Standardization of the new flaw detection material for magnetic powder method non-destructive testing

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Abstract. The level of the current state in the field of information support (IS) of the activities of high-tech enterprises is considered in this paper. The main problems are shown on the way to achieving the required level of IS quality in high-tech enterprises of the country. The need for the formation of a number of standardized requirements for the IS quality of a high-tech enterprise to improve its level is determined. A typical list of requirements for the IS quality is determined and a model of a system for accounting for requirements for the IS quality is developed using the example of Scientific and technological center of unique instrumentation of the Russian Academy of Sciences.

Introduction

The magnetic powder method is a magnetic non-destructive testing method based on the use of magnetic powder as an indicator [1], used to control the surfaces of products made of ferromagnetic materials during their production and operation.

When the magnetic powder method of control is used, powders, suspension, and pastes magnetoluminescence are applied as radiographic material. Currently, magnetic powders are widely used in industrial enterprises, on the basis of which suspensions are prepared.

Requirements for the method of magnetic particle inspection, equipment, and applied flaw detection materials are established in national (GOST R), interstate (GOST) standards, industry standards, rules, recommendations and guidance documents, as well as in standards of organizations (STO) and technical specifications (TS).

National standards give general requirements for the control method. To determine the specific values of the characteristics of the material, an analysis of industry requirements is necessary.

The analysis of regulatory documents [2-7] governing the magnetic particle inspection method made it possible to formulate universal characteristics of the used flaw detection materials. Table 1 shows the characteristics of the flaw detection material during monitoring at hazardous production facilities, trunk pipelines, gas pipelines, as well as in the railway and automotive industries [8]. It is allowed to fulfill certain requirements, depending on the type of flaw detection material.

Materials and methods

However, not all currently used flaw detection materials meet the requirements specified in Table 1, especially in terms of material stability, since the flaw material (suspension) usually has maximum stability of 120 hours. Therefore, it has to be manufactured and tested for suitability for each new control procedure. Besides, enterprises place high demands on the sensitivity level of the method, which depends on the average particle size of the ferromagnetic material, namely, the smaller the particle size,
the higher the detecting ability of the flaw detection material [8]. In this regard, it is necessary to develop a material that meets the requirements of various industries, is universal, and also increases the efficiency of the method by improving the stability and average particle size.

**Table 1. Requirements for magnetic flaw detection materials [8].**

| №  | Indicator                              | Characteristic (value) of the indicator                                      |
|----|----------------------------------------|------------------------------------------------------------------------------|
| 1  | Appearance                             | Black, colored, luminescent magnetic powders in dry form or as part of suspensions |
| 2  | Colour                                 | Maximum contrast to the color of the surface to be monitored                  |
| 3  | Detecting ability, not less, %         | Method applied magnetic field - 98, Method residual magnetization - 95        |
| 4  | Mass fraction of the main substance, %  | For dry powders – 80-85; For use in suspensions – 20-30                     |
| 5  | Concentration of hydrogen ions (pH), not less | 8                                                                            |
| 6  | Average particle size, microns, no more than | Dry application - 150 microns; Use in suspensions - 50 microns              |
| 7  | Viscosity, m²/s, no more than          | 36·10⁻⁶ (36 cSt)                                                           |
| 8  | Dynamic viscosity at (20±2)°C, no more, MPa • s | 5                                                                            |
| 9  | The concentration of powder in suspension, g/l | (25 ± 5) - for black or colored (non-luminescent) powder; (4 ± 1) - for fluorescent |
| 10 | Suspension stability, not less than, h  | 120                                                                          |
| 11 | Heat resistance                        | Materials must not degrade after 5 minutes of heating to maximum operating temperature |
| 12 | Corrosion ability                      | Non-corrosive                                                               |
| 13 | Foam generation                        | Resistance to foaming                                                        |
| 14 | Sulfur and halogen content             | Sulfur content should be less than (200±10) parts per million; The halogen content should be less than (200 ± 10) ppm (halogens are understood as chlorine and fluorine) |

The new flaw detection material for the magnetic particle inspection method is magnetic fluid. Due to the unusual combination of the properties of magnets, liquids, and colloidal solutions, magnetic fluids (MF) are promising materials and can be used in non-destructive testing [9]. Magnetic fluid is a stable ultrafine colloidal system of highly dispersed particles of magnetic material (ferro- or ferrimagnetic substances) with an average size of 5 to 50 nm, dispersed in various liquids and performing intensive Brownian motion, stabilized by surface-active substances, which is able to interact with a magnetic field and in many respects behaves like a homogeneous liquid [10]. Magnetic fluids can be obtained from iron-containing wastes (ICW) using technology [11-12].

To obtain magnetic fluid, three components are necessary: magnetic particles of colloidal size (magnetite), a liquid base, and a stabilizer that prevents the adhesion of colloidal particles. Each component has to satisfy certain requirements; it is possible to obtain a magnetic fluid suitable for use in a particular direction only under this condition.

It is known that the interaction of aqueous solutions of ferrous and ferric salts and their joint precipitation results in the formation of magnetite in the form of highly dispersed particles.
Iron-containing waste from industrial enterprises can be used as a source of ferrous and trivalent iron. The technology for producing magnetic fluids [11-12] consists of two main stages: 1) obtaining highly dispersed particles of magnetite (dispersed phase of MF); 2) stabilization of magnetite in a carrier fluid using a surfactant that prevents aggregation of magnetite particles in a carrier fluid and ensures the stability of MF. The kerosene-based magnetic fluid obtained by the technology [11 -12] is a black mobile fluid. By structure, it is a colloidal solution of magnetite in kerosene with particles stabilized by oleic acid (Table 2). Technical requirements for kerosene-based magnetic fluids are given in Table 3.

Table 2. Composition and content of components of a magnetic fluid based on kerosene.

| Component                        | Content of the component, mass. hours | Component Assignment     |
|----------------------------------|--------------------------------------|--------------------------|
| Kerosene brand MRTU-12N43-63     | 65 – 80                              | liquid base              |
| Magnetite                        | 15 – 20                              | colloidal particles      |
| Oleic acid according to TS 6-09-5290-86 | 5 - 15                              | surface-active substance |

Table 3. Technical requirements for magnetic kerosene fluids.

| Indicator                        | Value       |
|----------------------------------|-------------|
| Density, not less                | 980 kg/m³  |
| Volume fraction of magnetite, not less | 6 %        |
| Saturation magnetization, not less | 10 kA/m    |

Studies have shown that magnetic fluids from ICW meet the requirements for flaw detection materials and provide the necessary level of sensitivity. To ensure organizational unity and create conditions for the use of a new flaw detection material – magnetic fluids in magnetic particle inspection, appropriate regulatory and technical documentation is necessary to develop. According to Federal Law No. 162 “On Standardization in the Russian Federation” (dated June 29, 2015), the technical specifications and standards of the organization are documents in the field of standardization and have the same status. Technical specifications are a type of organization standard approved by the manufacturer of the product or the contractor of the work, service [13]. It is most expedient to develop technical conditions for a new flaw detection material - magnetic fluid. Technical specifications (TS) are developed according to GOST 2.114-2016 [14]. Specifications for a new flaw detection material - magnetic fluid - should consist of an introductory part and the following sections:
- technical specifications;
- safety requirements;
- environmental protection requirements;
- acceptance rules;
- methods of control (testing);
- instructions for use;
- manufacturer's warranty.

The contents of the technical specifications can include terms and definitions, designations and abbreviations.

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Fe^{2+} + 2Fe^{3+} + 8OH^- = Fe_3O_4 \downarrow + 4H_2O
\]
In the water part of the technical specifications indicate the name of the product, its name, scope and operating conditions, for example, "These specifications apply to flaw detection material (MF DF - 001) - a magnetic fluid based on kerosene, used in the magnetic particle non-destructive testing method". The requirements, norms, and characteristics that determine the quality indicators and operational characteristics should be given in the section "Technical requirements".

Flaw detection material (MF DF - 001) - kerosene-based magnetic fluid must meet the requirements given in Table 2, 3. Operational characteristics are presented in Table 1. The section, as a rule, should consist of the following subsections:
- the main parameters and characteristics (properties);
- requirements for raw materials;
- completeness;
- marking;
- packaging.

In the “Safety Requirements” section, requirements are established that contain all types of permissible hazards in such a way as to ensure the safety of the product during its service life. For flaw detection material, the section should indicate:
- fire safety requirements;
- explosion safety requirements;
- safety requirements from exposure to chemical and polluting substances, including maximum permissible concentrations of substances or its constituent components;
- safety requirements for servicing the product, including safety requirements in case of erroneous actions of service personnel and spontaneous malfunction;
- requirements for protective equipment and safety measures.

The section “Environmental Protection Requirements” sets out the requirements for the prevention of harm to the environment and human health during testing, storage, transportation, operation, and disposal. For flaw detection material, the section should indicate:
- requirements for the permissible level of chemical impacts on the environment;
- requirements for the stability of polluting, toxic substances in the environment (water, atmospheric air, soil);
- requirements for utilization and disposal sites.

In the section “Acceptance rules”, it is necessary to indicate the procedure for product control, the procedure and conditions for presentation and acceptance by the organization’s technical control bodies and the consumer (customer), the size of the presented lots, the accompanying bearer documentation, as well as the procedure for processing acceptance results.

In the section "Control Methods", it is necessary to establish programs, methods, and modes of control (testing, measurement) of parameters, norms, requirements and characteristics, the need for control of which is provided in the section "Acceptance Rules". Programs and methods of control should be objective, clearly formulated, and accurate and should provide consistent and reproducible results. For each program or control method (tests, measurements), depending on the specifics of the conduct, should be established:
- sampling methods;
- equipment, materials, and reagents;
- preparation for control (testing, measurement);
- carrying out control (tests, measurements);
- processing of results.

In the section "Instructions for use", it is necessary to establish the requirements for operation and application at the place of their operation. This section may include subsections establishing requirements for transportation, storage, and disposal.

In the section “Manufacturer's warranties”, it is necessary to establish the rights and obligations of the manufacturer under warranties according to applicable law.

The development of technical specifications (TS) would allow for the use of a new flaw detection material of magnetic fluids for magnetic particle inspection at various enterprises.
Conclusion

The final integration of groups of indirect and direct requirements finds its final expression in the personnel requirements for the IS quality, since it is personnel that is the main consumer of IS of a high-tech enterprise.

In this regard, it becomes necessary to conduct an accompanying comprehensive study of personnel requirements for the IS quality at workplaces of specific stages, taking into account the specifics of creating high-tech products.

The final set of requirements for the required level of IS was formed as a result of the comprehensive analysis of the current specifics of the production of high-tech products within STC UI RAS, as well as the personnel requirements for the IS quality:

1. A high degree of compatibility between ACS and ADS in the integrated information environment (IIE) of a high-tech enterprise.

   In modern high-tech enterprises, a large number of ACS and ADS of various functional and technical purposes are widely sold, the main purpose of which is to ensure the effective work of personnel with the information resources of the enterprise. In this regard, the implementation of this requirement becomes especially important, since the effective creation of high-tech products becomes impossible without a high degree of information compatibility of data on separately executed processes of the organization.

2. High efficiency of information monitoring of technological processes.

   Information monitoring allows continuous monitoring of the emergence of new information about the processes of the product life cycle for given information flows in a fixed thematic field for analysis, management, and prediction of its development [8]. Fulfillment of this requirement becomes necessary in the context of the implementation of the ideas of continuous information support for the product life cycle, which is consistent with the main task of IS in modern high-tech organizations.

3. The maximum possible degree of implementation of simultaneous group work of personnel in ACS with large amounts of information.

   Ensuring the joint work of personnel during the implementation of research and development works becomes the main factor in reducing time and costs in the development of high-tech products.

4. High speed of obtaining information about created high-tech products at any stage of its life cycle.

   The speed, at which information is received by the organization’s personnel, plays a crucial role in determining the competitiveness of an enterprise. The fulfillment of this requirement allows ensuring the effectiveness of the existing material and technical base and information flows in the enterprise involved in the processes of information transfer.

5. The prevailing position of electronic data interchanges in organizations.

   The widespread use of electronic forms of documentation and the rejection of paper media is becoming one of the priority areas for the development of information technologies in the modern world [9-10]. The implementation of this indicator will help to form the basis of measures for material and technical equipping of the necessary ACS by the organization, as well as determine the need for organizational measures aimed at training personnel to work with the electronic documentation form.

Thus, accounting of the requirements given above, while informing high-tech industries, can serve as the development of widespread study and solution of existing problems of high-tech organizations' IS and ensuring the required level of quality of processes for creating high-tech products.

It should be noted the need to develop methods for quantitative assessment of requirements, as well as their possible supplement as further ways of research aimed at improving the quality of IS of high-tech organizations.

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