differs from similar systems recommended for the enterprises that use mostly modern last generation equipment with integrated and combined control and condition diagnostics systems. It can be introduced at the enterprises that use technological

equipment of the previous generations continuously by several steps increasing the abilities of the system:

- equipment condition monitoring after maintenance and current condition monitoring on request of operating personal,
- periodic condition monitoring and condition prediction for auxiliary equipment (aiming in significant decrease of unscheduled stops of main and auxiliary equipment),
- continuous monitoring and periodic condition prediction for the main equipment,
- creation of united information collection center for enterprise assets condition information for repair planning and control at the enterprise.

Description of such systems abilities and main technical solutions used in such a system are presented below.

1. Input signals and data.

Volume of diagnostic information obtained by the condition monitoring and diagnostic system for each object should depend on the possible object failure consequences, maintenance costs, and residual service resource of the object. Often we observed situation when costs for monitoring have been increased for the auxiliary equipment because its failure may lead to significant losses due to consequential changes in technological processes.

Main equipment at the enterprises typical possess integrated working processes monitoring means that are used its protection. Its output data are not enough for detailed condition diagnostics and machinery save service life prediction. The corporate diagnostic system may require information on time, value and duration of processes values deviation from the acceptable levels zone. Such data can be obtained from the process control systems.

The combined control, protection and diagnostic systems are used in the latest generations of the main equipment. These systems detect current machine condition and use this information to optimize operation modes of the machine. At the same time these data and analysis depth are not enough for the condition prediction. These systems are used in the corporate diagnostic system to retrieve data on processes values deviation from acceptable parameters zone and on current process parameters of the equipment.

Most of the attempts to use raw data from the process control and protection system for the corporate diagnostic system fail. Two reasons for it can be mentioned. The first one is problem in interfacing communication of raw data from sensors to the diagnostic system. It requires approval of the control and protection system designers. The second and most often problem is insufficient technical characteristics of the control and protection sensors for purposes of detailed analysis diagnostics. That is why a typical case is when two measurement sensors are mounted on the same machine unit to sole two tasks – control and protection and condition diagnostics.

The lower installation costs of the process values transducer are for the current transformers (transducers). Drive motor or generator current posses a lot of diagnostic information not only for electric machines defects, but for the driven machines as well. Drive motor current is one of the most widely used diagnostic signals in the detailed diagnostic systems. Analysis of this current is done by specialized computer software within corporate diagnostic systems.

Among the secondary processes the most informative is vibration and acoustic noise. These signals are the sum of numerous components each of them is excited by its own source of oscillation forces and carry information on some specific machine unit condition. The most important analysis operation for vibration signals is detailed diagnostic systems is separation of all vibration components with no information loss. This task is most successfully solved in the machine and equipment condition diagnostics by vibration. Problems of separation for vibration components with different nature with further diagnostic analysis for each of them are solved by means (software programs) corporate diagnostic systems.

Analysis of infrared (IR) images of the monitored objects is another type of signal analysis within corporate diagnostic system. The most information can be retrieved from the special distribution of the IR emission sources on the object.

All other numeric measurement results for any parameters of the monitored object can be entered on the corporate diagnostic system database through the enterprise information network or directly from devices via standard data exchange protocols, or manually by an operator. The preferred data are those having information for acceptable levels zone in the database as well as and operation mode of the machinery during measurements. It allows monitoring of the parameters.
Data on the parameters monitoring – time of parameter deviation from acceptable levels, nondestructive tests results, qualitative estimations of the machine condition, or indirect information on defect development are entered in the corporate diagnostic system as a notes that can be used by experts for object condition estimation.
Thus the machine and equipment condition diagnostics and long term condition prediction in corporate system that does not require redesign of the monitored objects is based on deep analysis of drive motor current, vibration of machine parts, IR emission. Additionally the parameters that carry information on specific equipment types can be monitored when measured by existing transducers during machine operation with no need for disassembly..

2. Condition Monitoring.

The main task for object chosen parameters monitoring is detection of stable trends for parameter changes in time. The task for condition diagnostics is identification of reasons for such changes and prediction for further changes that allows switch from parameters monitoring to condition monitoring for the exact object.
The following aspects should be taken into account for condition monitoring and diagnostics of all existing machinery and equipment for united technological process: main reasons for near to failure condition development, possible consequences of failures, requires reliability of diagnostics results, acceptable costs.
Significant number of emergency situations occurs not due to natural wear and degradation of machinery parts, but due to admissive operation conditions violation. The most often reasons for such violations are operators mistakes, technological process control system failures, changes in external conditions such as temperature, building and basement condition for the diagnosed equipment, etc. In each practical case it is vital to determine the most probable cases for possible violations and provide methods to detect and transmit information about violations to the condition monitoring system.
In some cases data from the existing protection systems are used to monitor operation mode violations for one machine or for all machines in linked technological process. In other cases condition monitoring system incorporates means for continuous monitoring of a few predefined parameters of one or two machines most sensitive to operating modes violations. Most common parameter for such monitoring is vibration of heavily loaded machines and transducers installed are used simultaneously for vibration diagnostics tasks. Sometimes drive motor current is used as such parameter and detailed analysis of current is used for condition monitoring of drive motor, mechanical transmission and driven machine.
Vibration monitoring is one of the most efficient methods for near to failure condition detection for operating machines and equipment. But the less frequent are the measurements, the more tight requirements are set on the measurement precision and detection of external factors that influence on diagnosed objects operation. It is very difficult to obtain repeatable measurement results and thus reliable condition monitoring results with portable measurement instruments. That is why this task is commonly solved by installation of permanent transducers in the measurement points of the machinery. But stationary on-line condition diagnostic systems with several transducers on each machine are not only costly in manufacturing and installation, but maintenance and operation costs of such systems are high as well. For this reason such systems are used mostly only for the main and very important equipment.
On-line stationary vibration monitoring systems for main equipment can be equipped with temperature probes, integrated in the vibration sensor body, drive motor current transducers, other

parameters and the working process measurement instrumentation. The main task for such a system is detection and identification of reasons for vibration or most powerful vibration components increase more than on 25% compared to average values in the monitored units or the temperature increase on 5 degrees. The common task for drive motor current monitoring systems besides detecting the current increase is detection and identification reasons for current periodic fluctuation on more than 2%. For all other monitored parameters, and some times for the above ones, acceptable variation is set by the equipment manufacturers or different governing documents.
In many cases for condition monitoring of the equipment in reserve or auxiliary equipment the number of stationary installed transducers is decreased in the on-line condition monitoring system. Instead of a group of vibration transducers sometimes only one drive motor current transducer is used.
Most tasks on identification of reasons for monitored parameters dangerous increase detected by condition monitoring system is not that difficult. The reasons for parameters increase is violations in operation conditions of the machine registered by different methods. For the analysis of complicated situations experts can be invited. Experts may conduct additional diagnostic study of the object if necessary.
There are two main methods to use portable measurement systems for equipment and machinery condition monitoring with mounting transducers on the equipment only for the time of measurements. The first – utilizing the on-line stationary system algorithms with minimum possible intervals between measurements and conducting extended diagnostic measurements when some dangerous changes are detected. The second – conducting intermittent diagnostics studies of the equipment or machinery predicting the safe operation of it till the next diagnostic study. Medium variant is also possible – use of portable condition monitoring and diagnostic system for often monitoring measurements and more rare diagnostic measurement.
The first variant is most labor consuming, but it minimized the use of experts who are in deficit in most regions. Besides, efficiency and reliability of periodic condition monitoring decreases dramatically with the increase of time intervals between measurements. In the second variant it is vital to provide high reliability of condition prediction and it is possible to achieve it by increase of study volume and diagnostics depth. As a result the experts efficiency decreases with the increase of diagnostics costs. In the frame of the second variant the most prospective approach is design of automatic condition diagnostics software programs that replace experts in most common diagnostic tasks.

3. Diagnostics by set.

Diagnostics aimed on the long term condition prediction should be able to detect all typical defect types for the machinery on each stage of their development, including incipient defects. After detection defect development is monitored. It is possible to detect defects not only by analysis of defect symptoms development in time, but also comparing these parameters measured on several identical machines. Diagnostics based on this type of comparison is called “diagnostics by set”.
Success of diagnostics by set for powerful equipment is defined by two main factors: large number of independent information parameters for a number of working and secondary processes, especially vibration, and possibility to automate information processing and analysis. Automation of information processing by set allows eliminating limitations on the number of diagnostic symptoms for each defect, on one hand, and using common symptoms for several defects even when their sensitivity to different defects varies, on the other hand.
On practice it is sufficient to use three - four symptoms with different physical nature, but characterizing development of this very defect for each defect type. For example, let us consider the rolling surfaces defects in the bearing such as wear, cracks, spalls. These defects can be detected by low frequency rotor vibration, pulsating pressure in lubrication layer, and acoustical vibration of bearing unit exited by these pulsations; by shocks of rolling elements over the stationary bearing race destroying the lubrication layer and ultrasonic vibration excited by these shocks; by electric

conductivity of lubrication layer, by lubrication contamination; and by other methods. To decrease labor costs for diagnostics, it is recommended to select the group of methods requiring minimum number of diagnostic signals measurements in minimum number of points. For bearing diagnostics it is quite enough to measure only vibration signal in one point on bearing shield, but to use symptoms for defects found in low, acoustic and ultrasound frequency bands excited by oscillation forces of different nature.

Besides optimization of defect groups early detection of which is required for long term condition prediction for machine or equipment, and all combination of their defect symptoms it is necessary to define the defects thresholds that will split the whole machinery set to good and defective ones with different defect severities. It is possible to calculate the defect thresholds for each standard machine by means of independent statistical analysis on a group of identical machines for each of measured parameters what have quantity values. As it is nearly impossible to obtain a set of machines with identical links to other machines and working in identical modes, the route mean square deviations for diagnostic parameters from the mean values turn out to be rather high. That is why it is essential to choose the diagnostics parameters that are known to change greatly at least at some defect development stage for the particular defect than the statistical deviations on the set of identical machines.

The main advantages of the diagnostics by set is ability to built the diagnostic model with the defect levels thresholds separating good and defective objects immediately after diagnostic measurements on a small group (about 10 pieces) of objects, as well as possible diagnostics by portable systems immediately after the first measurement on an object. The described thresholds are defined by mean value for each of the monitored parameters and their deviations in the set. As the probability of same defects existence in all machines of the set is rather low, their influence on the mean value of the considered parameters can be minimized. On the initial stage of diagnostics by set application for the defects detection that are found by increase of several vibration components that are nearly absent in the good machines and appear with particular defects, we can suggest to use widely used thresholds – increase of vibration over mean value on 10dB (in three times) for alerting and on 20 dB (in ten times) for danger alarms.

Diagnostic by set methods are most widely used for the condition monitoring and prediction of the bladed machines (fans, blowers, compressors, pumps) with electric drive motor. Commonly diagnostics of electric machines by set is based on vibration analysis, but in some cases it is added by diagnostics by current of drive motor. Both types of signals possess complicated structure. Each of measured signal components may carry diagnostic information that contains in its power, frequency and shape. A lot of information can be found in non-linear interaction in the process of signal components formation. Non linear interactions, first of all modulation, take effect on the formation of oscillation forces that excite vibration. Vibration interacts with electromagnetic field of the electric machine and induces additional components in the electric current supplied to the motor. The most complex methods of signal separation of components with different origin and further component analysis are used to retrieve diagnostic information for diagnostics by set.

Diagnostic measurements are done 4-6 times a year by portable instruments on the typical machines operating in normal mode. Automatic condition diagnostic programs designed by a number of producers and based on diagnostic by set methods allows significant intensification of the experts efficiency as they process great amount of data and form expert estimation of the machine condition. An expert can just verify the automatic diagnostics results. Probability of missing dangerous defect when using the best automatic diagnostic system based on diagnostics by set methods is considerably lower than one percent and the time required for automatic diagnostics is significantly lower that time required for diagnostic measurements. Thus the annual costs of functional diagnostics and condition prediction for typical rotating equipment mostly working in one mode are pretty low and in rare case may approach 1% of the new equipment value.

4. Technical means of condition monitoring and diagnostic systems.

An evident link exists between detected defects severity found in the working equipment and required speed of decision making – the more severe defect found, the sooner object of diagnostics should be replaced or repaired. By this factor the condition monitoring and diagnostics means are divided into several categories – protection systems, condition based operation control systems, well developed defects detection systems, long term condition prediction systems. Besides special maintenance means are separated into additional group. They are used to support machine operation without deep disassembly for maintenance and repair.

Protection systems should provide alarm or switch off the equipment very fast – typically within one second. This time is not enough for any signal analysis of measured signal. That is why protection systems typically measure just main operation parameters and automatically switch off the equipment when deviation of the parameters exceed the programmed threshold level. Usually protection systems are integrated in the equipment on the equipment design stage.

Condition based control systems time for decision making is prolonged to several seconds. It allows monitoring of main parameters not only for working processes but some secondary processes as well, for example temperature and vibration of some machine parts. Besides at allows some analysis methods application for the signals that do not require long measurement time. The main peculiarity of condition based control systems are parallel measurements and analysis of different signals in several measurement points and extended dynamic range for measurements.

The most required condition based control systems produced by independent manufacturers are external danger alarming systems based on working and secondary parameters measurement that can be measured with no need for equipment and machinery redesign for transducers installation. Such processes are vibration, drive motor current, temperature of particular machine parts. In difference to integrated condition based control systems that are not capable for condition diagnostics and prediction tasks, the best available external condition based control systems can be extended from external alarming systems to condition diagnostics and prediction ones. But to do this the systems should be initially equipped with the transducers with extended characteristics and possess interface to diagnostic software programs.

Condition based control systems can be produced in both stationary and portable designs. Portable systems are most often used during startup service of the equipment to monitor the condition of the equipment that is not designed for often startups as such starts may significantly decrease the residual service live of the machine. Besides, such systems are often used by experts in machine commissioning for organization of feedback on machine condition during machine adjustment procedures. These systems consist of multichannel measurement device connected to computer network and a computer with installed software for monitoring machine condition in dynamic modes of operation. For example we can mention such a measurement device (fig. 1) by Association VAST, Ltd. Capable of simultaneous 8-channel measurements of vibration or drive motor current up to 50 kHz frequency range and up to 8 low frequency channels for temperature or other parameters. Additionally two rotation speed measurement channels are present. All measured data are transmitted to host computer via Ethernet network.

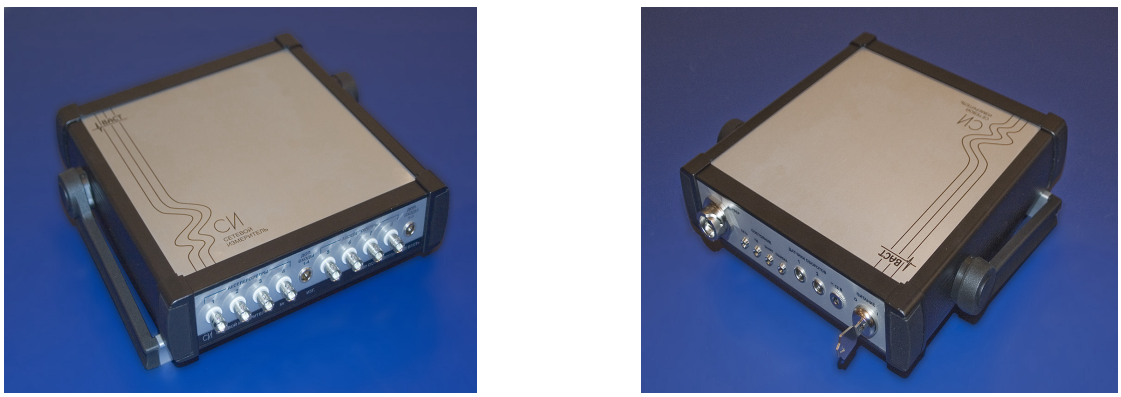

Fig. 1. Multichannel network measurement device for vibration, current, temperature, rotation speed measurements

Means for well developed defects detection and identification can be of stationary, portable and combined design. Defect identification is done prior to defective machine shut down, it allows planning of repair works according to actual machine condition. But the methods of defect identification differ significantly from methods based on periodic measurements or diagnostics by set. It defines the system configuration in its turn.
As usual each diagnostic system capable of defect identification includes portable measurement instruments. If we consider stationary online systems it is an often case that to identify defect type some additional measurements are required. These can be secondary process parameters measurements in different measurement points by portable vibration analyzers or IR cameras. In systems for well developed defects based on diagnostics by set method the main work is done by portable instruments and stationary permanent transducers can be used only n measurement locations with no access for temporary transducers installation during machine operation. There are no specific requirements for measurement instruments in the discussed systems and a number of manufacturers produce such monitoring equipment.
Requirements for measurement instrumentation for detailed condition diagnostic and long term condition prediction systems are much more sophisticated. It relates to both primary transducers including dynamic, frequency ranges, linearity, stability of specifications, and to types and depth of signal analysis conducted by integrated and external analysis software in digital domain. Since recently we see a tendency to install on the monitored equipment and machinery as stationary transducers for working and secondary parameters measurement only the devices capable for detailed diagnostic measurements. This approach allows at minimum cost to switch from danger alarming tasks protecting equipment from operators mistakes to in time detection of developing operation defects and long term condition prediction for monitored equipment.
The main peculiarity of the signal analysis for the detailed diagnostics systems is that there is no need for continuous measurements. Time interval between diagnostic measurements in portable diagnostic systems based on secondary parameters analysis is determined the period for safe operation time prediction and intervals between measurements may be up to 2-3 months. Single or dual channel vibration analyzers are most common instruments for vibration measurements. For IR imaging the IR cameras with 100[100 pixels resolution are suitable, besides, oil analysis instruments may be required. In the on-line stationary condition diagnostic systems the intervals between measurements can be decreased in several times down to several measurements per day. In the list of measurements several machine transient operation mode measurements can be included and the software program may require some additional data measured with portable instruments in additional measurement locations.
Commonly the software for deep diagnostic signals analysis are part of the condition diagnostic software programs, but not the measurement instrumentation and in this case measurement instrument for diagnostic signal becomes a converter of the analog signal to digital steam of data transferred via network to host computer for further processing and analysis, or as a digital signal recorder. In particular for transport vehicle equipment periodic recorders can be used for diagnostic signals collection. The data can be downloaded from these devices during vehicle maintenance in the depots. In many cases such data recorders can also function as danger alarming devices and signals can be recorded only is case of alarm.

5. Software program for a corporate condition monitoring and diagnostic system.

Software for corporate condition monitoring and diagnostic system should collect and provide complex analysis of all diagnostic information related to production means of the enterprise to manage its technical maintenance and repair according to its actual condition. The multiuser diagnostic software DREAM-5 is being designed in the Association VAST, Ltd. for a few years. The software design is based on the experience in design of automatic condition diagnostic systems and recommendation of the MIMOSA organization.

The basis of the software is ISO standard open database for collection and analysis of information required for maintaining of the machinery and equipment in operating condition. This database can contain not only diagnostic information, but all information related to maintenance and repair of the machines and equipment. All this information can be supplied to the EAM systems in standard compatible format.

Figure 2 presents the functional diagram of the DREAM-5 software. There are five subsystems in the DEAM-5 besides the database. The first is diagnostic objects description and requirements for gathered information (configuration subsystem). The second is data collection and basic analysis of the information. The third is data processing and collection of information and analysis results. The fourth visualization of data stored in the database and its transmission to other information systems. The fifth includes means of working with DREAM for outside users through Internet (Web server).

All basic subsystems work independently on each other retrieving information from common database and saving results in the same database. Besides the main subsystems the corporate diagnostic system may contain other additional subsystems that also work directly with the database of the software. For example, it can be protection and alarming subsystem presented on fig. 2.

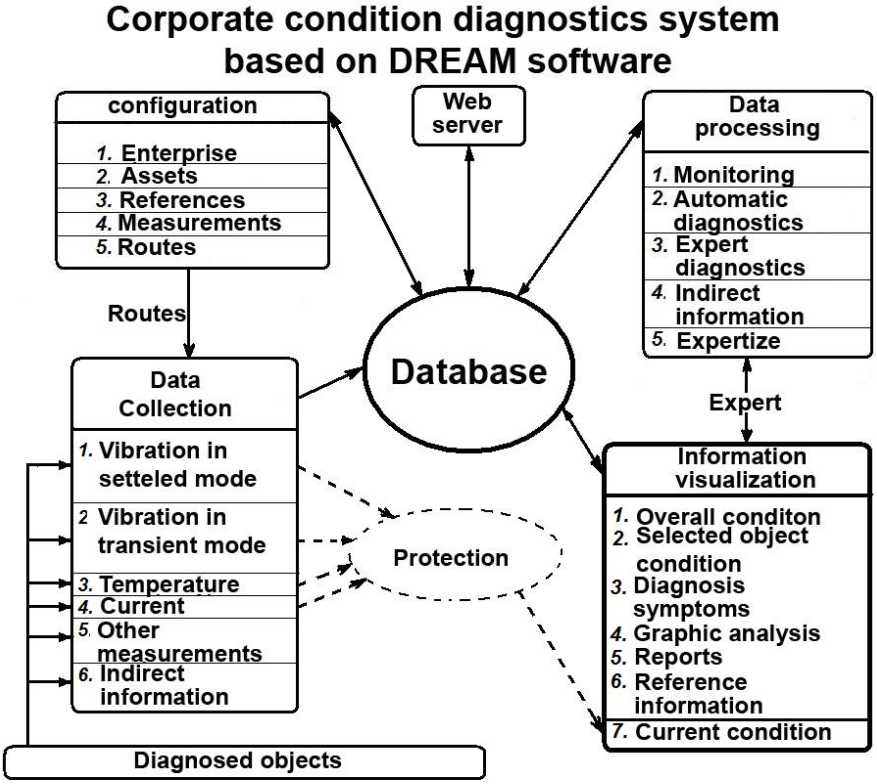

Fig.2. Structure of corporate MCM&D system, based on DREAM-5 software.

The first task of the configuration subsystem is entering in the database the data on the enterprise, diagnosed equipment and other reference information. The second task is description of measurement instrumentation used by diagnostic system and establishing links between measurement transducers and diagnostic objects. The third task in determining list and requirements for measurements foe each measurement location, including measurement types, measurement setup and periodicity of measurements. The subsystem operation results in setting up a route map for measurements in each measurement point and periodicity of measurements if there are no defects in the machines.

The main task of data collection subsystem is not only the initial information collection, but conditioning of these data, signal processing and presenting data to condition monitoring, diagnostics and prediction programs from the data processing subsystem. Basic structure of the data collection subsystem including stationary and portable measurement instrumentation is presented on fig.3.

According to MIMOSA organization recommendations, the main information for diagnostics and monitoring of the machines and equipment should be retrieved from working processes parameters of the machines and from such the secondary processes as diagnostic object vibration, thermal emission (or surface temperature), lubrication aging, and lubrication contamination with wear particles. It is possible to enter in the database particular parameters of monitored object retrieved in process of non destructive tests operations. Besides, the database can store indirect information, in particular visual inspection results for the machinery and equipment. Such information is entered in the database as comments.

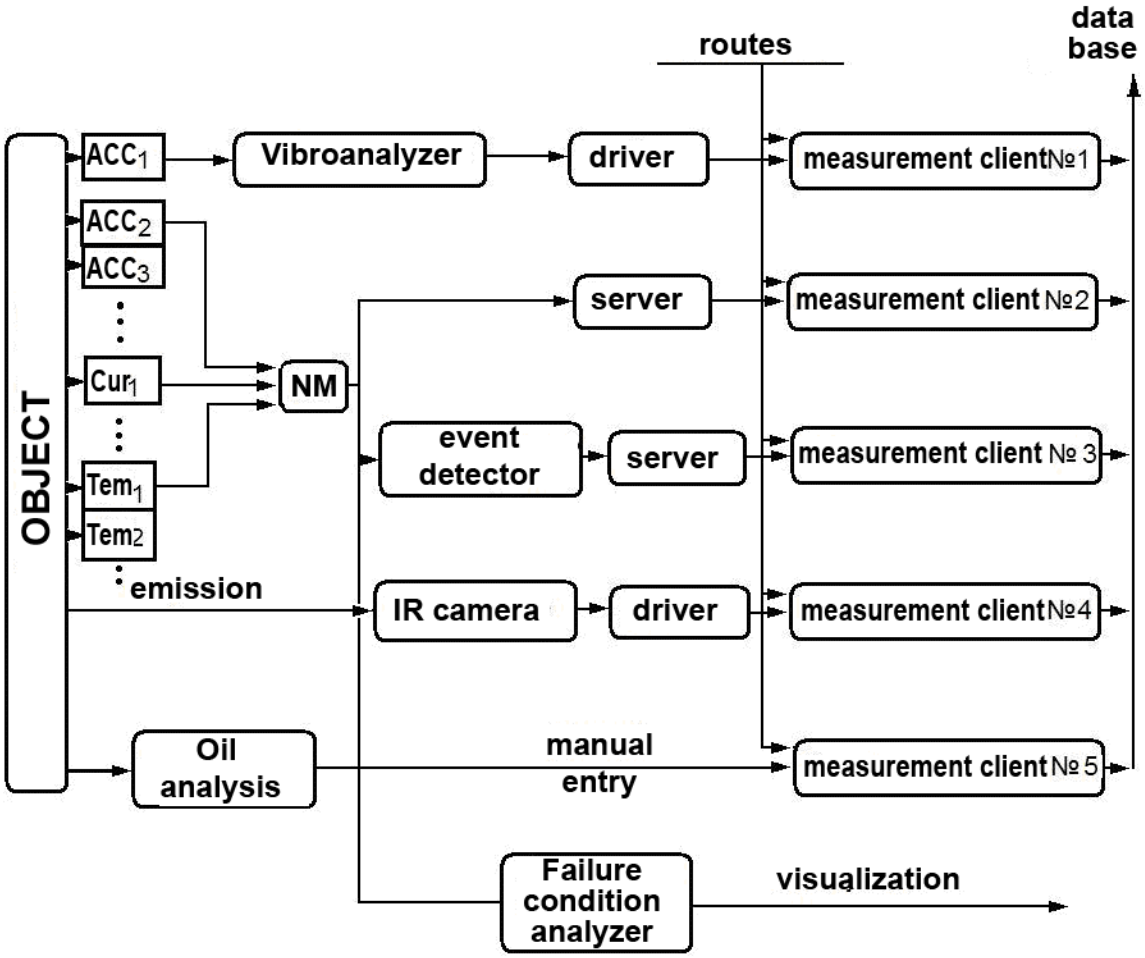

Fig.3.Sample of data collection subsystem of corporate MCM&D system.

For vibration measurement instruments that have only analog to digital conversion, but d not provide comprehensive signal analysis, the software possess signal analysis module (measurement server). It takes digital signals from any measurement instrument and processes them according to the tasks from route maps from the measurement client module.

If the diagnostic information should be retrieved from the transient processes in the monitored object and time of these processes is unknown in advance, it is possible to use the channel of the transient processes detection that will trigger the measurement server data recording and processing. Finally, for measurement of several characteristics of stationary processes, e.g. lubrication quality, when the measurement results are scalar values it is possible to enter them manually from the keyboard. Besides you can enter manually information on object service life, operation hours, data and volume of repair or maintenance works, comments of quality of that works, comments of quality of measurements, and on machine functionality.

Information processing subsystem solves all tasks on decision making related to condition monitoring of the objects, diagnostics and diagnosis verification, condition prediction. It defines measurement intervals for the particular machine units and for machine as a whole object.
The subsystem includes programs for levels thresholds calculation and setup for chosen diagnostic parameters, programs for comparison of measured parameters to set up thresholds, spectra processing programs, trending programs, and condition diagnostics by set programs.
Automatic and expert diagnostics programs are also included in the information processing subsystem. Automatic condition diagnostics of the machine or equipment units is done according to algorithms set by the software designers and expert diagnostics is done according to known algorithms that the customer can change (or add) to his own algorithms and decision making rules.
The task for expert diagnostics is condition estimation for the diagnosed object as a whole by condition monitoring and diagnostics data of its particular units and parts. The indirect information of machine or equipment condition should be taken into account as well. The responsibility for the reliable expert diagnostics lays on the expert that adapts the system to a particular equipment type, but not the designers of the system
If there is no expert diagnostic program available for the particular machine or equipment type or the efficiency of such program is very low, an expert can take this function on himself. If there is no enough diagnostic information to make a decision, the expert can order additional diagnostic surveillance of the object.
Data visualization subsystem presents the condition information on the enterprise manufacturing assets as a whole, or particular monitored objects, graphical presentation of he raw diagnostic signals, intermediate and final results of signal processing and analysis, data proving the diagnostic and condition prediction results, reports and reference information.
Experts in charge may work with the corporate diagnostic system via Internet once they have the access rights. Besides retrieving the required data on current and predicted condition of he machinery and equipment, an expert can get information to verify diagnostics, make orders on additional diagnostic measurements after that process data and store the corrected information in he database of the system.

Conclusions

Analysis of corporate MCM&D system on the example of VAST vibration and drive motor current analysis system allows the following conclusions:
1. It is not economically proved to use corporate CMS for old generation machinery in full mode including analysis of process values and diagnostic siglnals.
2. Corporate condition monitoring system can be introduced in the enterprise step by step. First solving tasks of periodic condition diagnostics of typical defects for standard equipment, monitoring of maintenance quality, on-line monitoring and off-line diagnostics of main machines' condition, and only on the last stage solving the task of condition based maintenance.
3. When ordering new measurement instruments it is recommended to pay special attention to compatibility of all instrumentation with MIMOSA international specifications. It will allow further building of the corporate system based on existing components.
4. Leading diagnostic centers and experts should be attracted to the work of introducing corporate diagnostic systems and its further support. A possibility of distance work with the corporate systems can be provided to these experts, they can also use this technology to train personnel and provide consultations in complicated cases, and help in decision making process in real time.