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Mechanics

CALS Technologies and the Role of Machine Park Equipped with CNC Control Systems in the Functioning of Modern Enterprises

David Tavkhelidze[*,§], Vazha Qiria[**], Mikheil Janikashvili[§]

[*] *Academy Member, Georgian National Academy of Sciences, Tbilisi, Georgia*
[**] *Faculty of Transport Systems and Mechanical Engineering, Georgian Technical University, Tbilisi, Georgia*
[§] *Department of Science and Innovation, Georgian Technical University, Tbilisi, Georgia*

CALS (Continuous Acquisition and Life Cycle Support) is continuous information support of the product life cycle. CALS technologies were created in the United States by the military department at the end of the last century, in order to improve the planning and management efficiency of inventory development, ordering, organization in the process of engineering and other types of production operations. This concept became very effective and spread all over the world. In Georgia, the introduction of CALS technologies at the modern stage of development is taking place at a very slow pace and is understood as the introduction of modern technologies and methods of evaluating the effectiveness of their implementation together with CNC machine tools in industrial enterprises, which makes possible to reduce production costs in order to increase the competitiveness of products.

production, products, life cycle, computer control

Basic Principles

The CALS concept is based on the application of information support principles and technologies at all stages of the product lifecycle, based on an integrated information environment that provides a unified way to manage processes and interact with all participants in this cycle [1].

The integrated information environment is the Basis, and the core of CALS is a distributed data stored in a computer system that includes all departments of the enterprise directly related to the processes of the product lifecycle. In an integrated information environment, there is a unified system of rules for the presentation, storage and exchange of information. Based on these rules, all processes take place at all stages of the product manufacturing and lifecycle. That is why the basic principle of CALS has been implemented: information that first appeared at any stage of the life cycle is stored in an integrated information environment and is available to all participants at all stages (depending on the rules of information use). This eliminates duplication, transcoding and unauthorized modification of data. In addition, one of the main components of CALS technologies is the use of CNC (computer numerical control) control principles, which ensures accuracy, purity and reduction of

machine time of complex configuration products created. The said, reduces the cost of the production process itself and ensures an increase in the life cycle of the products produced.

CALS technologies for industrial enterprises. For industrial enterprises, CALS technology has made it possible to solve such tasks as obtaining the maximum economic effect in the shortest possible time. This is achieved by reducing the release time of new products, reducing the cost of new types of products (especially complex structures), sharply reducing the percentage of design flaws, reducing the cost of preparing technical and operational documentation, as well as reducing the cost of branded products through the use of a modern package park equipped with CNC technologies.

Based on this, the Georgian Technical University is modernizing universal machines using CNC technologies, which will be aimed at creating a flexible production site in order to manufacture parts of complex configuration of various nomenclature.

The creation of this flexible production site is due to the fact that today such types of enterprises as enterprises of the agricultural and food industries, road construction organizations, service centers for the repair of cars and household appliances, etc. are successfully operating in Georgia. Modern enterprises of all these categories are mainly equipped with imported western-made machinery and equipment, to which depreciable and replaceable spare parts are also imported, the cost of which is quite high, and in many cases, the purchase of these parts and their installation are associated with large financial losses for our entrepreneurs. Our proposed enterprise, which will be managed using CALS technologies, will allow us to launch a modern production site in our country and to a certain extent balance export-import indicators in the design and production of spare parts for foreign-made machinery and equipments. To assess the effectiveness of the implementation of the mentioned technology, the method of evaluating the return on investment is used, for which, at the initial stage, it is necessary to estimate the costs (i.e. capital investments related to the acquisition and development of software), which are determined by the accompanying formula [1]:

$$E_s = \sum_{i=1}^{n} (E_p + E_b + E_i + E_l + E_o + Em) * (1+D)^t, (1)$$

where: E_s is software development costs; E_p – software development costs; E_b – software purchase costs; E_i – software implementation costs; E_l – the cost of training personnel to work with this software; E_o – other expenses related to the acquisition and implementation of software, as a rule, in enterprises range from 3 to 7% of the cost of software; E_m – expenses incurred for the operation of new or upgraded technological installations; D – discount rate; t is the life cycle period of the software and maintenance.

The importance of the economic effect resulting from the introduction of the above-mentioned E_C technology is determined based on the following calculation [1]:

$$E_C = \left(E_{ya} - E_{yb}\right) - \left(P_p \times K_n\right), \qquad (2)$$

where: E_{ya} denotes annual savings after the implementation of the system; E_{yb} – annual savings before the implementation of the system; P_p – costs incurred for the development of software and management systems; K_n is the regulatory coefficient ($E_n = 0.15$).

As for the annual savings before and after the implementation of the Ey system, it is determined by the following equation [1]:

$$E_y = R_1 - R_2, \qquad (3)$$

where R_1 is the cost of design and development after the introduction of new software; R_2 is the cost of design and development before the introduction of new software.

As can be seen from the description (1), one of the key parameters is Em, which is associated with the costs incurred during the operation of new or upgraded technological installations. The following

are the issues of converting outdated circuit design machines into CNC systems based on your own experience.

Creation of flexible corporate platform based on the use of modernized CNC systems. At the present stage, companies from many countries of the world produce various types of computer control systems, and when the question arises about modifying the existing sachet fleet, it is very difficult to make a choice from the variety of systems offered by manufacturers [2]. Such systems can be divided into two types: industrial systems are specialized computer systems such as: Siemens, Fanuc, HEIDENHAIN, Bosch Rexroth, FAGOR AUTOMATION, etc. Special operating systems have been developed for them, which are characterized by high performance, reliability, flexibility, a variety of software functions and can be used to manage installations for various purposes.

It should be noted that all these types of systems are characterized by fairly high prices. It should be noted that the manufacturers of these systems guarantee the correct operation of the installations only if additional electronic devices of their production (such as servo motors and drivers) are used, therefore the total cost of modifications increases several times (3-6 times).

The development of electronic and computer technologies over the past 10-15 years has allowed many manufacturers to develop cheaper control systems based on work in widespread environments of WINDOWS and LINUX operating systems. It should also be noted that special adapters have been developed for some of them to control the device from a computer, which are also much cheaper than industrial systems.

Based on the above mentioned, we considered that it is necessary to make some comparison of these systems, taking into account the characteristics and prices, and to form recommendations in the direction of the expediency of their use. However, it should be noted that this comparison cannot be the final verdict when choosing a management system, since it depends on many factors that determine the capabilities and requirements of a particular enterprise. For example, the general parameters of one of the models of the Sinumerik system are providing 96 coordinates based on the use of 24 spindles and are characterized by a high speed of movement up to 300 m/min. It is also worth mentioning here the control panel manufactured by the Spanish company FAGOR, which can control 28 coordinates. Other industrial systems also have similar parameters. Obviously, a powerful processor and special software are needed to implement such parameters.

Table. Some parameters of the most common systems and approximate prices

Model	Price	Reference	Speed of rapid movement, rpm	Number of coordinates
Mach 4 – 1-lisence	200$	https://www.machsupport.com/software/mach4/	12	6
Centroid CNC	285$	https://www.stankoff.ru/blog/post/764	10	6
Planet CNC	157$	https://www.stankoff.ru/blog/post/764	10	4
UC100 USB CNC	85$	https://www.stankoff.ru/blog/post/764	10	
Adapter Mach4 -to Pokey57CNC	119€	https://www.poscope.com/product/pokeys57cnc/	10	8
BUILDBOTICS RASPBERRY PI	430$	https://www.poscope.com/product/pokeys57cnc/	10	4
Masso G3	657$	https://www.poscope.com/product/pokeys57cnc/	12	5
LinuxCNC	170$	https://www.poscope.com/product/pokeys57cnc/	18	5
Openbuilds Blackbox xPRO V5	175$	https://www.poscope.com/product/pokeys57cnc/	12	3

We also have a wide range of low-cost control systems. The Table shows some parameters of the most common systems and approximate prices.

Although industrial systems have programs that accept embedded G-codes, their functionality is much less than in the Windows environment, which, in addition to high functional characteristics, also has modeling capabilities that allow you to check the program before the G-codes "arrive on the device", thus preventing a defect.

It is clear that WINDOWS is not a real-time system, but modern medium-power computers allow cheap control systems to produce the desired result, taking into account accuracy and quality. In addition, manufacturers recommend using simple G code programs on the device.

To compile G-codes for complex parts, we need to use CAM programs running in the WINDOWS environment, such as Inventor HSM, SolidWorks, PartMaker, FeatureCAM and others [3]. All these programs have the ability to simulate. These types of programs require bachelor's degree in mechanical engineering and technology.

Conclusion

In order to produce modern types of machines with the appropriate quality of depreciable and replaceable spare parts, it is necessary to have machines equipped with computer technology. We believe that individual and medium-sized enterprises in Georgia, which do not need a variety of functionality, can be modified using the management systems we have considered. Thus, it will be possible to produce products of varying complexity with appropriate quality assurance. This, in turn, will lead to the creation of jobs in small and medium-sized enterprises and increase their incomes. Ultimately, this will allow Georgia to become a manufacturing country in the above direction and to some extent balance the indicators of exports and imports.

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მექანიკა

CALS ტექნოლოგიები და CNC მართვის სიტემებით აღჭურვილი საჩარხო პარკის როლი თანამედროვე საწარმოების ფუნქციონირებაში

დ. თავხელიძე[*,§], ვ. ქირია[**], მ. ჯანიკაშვილი[§]

** აკადემიის წევრი, საქართველოს მეცნიერებათა ეროვნული აკადემია, თბილისი, საქართველო*
*** საქართველოს ტექნიკური უნივერსიტეტი, სატრანსპორტო სისტემებისა და მექანიკის ინჟინერიის ფაკულტეტი, თბილისი, საქართველო*
§ საქართველოს ტექნიკური უნივერსიტეტი, მეცნიერებისა და ინოვაციების დეპარტამენტი, თბილისი, საქართველო

CALS არის პროდუქტის სასიცოცხლო ციკლის უწყვეტი ინფორმაციის მხარდაჭერა. CALS ტექნოლოგიები შეიქმნა შეერთებულ შტატებში სამხედრო დეპარტამენტის მიერ გასული საუკუნის ბოლოს, დაგეგმვისა და მართვის ეფექტურობის მარაგების შემუშავების, შეკვეთის, ორგანიზების გაუმჯობესების მიზნით სამანქანათმშენებლო და სხვა სახის წარმოების ფუნქციონირების პროცესში. ეს კონცეფცია გახდა ძალიან ეფექტური და გავრცელდა მთელ მსოფლიოში. საქართველოში CALS ტექნოლოგიების დანერგვა, განვითარების თანამედროვე ეტაპზე მიმდინარეობს ძალზედ ნელი ტემპით და გაგებულია, როგორც სამრეწველო საწარმოებში თანამედროვე ტექნოლოგიების განხორციელების ეფექტურობის შეფასების მეთოდები, რაც შესაძლებელს ხდის პროდუქციის კონკურენტუნარიანობის გაზრდის მიზნით წარმოების ხარჯების შემცირებას.

REFERENCES

1. Tavkhelidze D., Janikashvili M., Qiria V. (2023) CALS – the role of technology in the operation of modern enterprises, *Business-Engineering,* pp. 351-352.
2. Mamadjanov A.M., Yusupov S.M., Sadirov S. (2021) Advantages and the future of CNC machines. *Scientific Progress,* pp.1638-1639.
3. Miltiadis A. Boboulos (2010) CAD-CAM & rapid prototyping application evaluation. pp. 9-12.

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