Advanced tendencies of Russian training in engineering

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Abstract. This article is devoted to the problem of improving the quality of engineering education in Russia. The gap in the quality of engineering education and the growing requirements for graduates become increasingly noticeable and is an obstacle to the reforming and upgrading the Russian economy. The success of Soviet engineering schools was mainly associated with two military mega-projects: aerospace and nuclear involved leading technical universities. The transition to a market economy and integration into the global economic system require reforming engineering programs, strengthening the economic training of engineers and restructuring the technical universities. The Russian leading technical universities occupy relatively low ranks in international rankings. The purpose of this article is to help in choosing ways (trends) to improve the quality of Russian engineering education by means of a critical analysis of the leading world technical universities' experience.

1. Introduction

The Government, the academic community, parents and graduates are concerned about the quality of higher education in Russia. It is known that many top officials and entrepreneurs send their children to study at well-known foreign universities. It is becoming increasingly apparent that in the context of globalization of the world economy, the low competitiveness of domestic products is associated with the low positions of Russian technical universities in international rankings. However, one must understand that Russia is in a state of deep transformation of a command (plan) economy into a free market economy, that differ in attitude to the ownership of production means, the pricing of goods and services, the monopolization of production and distribution, the absence of a labor market and the role of the Government in the economy. According to the author, the strategy of economic transformation in the 90s was wrong and lead to the deep economic downturn, high inflation, and a drop in the living standards. In universities and research institutions the real salaries of teachers and researchers fell, state funding for R&D fell sharply and many scientists emigrated abroad [1].

2. Bologna system and tuition fees

The modern trend in improving higher education in Russia has been the introduction of international educational standards, the transition to a two-level system of education (Bologna system) and the recognition of international university ratings. Let us consider in more detail on the two-level system adopted now all over the world and in Russia. The transition to a new model makes sense only if it is accompanied by a serious change in the programs and principles of the training. In Western universities, bachelors within the walls of university classrooms and laboratories receive complete training for practical activities in the enterprise. Only a part of universities has a license and a sufficient scientific

and practical base for the masters and doctors of philosophy (higher academic degree) training. The purpose of masters' training is to write and defend a master's thesis (an analogue of a candidate dissertation in Russia). Obtaining a degree opens the way for the master to pursue a scientific career in the scientific departments of a university or a partner corporation, create his own business in the form of a startup, defending a doctoral dissertation and the opportunity to start a teaching career.

In Russia, the "Bologna system" is very difficult [2]. Bachelor and master programs are as two parts of «specialist degree program». The bachelor is considered as an "incomplete specialist", special disciplines are transferred to the magistracy, so there is no fundamental difference between the master and the "specialist". In view of the weaknesses of the practices at technical universities, it may make sense to introduce compulsory work at the enterprise for 1-2 years before admission to the magistracy in aim to choose the topic of the master's thesis, which should help solve any technical or economic problem at the enterprise. In this case, the future master will choose those special courses (within the framework of the required number of credit units) that will help to solve the problem posed in the thesis. However, such break in studies will require reforming the draft in the army. There is also need in post-graduate schools as the main opportunity for a prolongation of the scientific or teaching careers.

Let's discuss another problem of higher education – tuition fees. In the USSR, higher education was free of pay with compulsory completion for 3 years in distribution, as a kind of tuition fee. In Russia, paid higher education is introduced gradually: in the bachelor's degree - partially, in the magistracy - more. 70-80% of high school graduates look for higher education. In world practice, the situation is different. In some countries (for example, UK or Germany), the initial selection the suitability of the teenagers for accepting university education is carried out at the school level, according to the results of examinations, only a part of pupils are admitted to the free public secondary school, preparing to enter universities. The rest are offered free secondary special educational institutions that train specialists in workers' specialties. Higher education in most countries is paid, depending on the ranking of the university, country and demand for higher education. Higher education is connected with the pension system. An employee who started working at the age of 16-18 can retire early 65-67 years (usual retirement by age). So, selection at school, connection with retirement and tuition fees lead to the fact that according to statistics in countries such as the USA and Italy, only 30-35% of graduates are enrolled in universities (prestigious universities have a competition and entrance exams are held). Most young people prefer to get free special secondary school and start to work as soon as possible. Distance learning is widespread, but this is a separate issue. For Russia, according to the author, the payment system adopted in Italy is more suitable: a student pays 20% (€2-5 thousand), the remaining 80% is paid by the Government and partner firms.

3. Methodology of international ratings

The fact that our leading universities occupy ranks in the third and subsequent hundreds in international rankings indicates not only the weakness of domestic higher education, but also the illusory ability to quickly overtake developed countries in high-tech industries, including civil aircraft, instrument making and electronics. The importance of the international ratings was "Project 5-100", it is a state program of additional financial support for a number of the largest Russian universities with the aim of getting five of them into the first hundreds of authoritative international ratings by 2020: Quacquarelli Symonds (QS), Times Higher Education (THE), and Academic Ranking of World Universities (ARWU).[3] All of these international rankings rank universities as separate specialties (about 50), five areas of knowledge (Arts & Humanities, Engineering & Technology, Life Sciences & Medicine, Natural Sciences, and Social Sciences & Management) and total rank.

The program "5-100" was started by the Ministry of Education and Science in accordance with the Decree of President V. Putin (May 7, 2012) "The improvement of the state policy in the field of education and science." 21 universities (out of more than 500) were selected on the competitive basis and 15 of them received the state finance support. Moscow State University and Saint Petersburg State University do not participate in the 5-100 project and are financed by a separate line in the State budget. Although the 5-100 project as a whole did not reach its aim up to 2020 while there are undoubtedly

certain changes. The process of improving the higher education quality in Russia has to be continued in accordance with international standards.

The methodology of three international rankings are correlated, especially QS and THE. The rankings are based on reputational and quantitative indicators, which can be summarized into four main criteria: teaching, research, the demand for graduates by employers and internationalization. Assessment of the university reputation is based on a survey of the academic community (about 180 thousand researchers at various universities) and employers cooperated with universities. Quantitative indicators are taken from the relevant databases. Firstly the assessment is carried out for separate specialties (for example, “Mathematics”, “Computer Engineering”, etc.), then for the five areas of knowledge indicated above, on the basis of which subject rankings are formed, and, finally, a general ranking is compiled.

Now we are going to analyze the correspondence of the international ratings’ methodology with the Russian higher education system. The quality of teaching consists in the ability to arouse students' interest in the chosen specialty, to add the knowledge to their natural abilities, which only teachers are able to conduct in parallel with scientific work. The evaluation of teaching includes also the number of publications, citations, international prizes, and awards. The educational infrastructure (laboratories, computer classes, technology parks, libraries, and campuses for living) show to future students what they are going to have at the university. Only the universities having the high positions in rankings can teach the master's programs and have the right to be awarded the highest degree (PhD). Teaching career depends largely on the creativity and research abilities of the applicant. To participate in the competition for the position of associate and full professor, the applicant must prove to be a talented scientist with PhD degree and world renown in a particular field of knowledge. The credibility of the scientist should be supported by high-quality publications and students' interest in his program, since in many universities students are given the right not only to choose subjects for study, but also the professors. In the competition for filling the professor position usually involves several applicants.

In Russia, teaching remains the main activity of universities’ staff. Hence, a very strong teaching load on the staff, which does not leave time for serious scientific work. Low salaries of the teachers push them to look for additional sources of income in the form of part-time jobs or non-scientific activities. The associate professors (candidates of science) prevail among a stuff who do not become full professors. In addition there are weak scientific laboratories, a small percentage of researchers who are able to propose and lead R&D and, as a consequence, the small number of full professors. Some universities have introduced the practice of “effective contracts” according to which the salary and duration of the teacher’s contract (between the mandatory 5-year re-election) depend not only on the position, but on the academic and publication activity of the teachers. This practice and additional investment usually increase the university rank.

The quality of R&D at the university is of great importance in world industrial development and is also assessed by its reputational and quantitative indicators. In fact his innovations play the main role, i.e. new products and technologies obtained as a result of the university’s scientific activity, transferred to industry and ensuring the country's economic growth. This criterion also includes the number of scientific publications and the citations in international databases. In the best universities are concentrated a large number of scientific laboratories in which researchers, teachers and students of all levels work. The leading universities have huge budgets for research, consisting of orders from Government organizations, various foundations and large corporations. Innovations can be made in the scientific laboratories of various universities. For example, the technology of producing graphene, marked by the Nobel Prize in physics and created by two graduates of the Moscow Institute of Physics and Technology A. Geim and K. Novoselov, increase a position of the Manchester University, where scientists conducted their research and where the Institute of graphene was created on the basis of the laboratory. The innovations create the intellectual property (patents, technologies, know-how, and scientific articles).

In the USSR, science was divided into university, academic, and applied branches. The science had a single customer, the Government, which financed all three scientific branches through various state structures. The university science was funded by state-owned enterprises through a system of business

contracts. For example, in Moscow Aviation Institute, where the author worked and continues to work, there were many orders. Most of the contracts were quite serious, in the process of their implementation prototypes of new devices and systems were created and transferred to the industry customer. Graduates and teachers without a degree defended candidate and doctoral dissertations, creating a teaching reserve. The heads of R&D defended doctoral dissertations and became full professors. The results of nonsecret works were published in domestic scientific journals, the results of secret works were published in closed editions. A similar model of the organization of university science is still preserved in Russia. Presently the quantity of business contracts is significantly less (enterprises enter the market and save on R&D). doctor's dissertations become rare. According the author's opinion this model could not successfully function in an open market economy and provide high positions for the Russian technical universities in international rankings [4].

Most of the technical universities in Russia (and not only technical) created during the years of the "Stalin" industrialization had a sectoral nature, trained and continue to train specialists for the respective industries. Presently it is necessary to create the number of successful commercial enterprises that can financially support the university with orders and provide attractive jobs for graduates. Twenty-nine universities (two-thirds of them are technical) were given the status of "national research universities" and state funding was slightly increased. However, the budgets of these universities are clearly small compared with the budgets of universities in North America, Western Europe and even Asia. There are clearly not enough to research laboratories and technical centers in universities. Russia has real innovations in the scientific research institutes of the Russian Academy of Sciences and in the secret laboratories of military research institutes, which only narrow specialists can evaluate.

In the best western universities, the graduate is not worried about the problem of job, even if he is weighed down by student loans. He is expected in companies that sponsor the university and follow the university curriculum, the acquisition of theoretical and practical skills that are useful for the company. Representatives of large business are part of the Board of Trustees and participate in the selection of teaching staff. The government gives tax breaks to those companies and sponsors that invest in universities. In university laboratories and technology parks, with the assistance of venture capital funds, numerous startups are created that are bought by innovative companies located in the neighborhood. An example is the Silicon Valley and its clones around the world. Employment data is collected from surveys of employers, tax offices and employment services. Such indicators as impact on the economy of the region, assistance in regional development, and youth retention in the region are also taken into account.

In Russia, the problem of employing for graduates of technical universities is quite serious. There is a lack of large high-tech companies while the rich raw companies and banks need mainly specialists in the field of computer technology and data protection.

The enterprises of Defense Industry Complex (DIC) willingly hire graduates, but the salaries are not large and the career prospects are vague. Some leading Russian technical universities (MIPT, MVTU, MAI-MATI, etc.) use the so-called "Russian method" to connect universities with potential employers. This practice consists in the cooperation of university departments with relevant organizations by opening departments' branches at enterprises and research institutes. Of course, such cooperation is far from real scientific and practical activity. In addition, many of these enterprises belong to the DIC, are engaged in the implementation of the state defense order (the same plan) and are under sanctions of the USA and the EU (for example, Rostec and its aviation holdings). These organizations do not work in a competitive environment and are not ready for the competition in civil segments.

Internalization (attracting foreign students) plays a large role in the prospect of scientific, economic and political relations with the countries from which students come to study in Russia. International demand for universities in a given country, that is, the number of foreign students, is a fairly objective criterion for assessing the competitiveness of a university. By this criterion, American and UK universities dominate today, accounting for about 40% of the international student flow.

4. Conclusion

What does the author suggest? Firstly, in universities closely connected with the defense industry have to be divided the curriculums at the level of departments or faculties into those who work on military topics and those who work on civil topics. There are too many differences between military and civilian customers: in technical requirements, level of competition, pricing system. The military customer is a monopolist limited by the defense budget, but there should be many civilian customers (industry partners) for civilian projects. Unfortunately there are few Russian innovative high-tech companies willing to sponsor university science. For university innovative projects (and startups), it is easier to find an interested partner abroad. Example: there is a cooperation of one of the MIRT departments with the American company Honeywell. Thanks to cooperation with the international company Honeywell, students have the opportunity directly in the learning process to apply the theoretical knowledge gained in the practice of real projects.

Secondly, for successful competition in world rankings, domestic technical universities should gradually move away from the exclusive industry orientation (similar to the best technical universities in the USA, and Europe). [5]. The best American and European technical universities have high ratings in all five areas of knowledge open the possibility for the university to conduct interdisciplinary R&D, and for students to form their future specialty themselves. The main weakness of the domestic industries is in civilian high-tech technologies and products. The author advises gradually to transform two or three big technical universities into a classical multidisciplinary university of a regional scale. Row companies financing half the country's budget do not invest their income in the development of the domestic high-tech sector, preferring to buy equipment and machinery abroad. The consequence of this situation is lack of high-tech companies, private funding for scientific research in the civilian sphere (state funding is clearly insufficient), and high brain drain [6].

Thirdly, it is necessary to overcome a gap between academic and university sciences. Obviously, the Russian Academy of Science (RAS) will not abandon its role as the “Ministry of Science” and will not transfer its many academic research institutes under the auspices of universities and industry, as China did, following the world trend. Here it’s necessary to look for good examples of cooperation. One of such examples is the Institute of Problems of Chemical Physics (IPCP) located in Chernogolovka (Moscow Region). IPCP is one of the largest scientific centers of the RAS, which has great achievements in world and domestic science in the fields of chemistry, physics and engineering. On the basis of IPCP, a faculty of Moscow State University was created under the name "Fundamental Physicochemical Engineering" with undergraduate and graduate degree programs. This faculty has possibility not only provide the special courses but also organize research practice for students. Every student receives the individual topic for term papers on chemistry, physics and engineering. The interdisciplinary work is carried out in the Institute laboratories. Thus the students accumulate a certain experimental experience for completing the data materials for the bachelor's degree, and then the master's thesis. There is also a postgraduate course at IPCP. The IPCP has agreements on scientific cooperation and practical training for students with many Russian universities including MGU, MAI-MATI and others [7].

Fourthly, the worldwide practice of increasing positions in international rankings is the creation of technology parks at universities. Positive examples are known also in Russia: the Novosibirsk State University considers Akademgorodok as its technopark since many innovations and startups in the technopark were created by professors and employees of NSU. The Tomsk Polytechnic University has a famous technology park. Both universities are included in the 5-100 program and have relatively high positions in international rankings.

Fifthly, in terms of internationalization, some universities have proposed the teaching programs in English, that are popular for foreign students in many non-English speaking countries. The effect was twofold: the increasing of the foreign students’ number and an additional motivation for teachers and students to learn English.

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