NEW METHOD FOR NON-DESTRUCTIVE EVALUATION OF IMPACT STRENGTH OF STEEL PIPELINES

Nasariy TATSAKOVYCH, Oleg KARPASH, Maksym KARPASH
IVANO-FRANKIVSK NATIONAL TECHNICAL UNIVERSITY OF OIL AND GAS,
Ivano-Frankivsk, Ukraine

Soumitro TARAFDER
NATIONAL METALLURGICAL LABORATORY
Jamshedpur, India

Recently the problem of safe operation time definition and extension is really urgent in all industrially advanced countries. Decline of metalware production for the replacement of decommissioned one causes the significance or problem solving. Primarily it concerns thermal and nuclear power stations, petroleum and natural gas industry, chemical industry, ground and air transportation, civil engineering [1]. Scope of Ukraine's pipeline system, a wide variety of severe hydrogeological conditions of pipelines laying and a large number of those which worked 50-75% of normative life time cause a special relation to their safe operation ensuring.

The application of technical diagnosis and non-destructive testing methods is normal operation for actual technical state evaluation and as the practice shows an effective way for assurance of technical reliability and safe operation of pipelines and gas transportation system as a whole.

Physical and mechanical properties of pipe metal are one of principal characteristics of pipeline technical state. These properties are changed (degraded) during long term operation. General trend of changes consists in increasing of yield limit, ultimate strength, hardness and relative elongation, and decreasing of relative reduction and impact strength. The issue of hardness and dimensional characteristics measurement as well as defects detection is solved at a high level and is implemented by number of technical means. At once the problem of mechanical properties change evaluation by non-destructive methods is unsolved including such mechanical property as impact strength of pipelines material.

On this basis the development of new methods of pipeline technical diagnosis is urgent and gains in importance for evaluation its actual technical state and safe operation ensuring.

The analysis of existing methods of metalware’s physical and mechanical properties evaluation shows that at this moment hardness is used as basic informative parameter is applied for yield limit and ultimate strength calculation. At the same time literary studies indicate that material’s strength factors could change after 10-30 years of operation: strength either remains unchanged [2–5] or increases [6–9]. It is clear that the final stage of pipeline failure is preceded by change of mechanical properties which ensured its operation capability at the beginning of operation. That is why the state evaluation of degraded metal using parameters that uniquely change with increasing the operation time and are sensitive to metal structure change offers the challenge for proper remaining life prediction of such critical object as pipelines of different purpose.

One of these properties is the impact strength of metal. Theoretical investigations of impact strength change effect on actual technical state of long term operation metalware show that some factors have significant effect:

1) The change of mechanical properties because of aging. Usually aging leads to degradation of ductile fracture resistance and increasing of sensitivity to stress concentrators and defects, intensification the tendency of metal to fracture nucleus formation.

2) Impact strength is the normative characteristic of metal that features its tendency to brittle fracture namely ductility level in initial conditions is normalized. The reduction of impact strength could cause reduction of metal's fracture toughness parameters.

3) The magnitude of critical brittle temperature of metalware material which is the temperature of fracture nature change – from ductile to brittle (cold shortness temperature). It is determined by the energy used for fracture. Impact strength value is the figure of this energy. The reduction of impact strength could cause increasing of cold shortness temperature to the range of operation temperature of metalware.

Considering these factors the descriptive physical model of impact strength change effect on the pipeline's actual technical state is proposed (fig.1.).

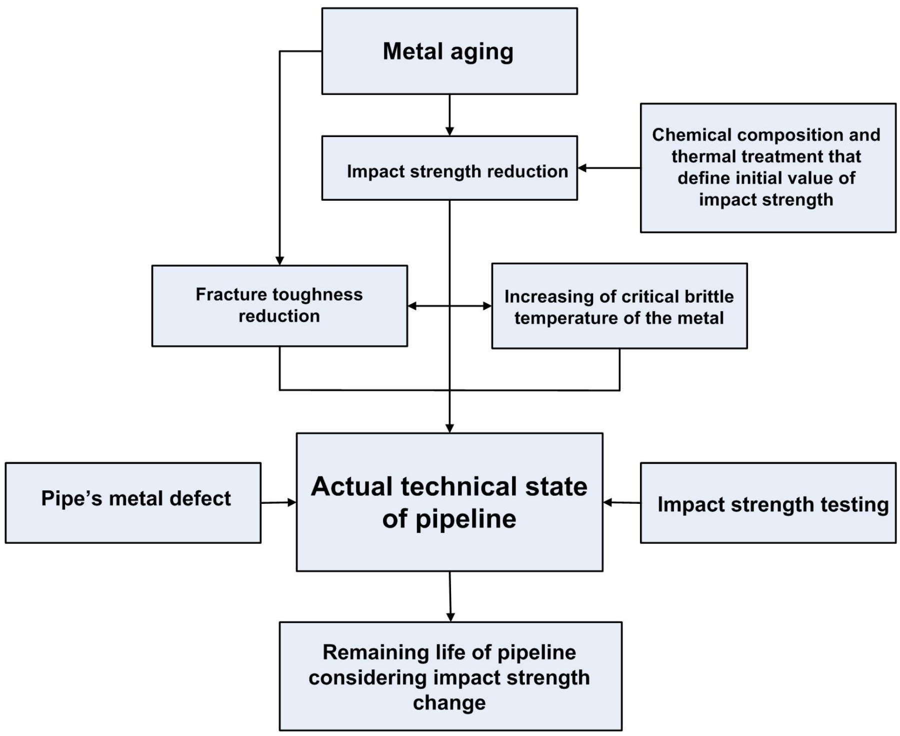

Fig.1. Descriptive physical model of impact strength change effect

This model generalizes analyzed approaches of pipeline's remaining life assessment using impact strength of the metal. Based on this model the NG-18 equation was improved by including impact strength change to the procedure of remaining life assessment. So the new grapho-analytical method was developed.

It is determined that existing assessment methods require continuous monitoring of impact strength magnitude for the purpose of its degradation nature specifying. These methods are based on samples rupture that is complicated for implementation. Thus it is arisen the need in experimental investigations of determination possibility of impact strength by non-destructive methods and in development of non-destructive device that allows quick and quite determining of actual impact strength.

Core of the investigation consists in specifying the relationship between informative parameters of non-destructive testing (hardness, coercive force, parameter of electromagnetic oscillation of inductive transducer) and impact strength. Considering that at this stage the availability of such dependence will confirm only experimentally so values of impact strength obtained by non-destructive method will accept as quasi impact strength.

Eighteen samples of different steel grades were selected for the investigation. Steel grades were from the range of widely used for pipelines construction (09Г2С, 17Г1С, X60, X70 etc.)

The resonant type hardness meter ТКР-35 was used for hardness measurement. Coercive force was measured by coercive force meter КРМ-ЦК. Impact strength was determined by destructive method that is based on destruction of sample with the notch in the middle by pendulum hammer impact (GOST 9454-78).

For the measurement of inductive transducer's electromagnetic oscillations frequency (informative parameter *I*) the experimental unit I-1 was developed. Operation concept of experimental unit I-1 is base on specified by experimental way dependence of electromagnetic oscillations frequency versus structural composition and mechanical properties of metalware's material.

Correlation analysis of impact strength values and hardness HB, coercive force H_c and experimental unit I-1 reading show that in general correlation coefficients don't reach high values (more than 0,7). It could indicate the nonlinearity of relation between given parameters of non-destructive testing and impact strength and the need of some parameters considering together.

The artificial neural networks algorithms were applied for determining the measured parameters optimal combination that ensures the most accurate definition of impact strength. Neural network of given structure was trained for approximation of impact strength value as a function of two or three measured parameters. The optimal combination of measured parameters was defined based on comparison of test outputs of trained networks

Two and three parameters sets – in total 4 possible combinations – were formed from three measured parameters (HB, Hc, I).

Set from 18 pipes samples was divided into two groups:

- training – results of 15 samples measurements were used for neural network training;
- testing – results of 3 samples measurements were used for testing of trained neural network and weren't used for their training. These values were selected from the beginning, middle and end of impact strength values range.

Levenberg-Marquardt Algorithm was used for training. This algorithm is widely used for training of small networks and is characterized with quick convergence.

The analysis of results obtained after testing of trained neural networks for each combination of input parameters allows maintaining that the best result of impact strength determining is given by the combination of input parameters (HB, I), (Hc, I) and (HB, Hc, I).

Therefore it is possible to conclude that using of informative parameter I in the complex of input parameters for the impact strength determining gives good results (the value of average normalized to the range error is within 3,47-4,11%). In terms of best result and minimal number of technical means optimal is combination of input parameters hardness – informative parameter I (average normalized to the range error is 3,90%).

The development of experimental sample of information and measuring system is one of the ways for work results implementation (fig.2.).

Fig.2. Information and measuring system I-2

Work results were approved within the contract of Ivano-Frankivsk National Technical University of Oil and Gas with Main Pipeline Department "Donbastransgas" under the conditions of Novopskov Local Gas Transmission Facility. In particular, it was carried out successful industrial tests of information measuring system. The decreasing of pipeline material impact strength was discovered by non-destructive method. The remaining life of the pipeline considering impact strength change was calculated based on the obtained data.

It is recommended to include developed grapho-analytical method in the procedure of safe operation life extension that is laid out in the draft international standard ISO 13623 Petroleum and natural gas industries – Pipeline transportation systems. Recommendations are sent to the ISO Technical Committee 67 “Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries”.

In addition, thesis materials were used by the development of Standard of Ukraine 60.3-30019801-067:2009 "Main gas pipelines. Assessment of the actual technical state of critical areas. Methods and techniques" (order by SC Ukrtransgas" № 126 from 27.04.2009).

So, as the result of carried out theoretical and experimental investigation the dependences of impact strength change effect on the pipeline’s actual state were specified. This allows proposing a new grapho-analytical method of remaining life assessment that is based on calculation of defect failure stress considering impact strength change with the operation time. The new non-destructive testing method of impact strength of long term operation metalware’s material was developed. It gives the possibility to enlarge the number of measured informative parameters and to use impact strength value for the remaining life assessment.

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