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MONITORING OF TECHNICAL STATE OF TECHNOGENIC UNSAFE PIPELINES

Introduction

One of the tasks in securing an accident-proof operation of main pipelines is monitoring of their stressed state. Some pipelines could transport substances unsafe as for the environment, so for engineering objects and infrastructures. In Ukraine, for instance, the ammonia pipeline only has an extension of about 1000 km. Taking into account additional risk factor from present military activity, the problem of transportation via pipeline systems and environmental safety parameters improvement are important tasks that require an urgent solution.

During operation the stresses in pipes vary as a result of influence of mechanical factors (ground shifting, water flows, seasonal climate changes etc.). The most pressing task is to control the technical state of the most hazardous zones of the pipelines – transitions across rivers, highways, railways as well as those located close to settlements.

These zones usually bear greater loads and in the same time in case of pipe failure and product leakage the ecological damage increases significantly.

It is close to impossible to take into consideration all operation loads and unpreventable deviations during construction, not to mention special processes occurring in structures older than ~25 years [1, p. 3–12]. Of course, designing methods are being continuously upgraded, so one may assume the newest pipelines to have very good degree of adjacency of static and temporal continuous loads during structure operation to ones used to design the structure. However, for short-term loads such adjacency is considered to be lower (good), for special ones it is no higher than acceptable. For the pipelines being in operation for 25+ years this characteristic (adjacency) can be assumed to be acceptable for static and temporal continuous loads,

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while for the other types of loads it is close to unsatisfactory [2, p. 11–14].

All above makes the development of methods and systems for in-service monitoring of the technical state of main pipelines an important task which involves not only development of measuring devices [3, p. 295–302], but also methods of identification of potentially hazardous areas [4, p. 352–360] and data transferring systems as well [5, p. 4763–4769; 6, p. 264–273].

A common approach to data processing includes application of artificial intelligence instruments which are rather effective for quality evaluation and prediction in metal structures' production [7, p. 31–38; 8, p. 88–93].

Objectives

The paper gives detailed description of the flexible system for monitoring of stressed state of main pipelines (hereinafter referred to as *system*)

System description

Research performed in the "Igor Sikorsky Kyiv Polytechnic institute" showed the effectiveness of the sensors operating on the basis of magneto-anisotropic effect for such systems [9, p. 48–51].

The method is based on the phenomenon of changes in the magnetic properties of metals under the influence of mechanical stresses and strains. Such measuring systems have shown themselves well for stationary conditions — when sensors are mounted on the structure and the measurement is performed periodically without sensors being moved (for example, there is no need in scanning the structure or there is no hard limit on the measurement time) [3, p. 295–302].

The system for monitoring mechanical stresses in pipelines was developed as a five-level-structured one:

– the 1st level — single-channel non-autonomous system with mobile measuring device;

– the 2nd level — multi-channel stationary non-autonomous system with mobile measuring device;

– the 3rd level — multi-channel stationary non-autonomous system with mobile information pickup device;

– the 4th level — multi-channel stationary autonomous system with discrete data storage device;

– the 5th level — automated multi-channel stationary autonomous system.

Detailed System Description

Here the detailed description of each system level is presented.

The 1st level – single-channel non-autonomous system with mobile measuring device (Fig. 1) includes: single-channel mobile device (for example, a measuring instrument for mechanical stresses MESTR), sensor (4-poled magneto-anizotropic transformer); software (SW1) allowing to draw stress diagrams in the pipe cross-section. The 1st level system is aimed to be used in stationary conditions as well as for local measurements.

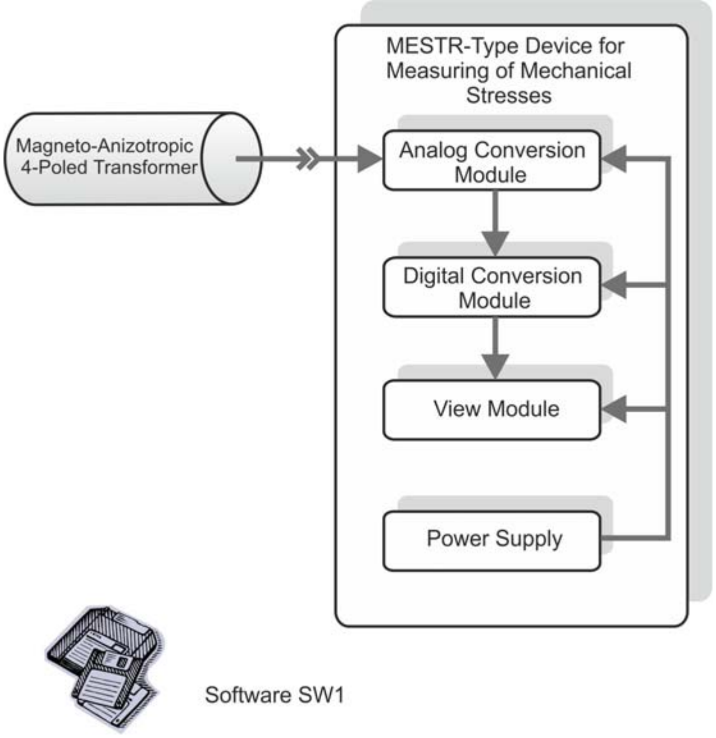

Fig. 1. 1st level monitoring system

The 1st level system allows:

– to evaluate working stresses during pipeline operation and to locate the most stressed zones;

– to perform pre-production experiments aimed to choose technology of assembling, welding, post-welding treatment for minimizing post-welding tensions and deformations;

– to evaluate stressed state during structure construction and repairing as well as to choose an optimal technology of construction and repairing;

– to locate zones on the pipeline with the highest stresses where stationary systems should be placed in future.

The system allows to perform manual measurement on any accessible place on the pipeline — in the wells, during preventive maintenance with and without excavation. Such system is reasonable for use during pipeline maintenance and as in-service inspection instrument if the required number of measurements per year does not exceed a couple of hundred.

The 2nd level — multi-channel stationary non-autonomous system with mobile measuring device (Fig. 2) includes: measuring device, sensors and software SW1 (same as for 1st level) and a switching unit. Ideology of the 2nd level is the same as for the 1st and they are fully compatible. The sensors are placed on particular zones of the pipeline and periodical data collecting from them is performed through switching unit.

Unlike the 1st level, sensors remain stationary during the whole period of system operation, not only during one measurement.

It is essential to ensure data identification for the 2nd level: the scheme of sensors' placement should be developed prior to system mounting on the pipeline, each sensor should be assigned with a unique ID.

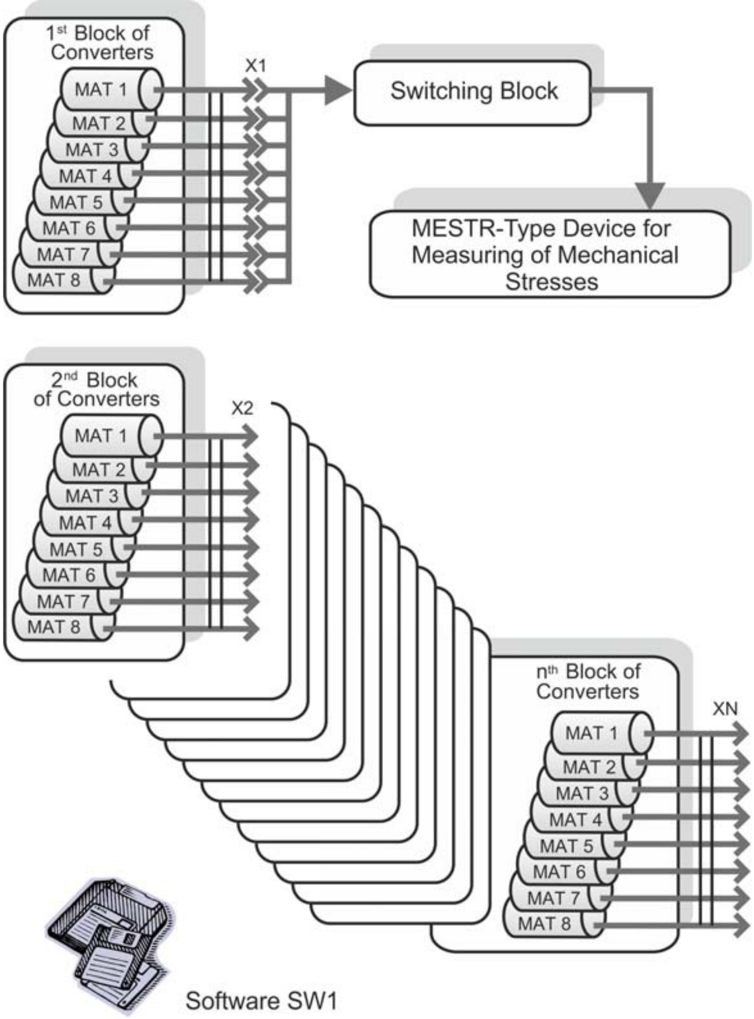

Fig. 2. 2nd level monitoring system

To collect data operator uses mobile device, no remote data transmission is performed. The sensors can be placed on the open zones of the pipeline, including underground ones. In this case an output with a socket for data collecting device should be brought on the surface.

Limitations for the 2nd level are those related to time of measurement and requirements to relocation of sensors. The 2nd level is good for zones with continuously high hazard, those requiring control in particular time (seasonal changes, landslides, washing out etc.). Estimated number of measurements per year for the 2nd level is around one to several thousands.

The 3rd level — multi-channel stationary non-autonomous system with mobile information pickup device (Fig. 3) allows to increase significantly system performance and number of sensors as well as the information value of the system as a whole. The 3rd level includes sensors, universal measuring device (UMD), mobile data pickup device and advanced software SW2 (different from SW1).

The 3rd level theoretically allows to place unlimited number of UMD's on the pipeline. The sensors are placed stationary and the operator uses an external data collecting device to obtain data from each UMD separately. Collected data are transferred to the mobile device and are proceeded with the SW2 software. Later they can be transferred to local or global servers if needed.

The 3rd level is good if the estimated number of measurements per year is up to 100000 and can be easily upgraded to levels 4 and 5.

The 4th level — multi-channel stationary autonomous system with discrete data storage device (Fig. 4) — is the same as level 3 with additional blocks of controller and repeater. Software used for level 4 is SW2.

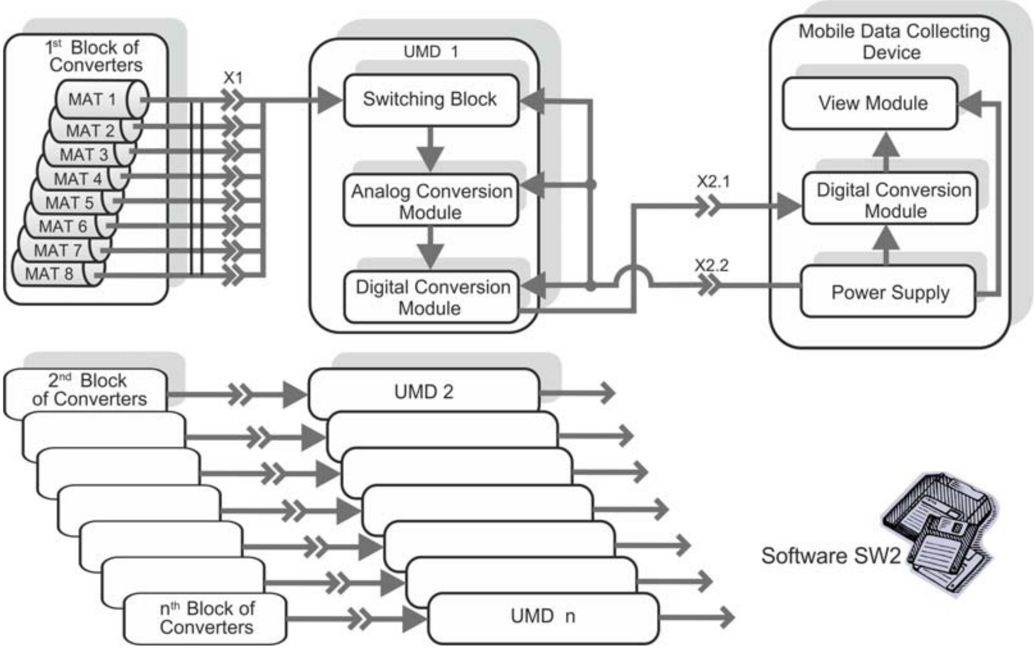

Fig. 3. 3rd level monitoring system

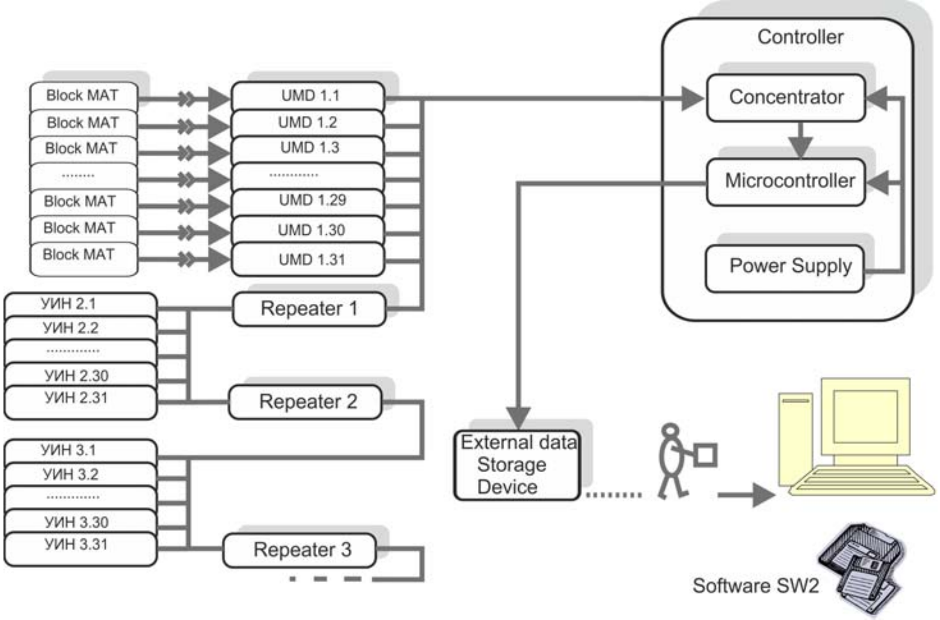

Fig. 4. 4th level monitoring system

Block of Controller allows to connect any desired number of UMD's to one dataline and to collect information from sensors in one node. Mobile PC can be connected anytime to the system for recording all information about measurements needed. Sensors, UMD's and repeaters are placed stationary on the structure.

4th level is good if hundreds of thousands of measurements per year are required. 4th level system can be easily upgraded to level 5, the only difference between them being application of means of automation of data transfer and processing. The system can operate fully autonomously.

The 5th level — automated multi-channel stationary autonomous system (Fig. 5) — is based on 4th level. The data are automatically transferred through communication channels to local and global servers.

5th level's full automation of monitoring of stresses in pipeline allows to analyze the state of potentially hazardous zones in real time without any limitations in operator's location and allows to perform millions of measurements per year.

The developed system of monitoring of stressed state of pipelines is flexible, it's structure can be optimized for each object of monitoring taking into account potential hazards and cost of each measurement. Though the system itself is not limited in quantitative and qualitative composition of levels being used simultaneously (basically, one can use any combination of system levels to fit the requirements), authors would like to emphasize that each level does has its own economical utility (Fig. 6). It was already mentioned that inter-level upgrades are possible: the 1st level can be upgraded to the 2nd; the 3rd — to 4th or 5th and the 4th to 5th.

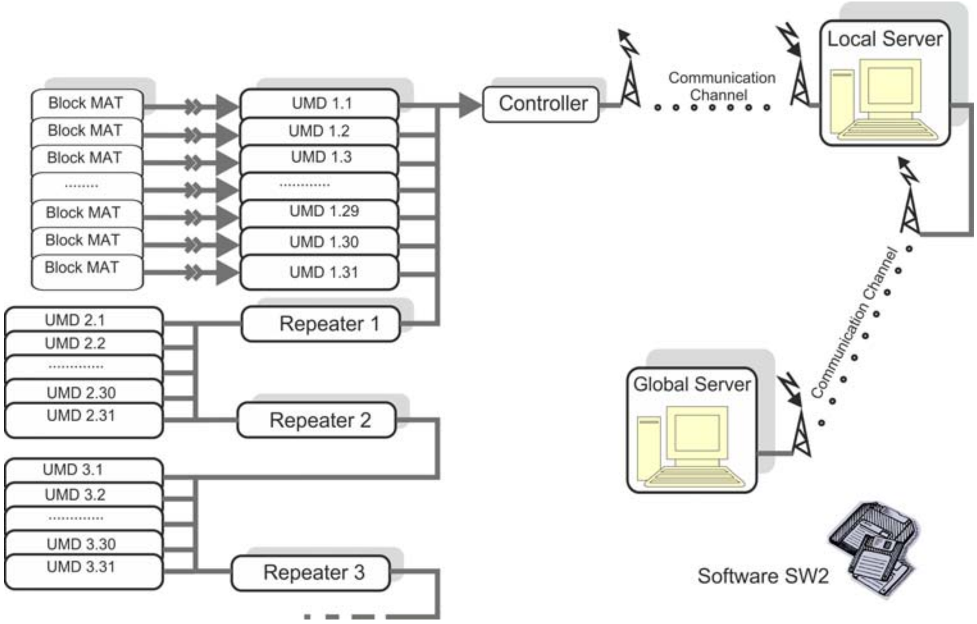

Fig. 5. 5th level monitoring system

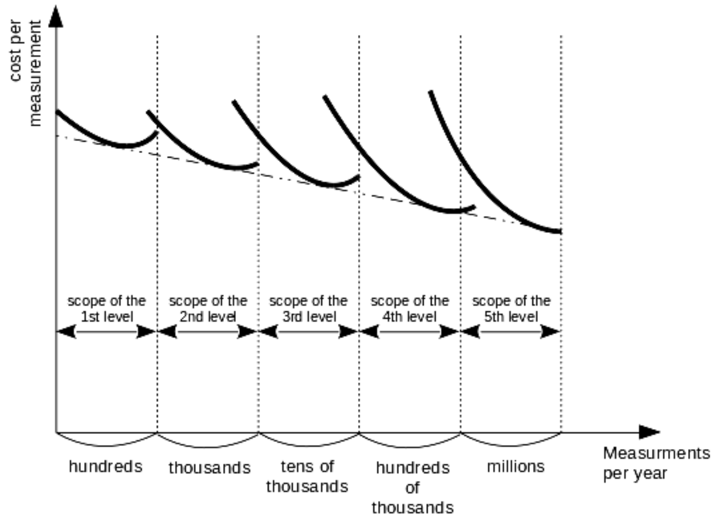

Fig. 6. Areas of system levels' application

Conclusions

1. The flexible system for monitoring of the technical state of pipelines allows to adjust its characteristics (number of channels, mobility, autonomy, level of automation, number of measuring units etc.) to the requirements aimed to ensure safe operation of the pipeline.

2. The system allows to improve information capacity of each level separately, inter-level upgrades are possible as well. This allows to minimize cost of system operation without reducing its information value. The system allows to obtain enough data for making decisions on any level of management.

3. As a general disadvantage of the system limitation of its application for structure scanning can be named. This limitation appears to result from the sensors used and is especially crucial for level 1. It is reasonable to continue research in a field of developing of real-time methods and means of measurement.

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MONITORING OF TECHNICAL STATE OF TECHNOGENIC UNSAFE PIPELINES

Ukraine has a wide network of main pipelines on its territory. For most of them pre-set operation time has already run out or is close to finishing. This fact together with a potential hazard of technogenic pollution of territory around the pipeline in case of accident rises a problem of monitoring of technical state of pipelines and, as one of possible outcomes, prolongation of operation life of the structure. Authors propose a system able to perform local measurements of mechanical stresses and deformations in the welded structure. Depending on the aim of measurement — single measurement, monitoring of an area, monitoring of the whole pipeline — system has a possibility to change its measuring and data processing sub-systems up to the case when its fully autonomous operation is needed.

Keywords: monitoring; main pipeline; technogenic hazard; complex system; sensor.

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МОНІТОРИНГ ТЕХНІЧНОГО СТАНУ ТЕХНОГЕННО НЕБЕЗПЕЧНИХ ТРУБОПРОВОДІВ

Україна має на своїй території розгалужену мережу магістральних трубопроводів, термін роботи більшості з яких вийшов або добігає кінця. У зв'язку з цим, а також із потенційною небезпекою техногенного забруднення територій навколо трубопроводів у разі аварії постає питання моніторингу технічного стану *труб та подовження ресурсу роботи конструкції в цілому. Автори статті пропонують систему, яка дозволяє виконувати локальні вимірювання напружень і деформацій на зварній конструкції. У залежності від мети вимірювання — одиничний контроль, моніторинг однієї ділянки, моніторинг по всій довжині трубопроводу — система має можливість розширення вимірювальної та обчислювальної частин із переходом до роботи у повністю автономному режимі.*

Ключові слова: моніторинг; магістральний трубопровід; техногенна небезпека; комплексна система; датчик.

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МОНИТОРИНГ ТЕХНИЧЕСКОГО СОСТОЯНИЯ ТЕХНОГЕННО НЕБЕЗОПАСНЫХ ТРУБОПРОВОДОВ

Украина имеет на своей территории разветвленную сеть магистральных трубопроводов, срок работы большинства из которых вышел или подходит к концу. В связи с этим, а также с потенциальной опасностью техногенного загрязнения территорий вокруг трубопроводов в случае аварии возникает вопрос мониторинга технического состояния труб и продления ресурса работы конструкции в целом. Авторы статьи предлагают систему, которая позволяет выполнять локальные измерения напряжений и деформаций на сварной конструкции. В зависимости от цели измерения — единичный контроль, мониторинг одного участка, мониторинг по всей длине трубопровода — система имеет возможность расширения измерительной и вычислительной частей с переходом к работе в полностью автономном режиме.

Ключевые слова: мониторинг, магистральный трубопровод, техногенная опасность, комплексная система, датчик.

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