

## Professional Competencies Development of Competitive Bachelors in Machine Engineering

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### ABSTRACT

The significance of the problem being investigated is conditioned by the need of introduction of considerable amendments to academic discipline content with the objective of ensuring effective education process and professional competencies development level increase of bachelors in machine engineering necessary in their professional activities while performing employment functions. The purpose of the article involves structural-functional model development of forming bachelors' professional competencies towards "Machine Engineering" qualifications in studies of qualified educational subjects, and also identifying a set of organizational-educational conditions of its successful implementation. The key method of the given problem analysis is meant to be model analysis which enables to study the matter point of this problem in great detail. The fundamental result of the article is a generated structural-functional model of professional competencies forming, including information-packed, assignment, and evaluative units in its structure and being implemented with respect to organizational-educational conditions. The content of the article may prove helpful for faculty members of technical institutions for the purposes of high quality vocational training implementation which meets unit standard requirements of machine-building complex enterprises.

### KEYWORDS

Content design, educational process, instructional design, professional competencies, quality of education

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## Introduction

Integration processes occurring in the world system of education show the necessity of renovation in the area of Russian education, the primary goal of which being training of highly-educated and highly skilled specialists carrying occupational mobility and capable of professional development (Dorozhkin & Shcherbina, 2013; Kalimullin & Dobrotvorskaya, 2016; Masalimova & Barinova,

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2016). Modern Russian society calls on the system of higher education a whole new level of bachelors training in machine engineering based on the industrial needs in the market economy conditions (Matyukin, 2013; Masalimova & Ivanov, 2016; Kalimullin, Khodyreva & Koinova-Zoellner, 2016). In terms of engineering and technical skilled workers training much attention is given to vocational education and relevant production alignment as a result of which the educational process structure in technical institutions needs to be repurposed, highlighting the applicatory component in training (Dorozhkin & Zeer, 2014; Gabdulchakov, Kusainov & Kalimullin, 2016). It is therefore important to provide strong interrelation with enterprises (Shevelev, 2013).

In contrast, the interaction between vocational education system organization and the one of employers are noted for instability and lack of their contacts; machine-building complex enterprises find it difficult to provide with engineering and technical personnel as the level of bachelors training is insufficient. According to Russian Union of Entrepreneurs and Industrialists in the sector of industry, in machine engineering particularly, there has been “as near as total deficit of human capital assets, in other words shortage of people having a good command of necessary professional knowledge, special skills, and experience”, and professional skills shortage is one of the main reasons of low-performing machine-building complex enterprises in Russia. The vision of a specialist of an industrial enterprise appears in unit standards as yet. This imposes introduction of significant amendments to technical education content, carrying out approaches and technologies renovation at all levels of training. In this context refocusing of cooperation between technical institutions and enterprises appears essential (Torkunova, 2014).

Requirements to the process of training of bachelors in a technical institution are determined in accordance with a qualitatively new informatory and engineering aspects being characterized by a competency-based approach. To create professional competence of bachelors with due regard to a competency-based approach implementation, a higher educational institution is obliged to realize professional environment with the purpose of full development of the human personality (Bayushta, 2012). Competencies formation refers to the planning of the educational process of bachelors’ technical training, competency-based content of subjects in a vocational course and its implementation in the educational process, which allows to feature main trends in the development of machine engineering as a leading industry of economy in Russia to the full extent. A significant factor for reaching a high level in education is the necessity of ensuring control objectivity and reliability of results evaluation in educational activities. This calls for the education quality assessment scheme independent of education authorities. It is set to become an efficient and proven tool of the effectiveness improvement and accountability of educational activities of educational establishments and subjects of education (Efremova, 2013).

## **Materials and Methods**

### ***Research methods***

In the course of the research the following methods were used: theoretical (evaluation and conceptual synthesis of the ideas reviewed in scientific sources regarding educational issues of bachelors training; competency-based approach implementation connected with the professional competencies forming);



diagnostic (job analysis; pedagogical modelling of the process of professional competencies forming); empirical (questionnaires, observation, testing); experimental (pedagogical experiment); mathematical statistics methods and graphical representation methods.

### ***Experimental facilities of the research***

State National Research Polytechnical University of Perm acted as trial facilities of the research.

### ***Research stages***

The research of the issue was carried out in three stages:

At the first stage the research background was identified; standardized documents of vocational education, scientific-theoretical references and methodological sources, published research findings associated with the research issue were under study and analysis. Educational experience of teaching theory and practice of vocational subjects was studied and thought through. As the result, a research problem, the aim and objectives of the research were distinguished, that enabled to determine an experimental base.

At the second stage of the research the formation model of professional competencies of bachelors of “Machine Engineering” speciality was being worked out, and the set of organizational-educational conditions of this model implementation was determined when studying vocational subjects by bachelors. Specific character and special aspects of the qualified educational subjects content were revealed for the purpose of professional competence formation of bachelors of “Machine Engineering” speciality; the process of education with relevant educational and methodological support materials was developed; teaching techniques were being examined and improved; the assessment of efficiency of the developed methodology was modified.

At the third stage research results processing, classification and evaluation were carried out; conclusions were drawn, thesis research was being prepared.

## **Results**

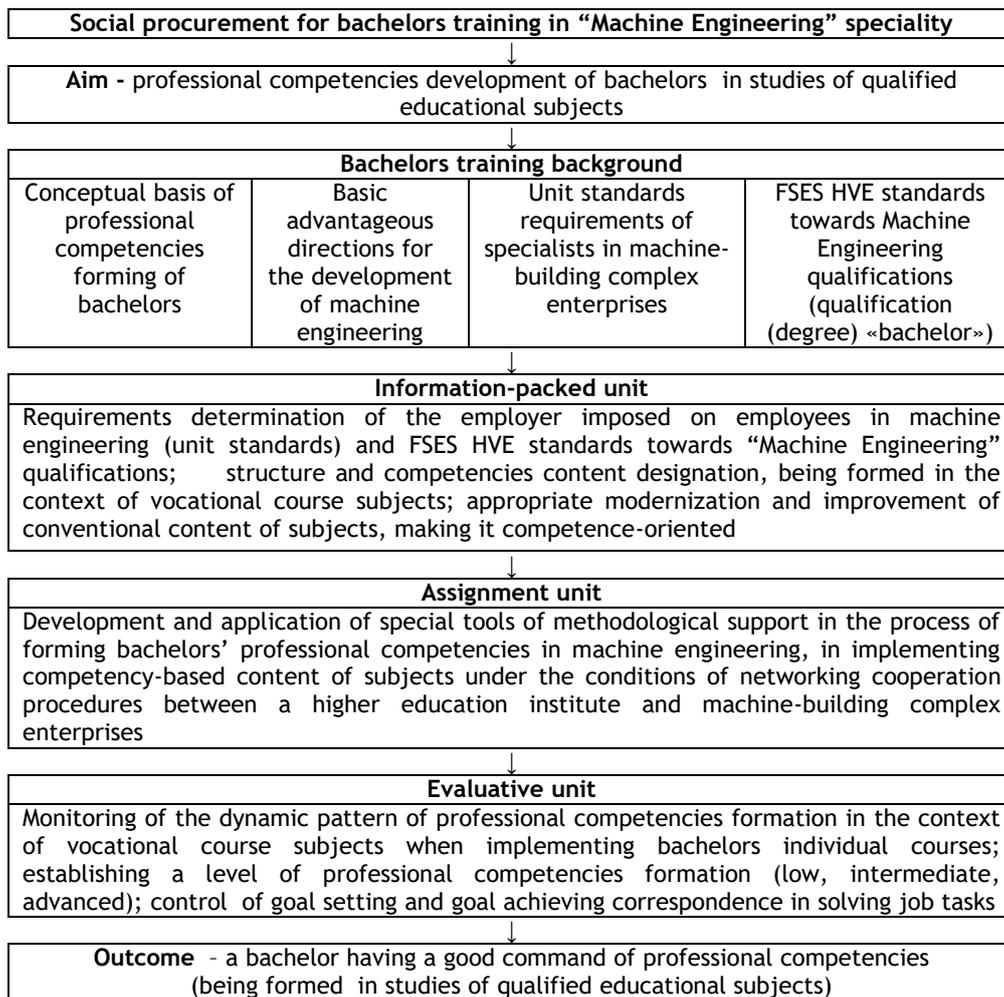
### ***Model structure and content***

Dynamics of development of the world education requires Russian education remodelling in implementing fundamental principles of the competency-based approach. In view of this, competency-based qualities of bachelors serve as core component parts of FSES, involving requirements for educational programmes learning results, being expressed in professional competence. Following the technologies and content being continually renovated, scientific and technological data base increase requires from a specialist of a machine-building enterprise the ability to apply acquired knowledge in job tasks solution, the key elements of which are stated in unit standards (Blinov & Yesenina, 2013). Consequently, these days bachelors training is aimed at necessary professional competencies formation being specific to the kind of the performance of a machine-building enterprise specialist, which allows them navigate freely in the information space for job tasks solving.

Achieving the required level of professional competencies formation in the performance of job-related tasks is possible when using instructional design as a

cross-functional assignment tool allowing a teacher facilitate consistency, goal focus and productivity, flexibility and variability of the whole teaching process. With that, details and internal relations of a designed project, characteristics of its functioning should be taken into consideration in the instructional design; along with being process cohesive, dynamic and should also implement all stages of a design process. Given that one of the principal stages of the instructional design is design basis study which has an impact on the process functioning and execution of the education process, we carried out an analysis of standardized documents which allowed us provide insight into common state of the issue.

Specifically, for the purpose of training quality improvement of bachelors, particular characteristics of modern machinery production, duty positions (relevant job descriptions) of staff members in machine-building enterprises which a bachelor may hold, were investigated. The results show that the most part of employment functions of staff members in modern machinery production, according to occupational standards, involves advanced materials usage, engineering parameters of the materials employed and of manufactured goods. Considering this statistics and bachelors FSES standards towards “Machine Engineering” speciality, we highlighted professional competencies out of each kind of performance being formed when studying subjects in a vocational course. Based on the findings, we developed a structural-functional model of professional competencies forming of bachelors in “Machine Engineering” discipline in studies of qualified educational subjects, and defined organizational-educational conditions of its efficient implementation (Figure 1).



**Figure 1.** A structural-functional model of professional competencies forming of bachelors in “Machine Engineering” discipline in studies of qualified educational subjects

A structural-functional model includes the following basic units in its structure: information-packed unit highlights standard educational framework in competency-based content; assignment unit includes a kit of educational and methodological support materials implementation, which specifies the content under the conditions of networking cooperation implementation; evaluative unit features the evaluation system of the professional competencies formation level. This model implies that in studying vocational subjects, bachelors gradually develop professional competencies’ components - knowledge, skills, working activities coordinated with unit standards requirements; the dynamics of bachelors’ individual achievement in the process under study is considered. Consistency, integration, practical aspects focus of the model’s elements enable professional competencies formation of bachelors in machine engineering, when studying specific subjects at the level stated by standardized documents.

### ***Organizational-educational conditions of the efficient model implementation***

For the efficient implementation of a structural-functional model we recommend a set of organizational-educational conditions which represents a range of interrelated actions necessary for the effective formation of expertise, knowledge, skills and personal qualities which are essential for bachelors to succeed in professional activities and to make self-education more active in their professional field.

The first organizational-educational condition involves availability of standardized educational facilities of the development of the competency-based content of bachelors training, including FSES HVE towards “Machine Engineering” qualifications, unit standards of machine-building enterprises and design criteria of educational subjects content.

Design process involves restructuring and content change, kitting out the process of education by scientific-methodological facilities including developed execution algorithms of design stages. Competency-based content of an educational subject is set to reflect the nature of a future professional activity. We developed the algorithm of the design of the qualified educational subjects content.

*Stage 1. General concept of the educational subjects content development.*

1.1. FSES HVE requirements analysis towards qualifications.

1.2. Determining labour market demands and business demand for a profession under current conditions.

1.3. Unit standards analysis of enterprises.

*Stage 2. Development of the structure of educational subjects content.*

2.1. Subjects position-finding within bachelors training.

2.2. Determination of expertise, knowledge and skills collection, required for professional settings and forming a disciplinary part of the professional competencies.

2.3. Determination of the amount of educational subjects content.

2.4. Identifying the logic of creating educational subjects.

2.5. Building-up the definitions. Development of educational subjects modules and sequencing of sections and topics when studying.

2.6. Development of educational subjects syllabus.

*Stage 3. Development of the assessment scheme of component professional competencies formation level.*

3.1. Development of the rating of educational subjects content mastering.

3.2. Development of educational subjects tests.

3.3. Development of competency-based assignments in educational subjects.

The given algorithm enables to develop correctly and define competency-based educational subjects content aimed at forming a disciplinary part of bachelors professional competencies.

In the context of the implementation of the second organizational-educational condition, the assessment scheme of professional competencies formation level when studying vocational subjects, was developed. For the assessment of qualitative and quantitative rate of expertise, knowledge and skills formation, we created a grade-rating system focused on the



encouragement of students systematic studies; motivation level increase towards learning job functions in professional activities; arrangements for continuous monitoring of the quality of expertise, knowledge and skills; defining objective criteria of learning content acquisition in educational subjects; training quality management based on the results of their knowledge and skills monitoring. Following the results of an educational subject inquisition, a recalculation of a rating score into the mark is being made (table1).

**Table 1.** Levels of professional competencies formation

Level of the educational content acquisition (traditional mark )	Rating score (total points)	Assessment of students performance
High (excellent)	86-100	Theoretical content of an educational subject is comprehensively acquired; hands-on skills are formed; tasks provided within an educational subject are carried out; the level of tasks performance meets requirements; the quality of the assignments performance is evaluated by the number of scores close to the highest possible
Medium (good)	71-85	Theoretical content of an educational subject is comprehensively acquired; some hands-on skills are formed insufficiently; all tasks provided within an educational subject are carried out; the level of tasks performance meets requirements but the score of the performed assignments is not the highest (assignments are performed incorrect)
Low (satisfactory)	56-70	Theoretical content of an educational subject is partially acquired but omissions are not of primary importance; necessary hands-on skills are formed in the large; the most part of the tasks provided within an educational subject are carried out but some of the tasks are fulfilled incorrect; the level of tasks performance meets the most part of the core requirements
Very low (unsatisfactory)	55 and less	Theoretical content of an educational subject is partially acquired; required hands-on skills are not formed; the most part of the tasks provided within an educational subject are not carried out, or the quality of their fulfillment is low

In the course of developing diagnostic range of tools we created tests facilities which is a subcomponent of a general system of quality control at the university and is focused on carrying out an independent control of the professional competencies level development within an educational subject. For the evaluation of knowledge, assignments of three challenging levels were applied: standard (60 % of assignments); advanced (30 %); highly advanced (10 %). To ensure that the control of bachelors' knowledge and skills is provided, the assignments are made on all topics of an educational subject and contain its basic definitions. In the course of the developmental-exploration study and during constant contacts with representatives of machine building enterprises, a set of competency-based assignments was worked out.

Competency-based formalized assignments contain educative situations of professional direction, i.e. highlight particular characteristics of bachelors professional activities and are focused on job tasks solution, being characteristic of it. Formalized assignments content helps the process of forming a disciplinary part of the professional competencies, i.e. acquiring theoretical knowledge, to apply them in practical activities when solving a specific problem. The content of such assignments involves individual compilation of the necessary information and its analysis. In such a way, a bachelor has much less of acquiring ready-made knowledge, than of intensifying their own efforts to meet challenge; and a teacher may evaluate both students' knowledge and the ability of making use of this knowledge. With a use of a grade-rating system one can solve the problem of estimating the level of bachelors professional competencies development within an educational subject.

One more organizational-educational condition, promoted by us, is the arrangement of networking cooperation procedures between a higher education institute and enterprises, with a view to developing education environment which highlights particular qualities of machine-building enterprises, being helpful to professional competencies formation. In our opinion, networking cooperation while forming professional competencies of bachelors in machine engineering is defined as networking of all the parties concerned (education, business, science), allowing to develop, evaluate and tender a qualified pedagogical community some innovative models of the process of bachelors training in technical institutions by resource sharing. To ensure theoretical knowledge comprehension, depth of experience and practical skills, a part of training sessions in vocational course subjects are given in the Centre of further innovative education and in the training research, development and production testing room. Its structure includes a classroom for professional education, a lecture hall with advanced equipment and an engineering centre. Generating such an academic structure (practical study platform) and its implementation into teaching and learning activities enables approach training to a real process of production. While in class in the centre, bachelors are permitted to put an end to the gap between theoretical education and necessary practical skills formation.

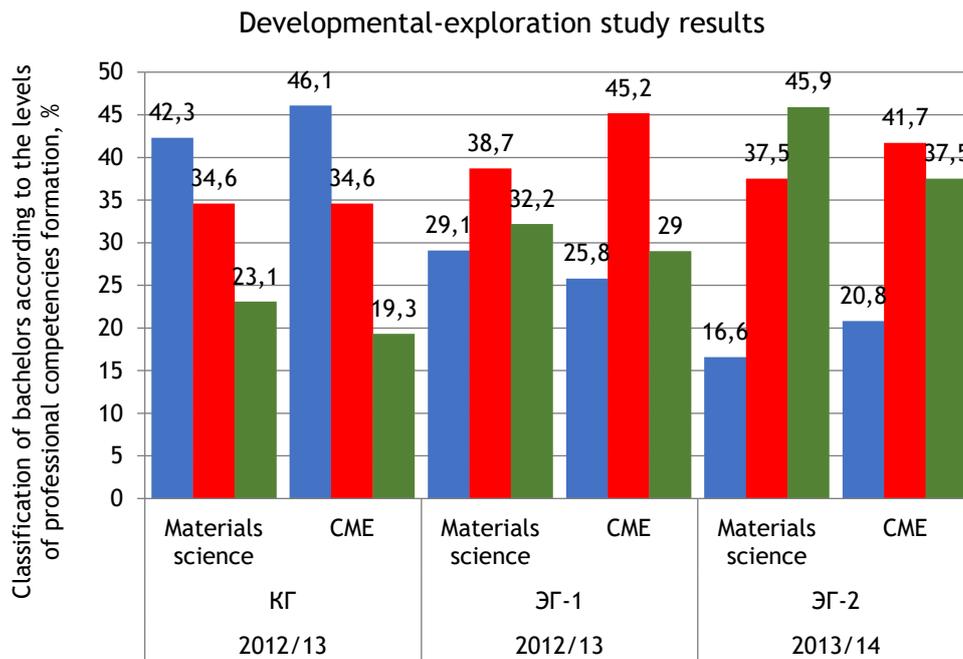
### ***Developmental-exploration study and classification of attained results***

In the context of the research for checking the effectiveness of the professional competencies formation model by means of content design of the vocational course subjects and highlighted organizational-educational conditions, a developmental-exploration study was carried out in the course of which the students studying towards "Machine Engineering" qualifications of State National Research Polytechnical University of Perm took part in.

Initially a control group and an experimental group were distinguished by us, wherein different forms of educational process organization were applied. In experimental groups a set of organizational-educational conditions was applied intentionally and consequentially, being focused on professional competencies formation; in the control group the components of the professional education system were used selectively. At a course acquisition of each educational subject the students were subject to controls with the help of the developed grade-rating system.



On the developmental-exploration study completion, the efficiency of the developed model of the process of professional competencies forming was estimated, in the context of the design of the qualified educational subjects content and a set of organizational-educational conditions implementation. In the course of the study the data were derived, on the basis of which a diagram was drawn illustrating growth rates of the level of professional competencies formation (Figure 2).



**Figure 2.** Growth rates of the level of professional competencies formation:

■ - low; ■ - intermediate; ■ - advanced; CME - Construction Materials engineering

The developmental-exploration study results showed that the implemented model of the process of professional competencies forming, based on the design of the competency-oriented educational subjects content, diagnostic range of tools and the development of networking forms of interaction, found to be highly successful. We observe the improvement, firstly, of the quality of the training material acquirement, secondly, of cognitive activities commitment, thirdly, of responsibility in fulfilling unsupervised activities, fourthly, of the quality of professional knowledge, i.e. of professional competencies formation level which will make it possible for graduates to carry out professional activities in machine-building enterprises successfully.

## Discussions

Scientific investigation analysis and gathered experience in teaching practice show that the problem of forming competencies of specialists in technical area is of interest to the state and society. In academic writings of the scientists V.N. Bobrikov (2003), N.N. Dvulichanskaya (2011), U.G. Tatur (2004) problems of the education of technical institutions graduates are given full

consideration. Particular characteristics of technical education are reported in academic writings of N.A. Kleshchyova (2007), N.V. Sosnin (2006). The analysis of competency-based approach in vocational education is covered in the writings of V.I. Baidenko (2004), E.F. Zeer & D.P. Zavodchikov (2007).

At present time in educational references, the definition “designing” is being used quite often. One may design educational subjects, specific lessons, particular topics, etc. The process of pedagogical design is the most important method of forming up the content of education, the main point of which is that, based on professional activities, it determines the process of the content forming-up. The gist and the structure of pedagogical design and education technology, principal stages of their implementation into teaching and learning activities were investigated in the writings of L.V. Lvov (2013), S.M. Markova (2014), I.V. Osipova & O.V. Tarasyuk (2009).

The system of control and quality evaluation of pedagogical process serves as an important mechanism of the education development, namely teacher’s activity involving assessment of the level of educational content acquisition by students in the course of modern technologies appliance. Writings of N.F. Efremova (2013), E.V. Karavaeva (2009), T.V. Malyutina (2013) are dedicated to the process of monitoring the quality of education in Russia and to the methods of educational determination.

Under current conditions in Russia, one of the key factors of the state competitiveness turns to be the quality of engineering and technical skilled workers training for machine-building complex enterprises. Discussion of the matters connected with networking cooperation is mainstream currently and is being introduced in the writings of S.V. Matyukin (2013), O.V. Tarasyuk & E.A. Sinkina (2014), A.M. Khanov, O.V. Tarasyuk & E.A. Sinkina (2015), N.A. Shevelev (2013), N.N. Davydova & E.M. Dorozhkin (2016), N.N. Davydova et al., (2016), O.N. Tkacheva, M.V. Simonova & Y.V. Matveev (2016). Against this background, it appears timely to re-focus the cooperation between technical institutions and real sector of economy, i.e. the development of networking relations between a higher educational institution and enterprises.

In spite of rather impressive scope of investigation, one may state lack of writings dedicated to the development of set of conditions for the implementation of the process of forming bachelors’ professional competencies, including the design of competency-based content of vocational subjects, based on specific characteristics of professional activities of a worker in machine-building enterprises and the requirements of professional standards; developing diagnostic range of tools, promoting motivation of bachelors’ systematic work, when acquiring the content of vocational subjects; promoting motivation of learning employment functions in the professional activity; organizing the continuous monitoring of determining the level of professional competencies formation; organizing networking cooperation between a university and enterprises with a view to developing educational environment, reflecting special characteristics of a machine-building enterprise in a way that facilitates professional competencies formation of bachelors.

## Conclusion

One of the challenging issues was investigated by us, which involves searching and developing of educational forms and development methods of



bachelors in a technical institution through content design of vocational subjects, with a view to acquire a competent specialist, ready and able to apply a set of professional knowledge and skills in professional activities. We studied the subject matter of the instructional design which we define as the implementation process of teachers activities for integration of new educational forms to teaching processes, and development of the new content of the educational process for its efficient operation and development.

On the basis of the research findings, we can assert that structural-functional model implementation of forming bachelors' professional competencies towards "Machine Engineering" qualifications in studies of qualified educational subjects, and a suggested set of organizational-educational conditions proves use perspectiveness of new ideas in professional skills training practice, maximally covering requirements and demands of the state, society and employers in machine-building enterprises.

In the context of study a new scientific idea of forming professional competencies of bachelors was developed towards "Machine Engineering" qualifications in studies of qualified educational subjects, the content of which is designed according to the requirements of contemporary standardised documents such as unit standards of machine-building enterprises, allowing a comprehensive approach of the educational process towards gradual formation of bachelors professional competencies, corresponding not only with the kinds of professional activities, documented in FSES HVE standards towards "Machine Engineering" qualifications, but also with employment functions presented in unit standards.

### Implications and recommendations

A non-conventional approach towards bachelors training and professional competencies forming in "Machine Engineering" suggested in the article, is based on the implementation of the competency-based content of subjects in a vocational course and its implementation in the educational process; it will be of benefit to teachers in technical institutions due to the fact that the given content allows to entirely reflect the basic tendencies of machine engineering development as a leading industry of economy in Russia, and particular characteristics of bachelors professional activities, thus to carry out a professional training of high quality, meeting the requirements of unit standards of machine-building complex enterprises.

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### Disclosure statement

No potential conflict of interest was reported by the authors.

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