Enhancement of Estimation Reliability of Metal Fatigue Condition by Combined Measurements of Thickness and Coercive Force in Zones of Loadings Concentration

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Abstract. To increase certainty in evaluation of stress-strained (fatigue) state of metal, combined measurements of thickness and magnetic characteristic – coercive force is used. Reported are the results of bench tests and diagnostics of operating facilities for such a two-parametrical evaluation in bench destructive tests of gas cylinders, as well for diagnostics of actual objects.

Improvement of certainty in evaluation of fatigue state of metal, in diagnostics of a wide array of articles always yields a tangible useful effect. With lesser risk the service life of the equipment is prolonged. At right time is decommissioned the equipment with unacceptable degree of reliability, and in so doing the accidents are prevented. Magnetic characteristic of a metal – coercive force Hc, is rather efficient for evaluation by non-destructive methods of the degree of accumulation of fatigue changes in the metal. Its value grows by a factor of 2 to 3 (depending on metal grade), while fatigue changes accumulates from the beginning of service life of new metal articles till their failure state. In this case instrument implementation of coercitimeter is simple and inexpensive. Thickness monitoring in loading concentration zones is in a number of cases also an effective parameter for evaluation of current state, although not so universal in evaluating stress-strained state of metal, as coercive force is. In the process of bench hydraulic destructive testing of gas cylinders and sections of pipelines, also in examining operating equipment, two basic mechanisms of development of fatigue processes, involving in their evaluation combination of metal thickness and coercive force values observed in loading zones, have been determined. The thickness initially decreases because of chemical-and-mechanical action on the metal of the pipeline wall or a vessel. → Specific working loading by internal pressure on the thinning wall grows. → The metal assumes tenacious-plastic state. → The thickness begins to decrease now under the influence of operational loading, and, as a result, secondary corrosion intensifies. → All that is accompanied by drastic growth of Hc, and so on. 2) Operational loading produced by internal pressure adds up with structural ones and with various residual stresses in local zones. → The metal locally, in such zones turns into tenacious-plastic state.→ Hc here rapidly grows → The thickness is decreasing because of high local stretching loading, also because of additional corrosion in such zones. → Hc grows even faster.

In practice often fatigue processes in their totality develop in a mixed way, by both mechanisms, and, as a rule, build up, with reciprocal aggravation. In diagnostics of pipelines and pressure vessels we in a number of cases efficiently used two-parameter evaluation of fatigue state of the metal, based on thickness and coercive force measurements. Reliability of evaluation in this case improves, according to the basics of classical statistical theory of evaluation, potentially $\sqrt{2}$ times. Also real advantage is always maximum one, since parameters of thickness and coercive force are independent both in their physical nature, and in the method of their measurement. We have developed portable non-contact electromagnetic-acoustic ultrasound thickness gauges and coercitimeters. Sensors of those instruments are mobile, on a hand cart. Distribution of values of thickness and Hc along the monitored surface is measured in a simple and quick way, without scraping the surface and without application of contact liquid. For prompt analysis results of on-line monitoring are displayed on the monitor of a pocket computer, with indication of zones of unacceptable stresses, with demonstration of histograms of distribution of information parameters. It is also convenient also in keeping an informational databank on each zone under supervision in monitoring dynamics and levels of metal degradation processes. In fact data obtained by coercimetry and thickness measurements in both instruments are already in a formalized form, fully fit for loading into a basic computer without any preprocessing.
It is natural that such a two-parameter diagnostics can not yet become a must everywhere. However in the versatility of practical situations there will always be such, where two-parameter evaluation will be not only justified, but also a unique one, enabling an expert to tale a final decision. Common, typical for such special situations, consists in coincidence of the place of the local concentrator in evaluation of metal state by coercimetry and electromagnetic-acoustical thickness measurements. Such a two-parametric evaluation is a more reliable testimony of ongoing fatigue processes having already developed up to the level of local plastic deformation of the metal. Such a state of metal requires immediate measures for prevention of already imminent and unavoidable failure. All this goes on in a still fault-free metal, when revealed by defectoscopy state of such zones is seemingly good, that is the method is inefficient from diagnostics point of view. Probability of detecting anomalous from coercimetry and thickness measurement points of view zones is markedly higher, than probability of detecting fatigue flaws in metal, unavoidably appearing in such zones, but only at already final stage of development of fatigue processes in them.
High practicability of both methods used has to be noted, since for their implementation scraping of metal surface is not required. Direct contact of sensors with the tested metal is not necessary, air gap of several millimeters is allowed. Measurements can be performed directly through the layer of paint or any other protective coating. Both methods allow monitoring of hot metal. Potentially up to temperatures of the order of 700° there are no physical limitations for measuring thickness and Hc, but for the difficulties involved with provision of operational capability of sensors at such temperatures. To the same degree it concerns also sub-zero temperature range, since no contact liquids are used here too.
Also of interest is such aspect of coercimetry application, as its rigid correlation with zones of appearance of future fatigue flaws in metal. In zones of monitoring, satisfactory from coercimetry point of view, probability of detecting fatigue flaws is zero, since they are not present there and will not, not until metal degradation process takes place, increasing coercive force of the metal up to the values corresponding to pre-failure state. Flaws, even though occurring in such places, can only be "sleeping" ones, of metallurgical or welding origin, not affecting safety of equipment operation. At the same time, if thickness measurements reveal smaller thickness of the shell in the zone of monitoring, but coercive force in that place does not differ from the values beyond boundaries of thinning, such thickness measurement data can not serve as a basis for restricting operational conditions of

the equipment. Thus, here classical axiom of measurement data processing is implemented: the more parameters are used in evaluating the state, and the more independent such parameters in their physical nature are, the more exact is evaluation of metal state.
The report contains the results from practice of monitoring different actual objects. Thus, two-parameter non-destructive testing involving combined measurements of thickness and coercive force, increases the level of certainty of diagnostics and expertise, since the resultant evaluation is based on more exact information of two physically independent methods of evaluation of metal state.