ZESZYTY NAUKOWE POLITECHNIKI ŚLĄSKIEJ 1987

Seria: MECHANIKA z. 86 Nr kol. 1012

XI OGÓLNOPOLSKA KONFERENCJA TEORII MASZYN I MECHANIZMÓW

11th POLISH CONFERENCE ON THE THEORY OF MACHINES AND MECHANISMS

27—30. 04. 1987 ZAKOPANE

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ON THE DIAGNOSIS OF THE SUPPORTING CAPACITY OF SPACE FRAMEWORKS

Summary. Large steel constructions (bridges, open cast excavators) have a unique character. The supervision of the state of these constructions demands the detection of defects which lead directly to a diminuation of the supporting capacity. This means a supervision of the stiffness behaviour of the system. One possibility forms the vibration analysis with an evaluation of the calculated natural frequencies of the system by means of the simulation results at a model.

Experimental results are presented.

1. Motivation

The considerations are related to the assessment of the state of large steel constructions, as for instance bridges in traffic communication or large machines in the lignite extracting industry (excavator, stacker). These constructions underlie a corrosion process by environmental influences as well as a more or less defined forces by their utilization conditions (ambient and transient loads).

Changes in the structure which can have direct effects on the system state can be explained by this. The detection and evaluation of these changes in structure are made at present in general by visual inspection under inclusion of ndt-methods. The task of the consideration consists in the development of diagnostic methods which diminish the high physical expense as well as the time of inspection.

2. Task and method of diagnosis

The aim consists in the detection of changes in structures, which are caused by existing defect states and lead to a decrease of the supporting capacity. This can lead to danger for the safety in operation and for the labour safety.

A change in the supporting capacity of the object under diagnosis means from the view of the applied mechanics a decrease in the total stiffnes of the structure.

Stiffnes changes are experimentally detectable by measurement of the static deformation behaviour as well as by the measurement of dynamic characteristic values of the system, e.g. natural frequencies.

The analysis of the vibration behaviour of mechanical systems for the purpose of the state asessment is a widespread, wellknown method.

Each diagnosis statement demands a comparison to evaluation measurement of a defined referred to state. Therewith, only a deviation can be detected. But, often an information on place and kind of the defect is important. This demands a problem adapted diagnosis model.

Further on, the natural frequencies of the system constitute diagnostic characteristics.

3. Diagnosis model

Since the considered diagnosis objects are unique constructions, the experimental possibility of the winning of diagnosis characteristics for typical damages by measurement of dynamic quantities and their signal analysis exist no longer.

This requires a system description with parameters corroborated by experimental results and sufficiently exact for the purpose of diagnosis.

Linear statements with very light damping and time-independent parameters, which directly correspond to the elements in question (e.g. beams in space frames) are used in the model formation to the mentioned constructions.

Simulation calculations permit the determination of the dynamic system characteristics for the defined reference state as well as for selected damages. The selection of damages is subjected to the diagnosis engineer, whereby the principle of completeness is excluded.

The modelling of such complex structures is not without any problems and requires a considerable expense in the computer simulation (cpu-time, memory requirement).

For the diminuation in expense and costs the utilization of special modelling technologies is necessary. Therefore methods of substructure investigation [1] and dynamic structural reanalyse techniques [2] can be used.

In the results of the simulations the system characteristics dependent on the defects are to be found, which are summarized in a special kind of demonstration (matrix of symptoms). Such a matrix contains, for instance, labelling of the defect in a line of the first column and in the following columns the attached natural frequencies. Examples are shown in [3] - [5]. Therewith a catalogue of patterns is at the disposal, which permits to evaluate experimentally determined characteristics of the topical state of the system.

The results of the theoretical simulation considerations were already published before [1], [2].

It is known that the objects of investigation are distinguished by low natural frequencies. Hence, for the case of structural modifications (changes of system behaviour) a very small amount of natural frequence changing follows.

The investigations confirm that in the reference indicated drifting effect of natural frequencies ranges from 0.1 to 0.01 cps for such steel constructions (e.g. off-shore-platforms.

4. Experimental investigations

The usability of natural frequencies of mechanical systems as diagnosis characteristics is as a matter of principles corroborated. But practical application requires some special demands for system exitation, measurement and signalanalytic measured value processing. Actually for the simplification of the diagnosis technology it is desirable to use the ambient loads based on the normal working conditions. Otherwise special test loads are necessary.

The applied measurement technique must acquisite the interesting frequency range in a sufficient sensibility. Other condition is an adequate resolution power by the applied methods of signal analysis. These two last statements are directly related to the hardware, which can be investigated at once.

The following two examples used vibration transducers and exciters from "robotron Messelektronik", tape recorder B&K 7004 as well as own software solution of frequency analizer based on the microprocessor-system MPS 4944 (academy of science GDR). This frequency analysing system realizes sampling frequencies in a range of 105 cps to 8323 cps) with memory of 16 Kbyte. The description is given in [5].

The examples demonstrate, that only massive damages in large steel construction can be detected by vibration measurements.

1. Example: cantilever beam

The object of study was a cantilerer beam fixed at the end (rectangular section) with an increasing depth of incision. At given stages of the incision process the dynamic response was recorded by action of an impulse load. The results are to be seen in Fig. 1. The figure demonstrates the significant peaks of the topic power spectrum dependent on the depth of incision.

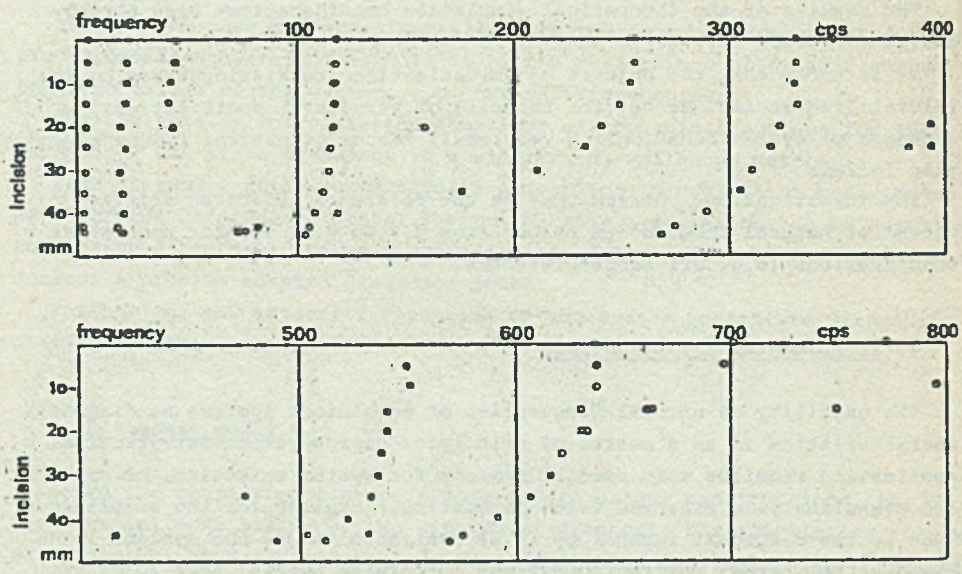

Fig. 1

For the shown frequency range (0...800 cps) the evaluation technology reached only a solution in 2-cps-steps. Due to it the drifting of frequencies dependent on damage can be shown only in the higher frequency range.

Theoretical researches allow to state that the higher natural frequencies react more sensitively on a damage process (e.g. incision).

2. Example: outrigger of a excavator

Figure 2 presents the object of investigations. The outrigger was stationary excited by electrodynamic vibration exciter ("white noise") with a relatively low power in a proportion to dead weight of the object.

The system response was measured at several nodal points of the space framework. In the sequence of the experimental research the framework was massively modified (parts of the space framework are incised and taken out) in 13 steps. An influence of incision on detected by the supporting capacity-changing could not be measurement of the static deformation.

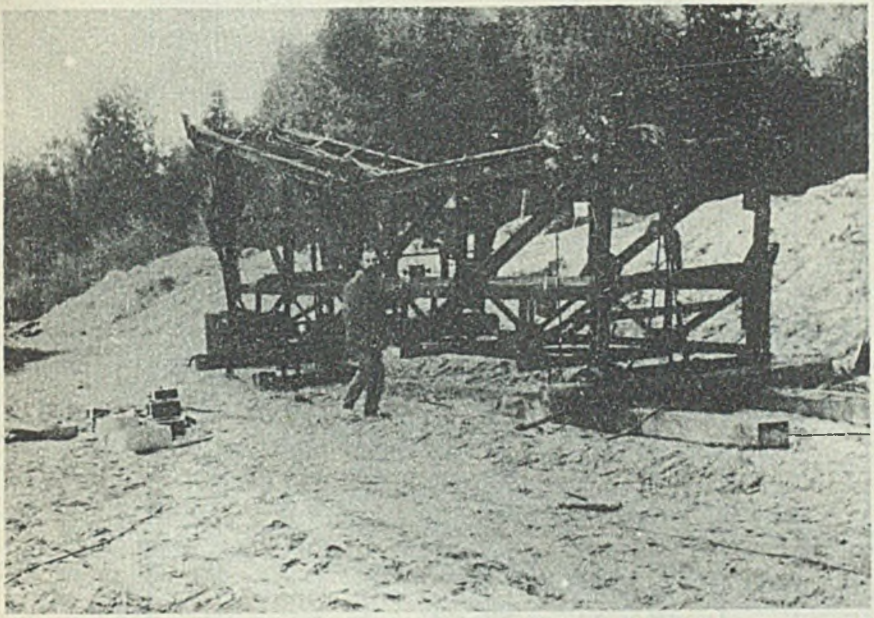

Fig. 2

The dynamic measurements are analized because of theoretical considerations in several selected ranges of frequency, where they depend on the strategy of analysing the finest solution of the power spectrum (0.1-cps-steps) were reached in a low frequency range (0...50 cps).

The effect of frequency-drifting in the measurement results dependent on structural modifications is clearly demonstrated in a selected frequency range of 0...14 cps.

A comparison in this range for the state of reference 0 (upper line) with an intermediate stage VI (middle line) and the end of the structural modification XIII (lower line) is shown in Fig. 3 and clearly demonstrates the drifting effect.

5. Conclusions

Observation of natural frequencies is a suitable diagnosis method to assess the topical supporting capacity behaviour on large steel constructions. This statement confirms theoretical and experimental researches. Open for such a method is the problem of sensitiveness. These means to reply the question, which degree a damaging process must reach, that the defect interrelated with that can be recorded by vibration analyzis. The

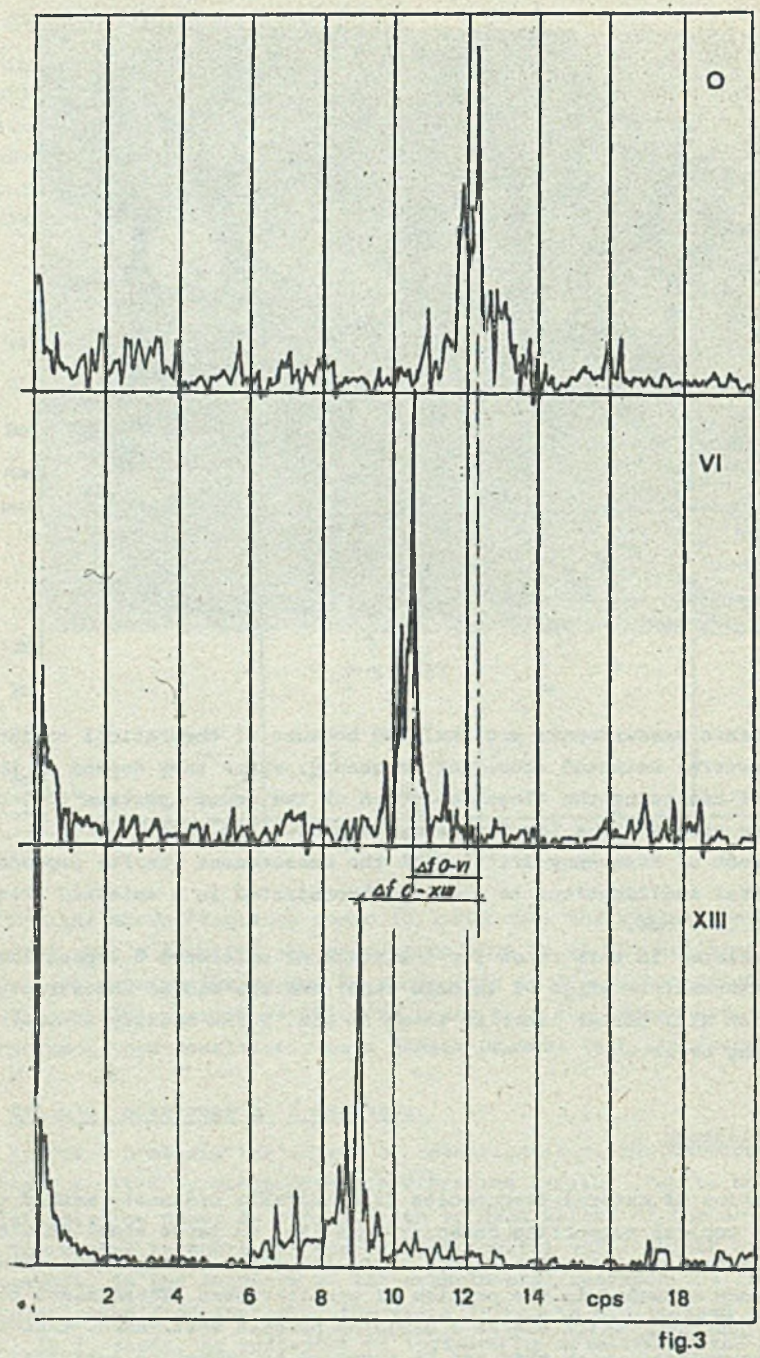

Fig. 3

statement very much depends on the avaible hardware for measurement and signal analyzis.

By a continuous observation of the system state exists a possibility to record the time-dependence of the process of damage.

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O DIAGNOZOWANIU NOŚNOŚCI KRATOWNIC PRZESTRZENNYCH

S t r e s z c z e n i e

Duże konstrukcje stalowe (mosty, koparki w górnictwie odkrywkowym) są specyficznymi obiektami badań. Diagnostyka stanu takich układów polega na wykrywaniu defektów, bezpośrednio wpływających na obniżenie nośności badanej struktury. W szczególności nadzór diagnostyczny może dotyczyć detekcji zmian sztywności obiektu badań. Jeden z możliwych sposobów określenia zmiany sztywności polega na wykrywaniu "płynięcia" częstości drgań własnych układu z zastosowaniem technik analizy drgań. W artykule pokazano możliwość zastosowania dla wymienionego celu badań modelowych i przedstawiono wybrane wyniki eksperymentalne.

ДИАГНОЗИРОВАНИЕ ГРУЗОПОДЪЁМНОСТИ ПРЕДЕЛЬНОЙ НАГРУЗКИ ПРОСТРАНСТВЕННЫХ ФЕРМ

Р е з ю м е

Большие стальные конструкции (мосты, карьеры) являются специфическими объектами исследований.

Диагностика состояния таких систем основана на обнаружении дефектов, непосредственно влияющих на снижение грузоподъёмности предельной нагрузки исследуемой структуры.

Диагностический надзор в особенности касается дефектирования изменений жёсткости объекта исследований.

Одни из возможных способов характеристики изменений жёсткости основывается на обнаружении "текущей" частоты собственных колебаний системы с применением техники анализа колебаний.

В статье показана возможность применения моделей в исследовании испытании для вышеуказанной цели и представлены избранные экспериментальные результаты.

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Wpłynęło do redakcji 12.III.1987 r.