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Consideration of various factors influencing acoustic logging equipment production accuracy

A M Gilmanova

Ufa State Petroleum Technological University, Branch of the University in the City of Oktyabrsky, 54a, Devonskaya St., Oktyabrsky, Republic of Bashkortostan, 452607, Russian Federation

E-mail: Alfiya_okt@mail.ru

Abstract. To improve quality of technological machines and equipment, quality and reliability of the downhole material obtained using acoustic logging equipment, it is necessary to take into account all factors affecting reliability and accuracy of the tools at all the stages of their life time - development, production, operation, and interpretation of the well material. The analysis results are presented in the diagram generalizing the principles of high-precision acoustic logging equipment production optimization.

1. Introduction

Accounting for various factors influencing accuracy of geophysical equipment requires development of principles for optimizing the high-precision equipment production method [1, 2].

These principles can be applied to any product. The article analyzes these principles without generalizing them by all the geophysical methods. Acoustic logging equipment production is used as an example.

2. Methods and materials

The results described in the article are based on the analysis of literature data, experimental and analytical methods.

3. Results and discussion

Analysis of factors affecting the quality of various GIS materials obtained using acoustic logging methods shows that the quality depends on systematic and random measurement errors [3–7].

The random component of measurement errors is influenced by geological and technical conditions of the recording process. The systematic component of measurement error depends on the quality of the entire process: equipment designing, manufacturing and operation. This error is influenced by such hard-to-control factors as probe centering, irregularity of radiation diagrams and discrepancy between spectral characteristics of transducers, discrepancies in power parameters of emitters and sensitivity of receiving elements, as well as violation of dimensions of the probes during the production process [7, 8].

The design process involves translation of product requirements, a "customer voice", into the technical language, i.e. the language of specific characteristics embodied in the design documentation. The role of design can be judged by the "70:20:10" rule which establishes that if a successful solution to the quality issue is taken as 100%, 70% of this success is due to designing, 20% is due to production,



and 10% is due to equipment operation. The more complex the product is, the more rigidly the rule is observed.

It is believed that quality is formed at the second stage in the conditions of mass production. However, the basics of quality are formed at the beginning of the product life cycle, i.e. quality formation precedes mass production (research and development works, designing, pilot production and debugging). In this regard, the first stage is a crucial for quality assurance. Works should be structured in such a way that the values of product characteristics are least subject to variation due to imperfect technology, heterogeneity of raw materials, variations in environmental conditions and other disturbances that are inevitable in production and operation processes [9, 10].

One of the most important criteria for the quality of designing, manufacturing and operation is reliability – the property to maintain the ability to perform required functions in given modes and conditions of use, maintenance, storage and transportation [11].

Reliability requirements are determined by various factors and conditions: purpose, responsibility, cost, quantity, operating conditions, etc. [12].

The following indicators are used to assess reliability:

- probability of failure-free operation $P(t)$, i.e. probability that failure does not occur within a given operating period (the duration of operation):

$$P(t) = e^{-\lambda \cdot t} \quad (1)$$

- mean time before failure is mathematical expectation of the life before the first failure $T = 1/\lambda$;

- failure intensity $\lambda(t)$ – conditional density of probability of failure for the unrecoverable equipment determined for the considered moment of time provided that up to this time failures do not occur

$$\lambda(t) = f(t) / P(t), \quad (2)$$

where $f(t)$ – time before failure distribution density; $P(t)$ – probability of failure-free operation over time t ;

- mean time between failures is the ratio of the time before failure for the repaired equipment to the expectation of the number of failures during the uptime.

Terminology related to reliability issues is defined in the Interstate Standard 27.002-2015 ‘Dependability in technics. Terms and definitions’.

Let us define basic terms used for reliability calculations:

- dependability is the state when the object is able to perform required functions preserving the values of target parameters within the limits established by the documents;

- reliability is the property of the object to preserve ability to perform required functions for specific period or time before failure in target modes and conditions;

- limiting state is the state when operation of the object is irrational or unacceptable, or recovery of its operating conditions is impossible or irrational;

- failure is abnormal performance of the object.

The most important indicators of durability are properties of an object consisting in its ability to perform the required functions in specified operation and maintenance modes and conditions until the limit state is reached:

- gamma-percentile operating life is the total time before failure. During this time the object does not achieve the limit state with probability γ expressed in per cents:

$$\gamma = 100 P(t), \quad (3)$$

For many mass production products $\gamma = 90\%$, i.e. only 90% of their operating resources are used;

- mean operating life is mathematical expectation of the operating life.

If the product consists of series-connected elements, probability of its failure-free operation is

$$P(t) = \prod_{i=1}^n P_i(t), \quad (4)$$

where $P_i(t)$ is failure-free operation of the i -th element.

If the product consists of parallel connected element, probability is

$$P(t) = 1 - \prod_{i=1}^n [1 - P_i(t)] \quad (5)$$

Failure probability is

$$Q(t) = 1 - P(t), \quad (6)$$

The processes which determine reliability of the product are random in nature. Quantitative indicators of these processes are random variables.

Relationships that establish connections between possible values of a random variable and corresponding probabilities are laws of distribution studied by the probability theory.

The most typical laws of reliability parameters distribution are normal, logarithmic normal, indicative and Weibull laws.

The results of downhole and acoustic logging equipment reliability calculations are presented in Table 1.

Table 1. Equipment reliability calculation results.

Name	Equipment time before failure (h)	Control unit time before failure (h)	Probability of no failure
AKTs-NV-36	270	1104	0.97
AKTs-NV -48	285	1104	0.98
AShIM-36	285	1104	0.98
AVK-42M	260	1104	0.95

When designing, it is also necessary to calculate systematic measurement errors which can occur in well logging [13]:

- volume or surface durability errors;
- own and (or) contact stiffness errors;
- wear errors;
- heat resistance errors;
- vibration resistance errors (or oscillations).

Any calculation is performed according to the following scheme:

- a) initial data for calculation;
- b) drawing up a calculation scheme;
- c) identification of the main performance criteria;
- d) direct calculation;
- e) conclusion.

The analysis of the material allowed us to develop a scheme presented in Figure 1 and to formulate basic principles for improving a high-precision equipment production method:

- maximum noise immunity of the measuring path;
- high reliability and permeability of equipment in a complex profile well;
- unification of components and parts which helps assemble equipment depending on the complexity of control over technical conditions;
- multi-level metrological support.

Let us analyze the design stage which affects the systematic component of the instrument measurement error. Negative designing results can be caused by give such major factors as:

- incorrect strength, heat, wear and vibration resistance calculations,
- unreasonable selection of tolerances on internal and external disturbing quantities,
- incorrect dimensional tolerances, dimensional chain errors,
- fuzzy description of the production and operation stages.

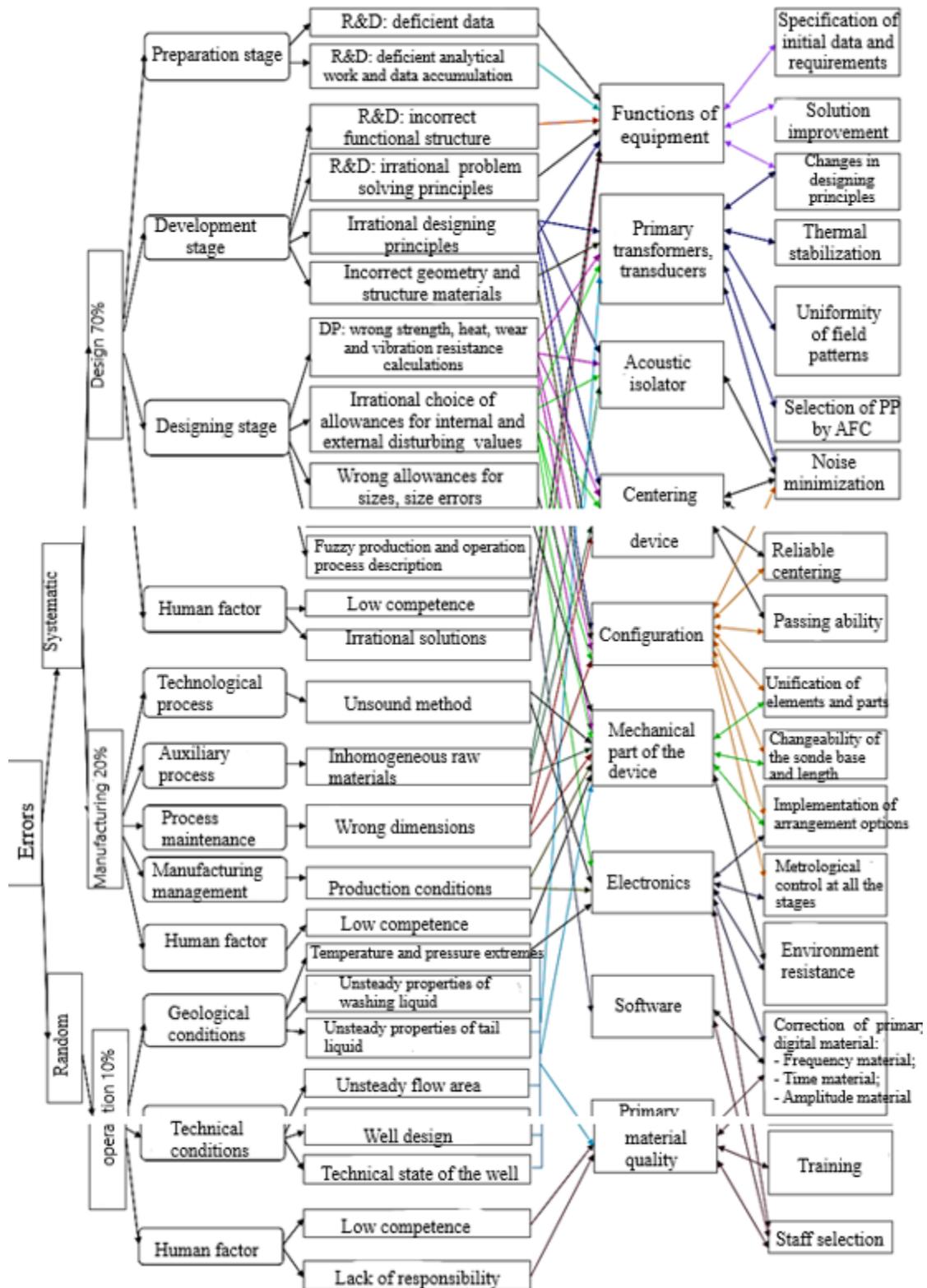


Figure 1. The diagram of principles of high-accurate equipment production method optimization.

Each of these factors affects the corresponding functional units (e.g., primary transducers, receiving-emitting assemblies, acoustic isolators, centering devices, equipment layout, other mechanical parts,

electronics) and the quality of the primary material. The scheme can be used to determine the bilateral influence of each functional unit on the quality of the diagram; for example, the element of the centering unit affects noise-interference when recording the downhole material during the movement of the tool in the well; failure-free operation of the tool in cased and uncased wells under reliable centering of the tool in the wellbore regardless of the presence of cavities and grooves; all the latter depends on the choice of an optimal design of the centering tool, its springs, slide blocks, etc., as well as on the consideration of the four factors mentioned above.

The human factor determines all components of measurement errors and depends directly on the level of qualification, competence, and responsibility of specialists at any stage of the equipment life cycle [14]. The main solution to this issue is qualified training and selection of the competent personnel.

4. Conclusion

The suggested principles and optimization scheme make it possible to determine systematic and random components of measurement errors, analyze and avoid possible errors at the designing, manufacturing and operating stages in order to produce high-quality downhole materials.

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