PAPER • OPEN ACCESS

Application of agile methodology at industrial manufacturing as part of the Industry 4.0

To cite this article: I A Kovalev *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **971** 052034

IOP Conf. Series: Materials Science and Engineering **971** (2020) 052034 doi:10.1088/1757-899X/971/5/052034

Application of agile methodology at industrial manufacturing as part of the Industry 4.0

I A Kovalev*, **D Yu Kvashnin, N Yu Chervonnova and A N Nikich**

Department of CNC, MSUT «STANKIN», Vadkoskiy per. 3a, Moscow, Russia

*i.kovalev@stankin.ru

Abstract. Many industrial manufacturing and enterprises are currently undergoing a digital transformation phase. The digital transformation of a manufacturing is a complex and multilateral process that affects almost all levels of production. For some, this is a necessary step that will reduce production costs, for others it is an opportunity to rethink the business processes of building a full-fledged digital production with the implementation of the concepts of Industry 4.0. This transition is mainly based on the principles of data collection, storage and processing, followed by analysis and the possibility of impact on production. But also an important factor is the approach to planning the activities of the enterprises. At the same time, the combination of flexible management methodologies with the possibility of obtaining data on the state of production will allow bringing existing business processes to a new level.

1. Introduction

There are several types of manufacturing activity planning: long-term (perspective), medium-term and current planning. Nowadays, flexible management methods and management (agile) are de facto popular. Agile practices have emerged in the IT industry in response to ever-changing product requirements, over-planning and micro-management. However, the use of flexible methodologies is no longer limited only to the field of information technology, now flexible planning methods are used in construction, accounting, state planning, commodity enterprises, etc. According to various estimates (Figure 1), the main areas of application of agile practices are IT (about 61%), Marketing (~ 10%), Retail (~ 8%), HR services (~ 7%), and other areas (~ 15%) [1].

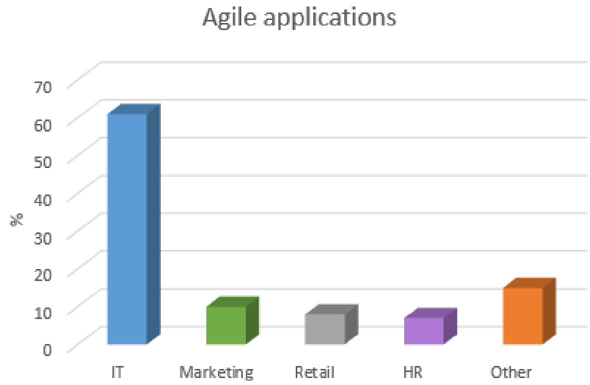

Figure 1. Agile applications in several direction.

In the Russian industrial sector, the use of agile approaches has long remained unclaimed due to some aspects. For example, when developing management systems, the principles “a working product is more important than documentation” or “changing requirements are welcome” and others do not correlate with processes that require hard real time and even small errors can lead to serious consequences. But at the current stage of production development on the principle of building smart industries, it is possible to conduct pilot implementations of some aspects of a flexible development methodology. For those control systems, these can be modules of the terminal part (Web, AR, VR), which 10 years ago seemed redundant.

To be called agile development methodologies must support the values and principles of the agile manifest. There are 4 ideas and 12 principles. One of the significant issues is the possibility of using the principles of building business processes in the IT sector in the industrial sector [2, 3].
Agile’s main advantage is the ability to quickly test hypotheses. Hypotheses are not necessarily productive, hypotheses can be aimed at optimizing internal processes. Hypotheses make it possible to increase efficiency both with the help of organizational changes and to evaluate the effectiveness of the introduction of automation or the application of new technologies [4].

2. The approach to the use of flexible methodologies at the workshop level

Consider the use of agile in the lower structural unit in industrial manufacturing. This level will be considered the workshop level of CNC machines and the production team working there. Currently, manufacturing rely on production plans, the plan is divided into teams. Planning is based on the planned output. Discussions and short-term planning can take place from once a week to daily meetings.

a) b)

Figure 2. a) A lot of information b) Personalized information in Active Cockpit.

This may cause a problem when one production workshop delays all other areas due to downtime, defects in parts or incorrect initial planning. Figure 2 on the a) side shows the traditional approach with daily extracts, scheduling and on side b) shows modern approach for demonstrating personalized information (developed by Bosch Rexroth's Active Cockpit) [5].

The two most popular planning approaches are scrum and Kanban. Scrum is a framework with a required set of practices and attributes. Kanban is a used toolbox. One way to solve such problems is to use the Kanban approach. Consider the Kanban method, as the most visual.

Suppose that the team has 4 people: an engineer-technologist of the workshop, a CNC operator, a machine adjuster, a programmer. This is one of the standard approaches; in some areas, all these 4 posts can be assigned to 1-2 people or can be significantly more. One engineer is selected as the responsible (sometimes called the scrum-master, which is not entirely true). In the framework of daily meetings (rallies), everyone talks about what he did yesterday, what are the challenges today, what are the current problems. The story should be quick, the rally should not take more than 15 minutes. A card is created for each planned task (pick up equipment from the warehouse, coordinate the drawing, check the G-code, measure the test part, transfer the details to the next workshop, etc.) and is displayed on the Kanban board [6].

Each task needs to be evaluated (this will allow you to compare the actual time and the planned one), there are many ways to evaluate it (you can vote, you can accept or reject the proposals of the formal leader, change roles daily, etc.). It is advisable for tasks to issue labels for subsequent grouping by label-labor-period. It is important that each team member sees the board during the day and moves the cards if it is finished (cards can be moved during the rally when you tell what you did yesterday and create the missing ones).

After each iteration, a retrospective is performed [7, 8]. In the framework of which the team identifies problems (communication, bureaucracy). In industry, the work of an ordinary engineer depends on other units (warehouse, logistics, technologist, metrologist, etc.).

Kanban, on the contrary, is logical to choose for long periods, for example, a quarter and conduct retrospectives when the accumulated base of solved problems. Kanban aims to improve the process, to increase the rhythm of production and flow.

One of the problems is rethinking the use of flexible methodologies for the industrial sector, because, usually for software development, these are teams of 5-9 people, which is difficult to imagine for the same workshop. But if you divide the workshop into sections containing separate brigades, combine the brigades into workshop groups, then you can monitor the state of the entire workshop at any time. Given the fact that most production processes are mainly long-term processes, Kanban boards can give some transparency to the current state of the workshop and individual workshop [9,10].

For such large tasks, you can use process optimization using the Jira task management system as an example. Jira is a universal task management platform that allows you to build complex processes that do not allow you to go past one of the stages. An example is shown in the figure 3.

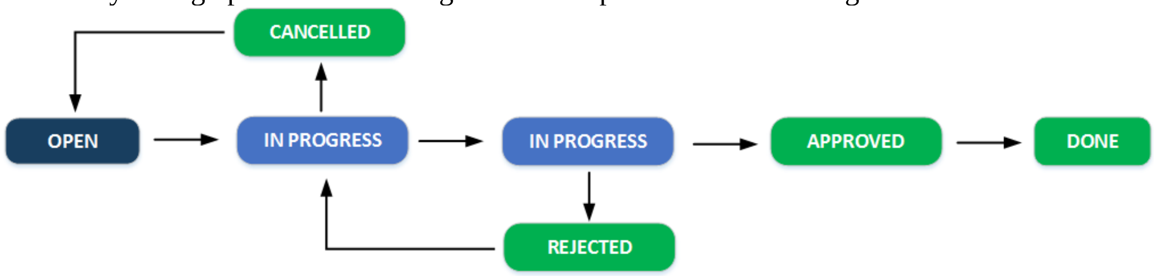

Figure 3. Visualisation of business process in Jira.

Jira also allows you to develop plugins embedded in the platform in Java, Kotlin. And has a built-in plugin store, including free ones. But such a powerful toolkit is more suitable for companies in the IT sector, or for industries that have already passed the initial development scenarios in agile practices.

3. Approach to use, taking into account the importance and urgency of tasks

Because the process can be from several structural units consisting of separate sections, then the board can look as in figure 4.

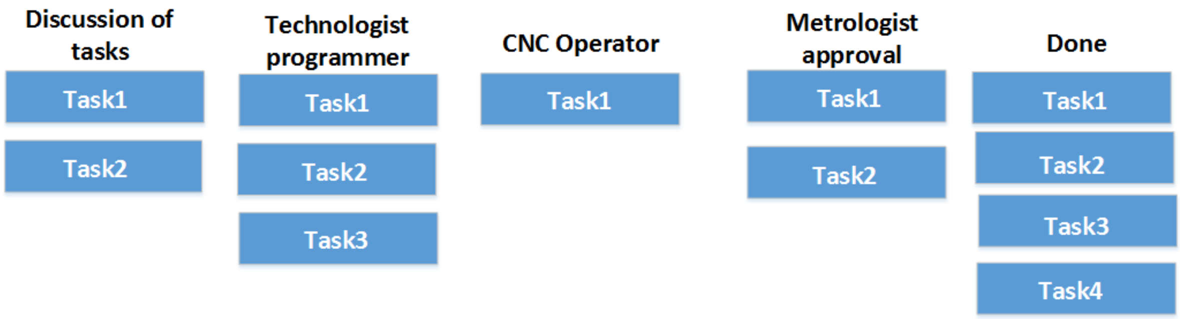

Figure 4. Example of Kanban board with tasks.

This arrangement will allow to identify at what stages downtime occurs, and where underload. Often, graphics and visualization allows you to find out the problem areas in the process. Sometimes the Little formula is applied L = λW, where L = the number of tasks, W - LeadTime (time at some stage of interest), λ - throughput. Accordingly, we can get to calculate the actual write-offs, miss the ability, or strive for time how much the task should be in the process. This allows not only to focus on "important" and "urgent" tasks (Eisenhower Matrix), but to focus on the rhythm of production.

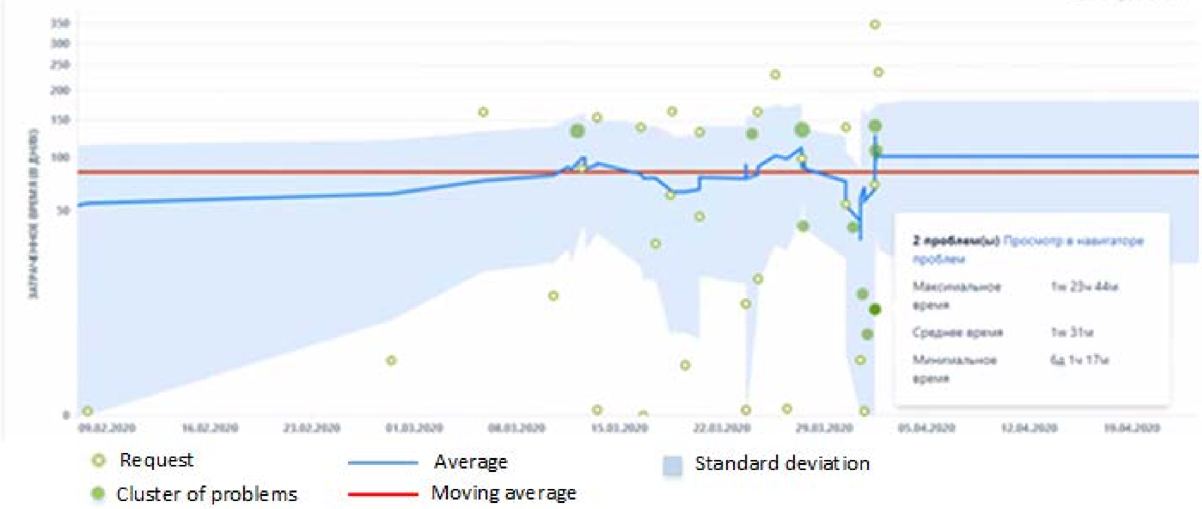

Figure 5. Status of work process.

In the figure 5, you can track the process state diagram in Jira, taking into account the average execution time of the task. Moreover, this visualization allows you to track the average time, for example, manufacturing parts, as well as problem areas and forecasts for solving problems. The figure 5 shows that in the middle of the task execution serious problems arose, with a more detailed examination, a long time of the task was found in the metrological department and waiting for an answer.

From the point of view of technology, we can visualize the process and thereby involve the employee in the overall process. Each employee will see the importance of their KPIs on overall performance. On the other hand, the technical manager can see bottlenecks, for example, it has been noticed that a lot of time a worker spends time searching for information (why the procurement did not arrive at the warehouse on time, what stage they are at now; why the G-code program is not ready yet), for such tasks Web technologies can be applied [11, 12].

Another case may be the direction when employees complain about the waste of time on coordinating documents and moving from one unit to another, in such cases they visualize pending tasks on screens, respectively, the party that is responsible for approving notes about the readiness in the general system.

4. Flexible methodologies and the concept of the Internet of things

Modern production as part of the development of the industry 4.0 concept and the Internet of things provides an opportunity to update information in real time, from remote monitoring of the state of the control program on a separate CNC machine to visualization of the overall equipment effectiveness (OEE) of the production workshop [13].

All data from the equipment goes to special data collection systems using SCADA or an MDC subclass. Most of the data may be required for MES and ERP systems to find bottlenecks in the production area: which machines were idle, where there were more errors, etc.

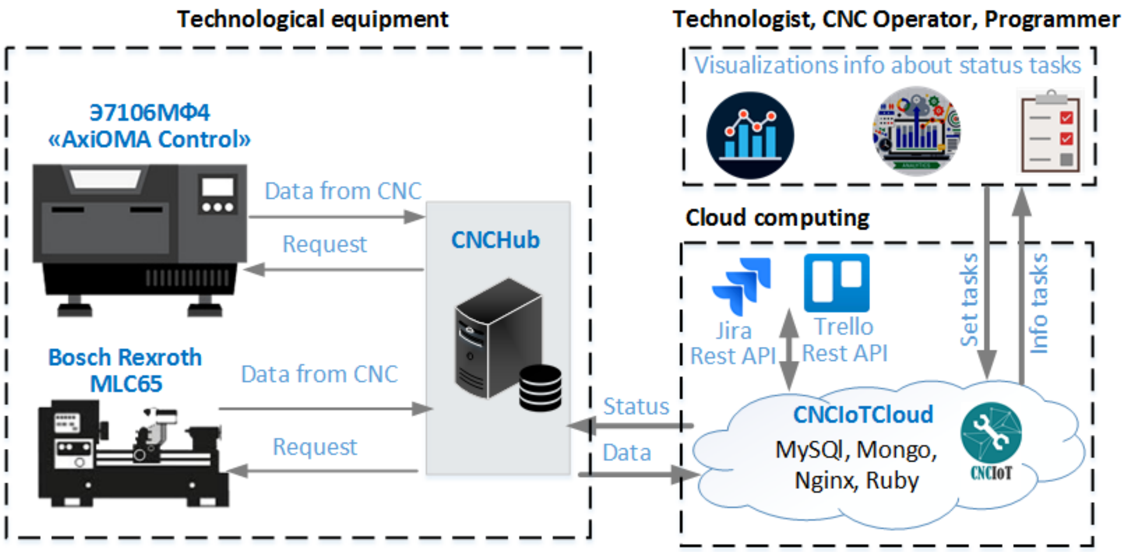

Figure 6. Structure CNCIoT with use Trello and Jira.

The figure 6 shows a system developed by the authors of MDC, which is called CNCIoT. This MDC consists of several parts: CNCHub is responsible for collecting data from equipment using the API for CNC systems, CNCIoTCloud aggregates and stores various information. CNCIoTCloud can be either a remote server or a local server [14]. This system has shown its efficiency for several projects [15]. At the moment, its further development is underway, one of the directions of which is the combination of information received from the shop floor and the tasks set by the example of Jira and Trello plug-ins.

This method may be suitable for marking the completed task, for example, for the CNC operator and the installer, because being in the workshop it can be problematic to note this through a web application.

Consider one case using Kanban and a task combustion diagram using the example of preparing a G-code program for processing a part. This process is divided into several stages: development of a CAD model according to the drawing, obtaining a CAM model with setting bindings to the plane, selecting a tool, etc. Then the program is transferred to the workshop (here again, cloud technology can be used to send the code directly to the CNC using DNC), where the machine adjuster selects the necessary tool and sets the workpiece. Next, the CNC operator comes into operation, which makes the necessary settings, launches the program, monitors its implementation. After processing, the part is transferred to the metrological department [16].

Each of these steps can be placed on a Kanban board (Figure 7), as shown in the following figure.

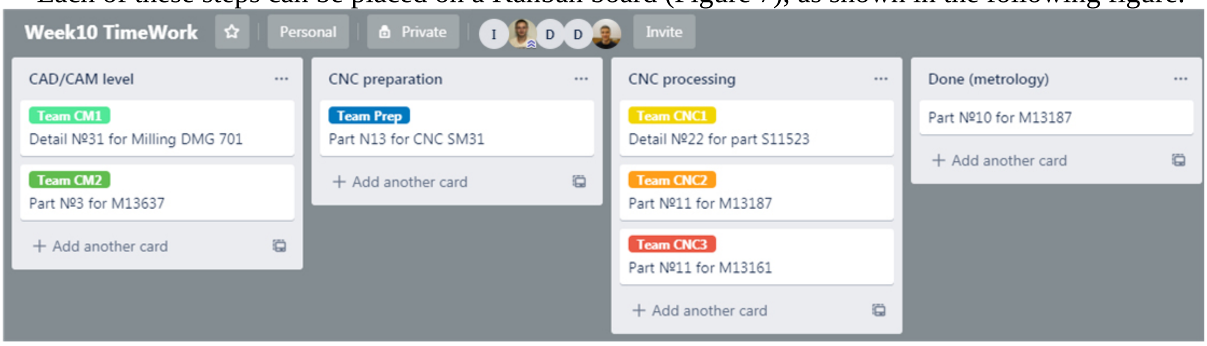

Figure 7. Kanban board for worktime of production team.

Tasks are scheduled for 10 to 11 working weeks, an advisory group is attached to each task (for developing Team CM1 and Team CM2 models, there is one Team Prep group for setting up the machine, there are Team CNC1, Team CNC2 and Team CNC3 commands for machining a part). Tasks move between the worksheet and you can clearly see at what stage the delay occurs and how much time was spent on each task.

The tasks that were planned to be completed within 14 days included the manufacture of several parts, which were either a separate unit or part of the batch. The total time for completing tasks was combined between all participants in the production team and evaluated based on their actual execution time, i.e. transfer to metrology. This is a somewhat simplified process (one production team). A full-fledged production process is much more complicated and includes additional points: synchronization between individual production teams and workshops, accounting for work in several shifts, correction of a program or technology, if there was a return from metrology with comments, etc. are necessary.

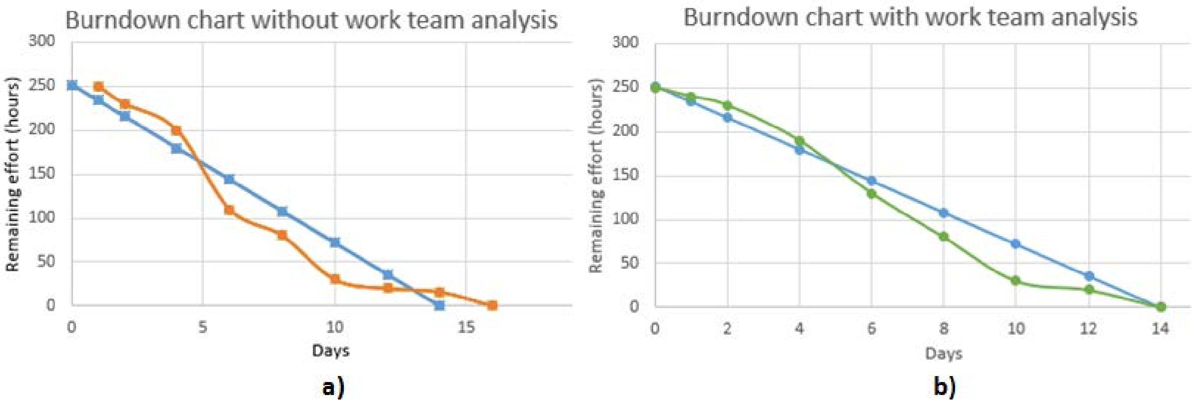

Figure 8. Burndown chart with/without work team analysis.

The figure 8 shows the graphs of combustion. This schedule is the main tool for tracking completed tasks during a certain period of time or throughout the project. The ideal trajectory is a straight line, which shows that in 14 days it was necessary to fulfill the plan. By the execution time on the left graph, it can be seen that the production team began to complete tasks late, performed tasks in a “relaxed” state and, as a result, was late for 2 days.

Then a Kanban board was started, data using the Trello Rest API was received on CNCIoTCloud. This server also receives data from the machines: preparation time, uptime, downtime, errors that appear. This information was available to all members of the production team. All team members saw what current stage each task is at, which stops its progress: errors on the machine, an unverified machine, or a simple machine.

As can be seen from the right schedule, the production team managed to complete the plan on time, but also worked in a “relaxed” state and could be sent to help another team, or start to carry out the tasks of the next stage.

The use of flexible methodologies in production is a promising direction, but additional studies are needed, because the processes are very specific and do not always fit the solution of production problems. For example, agile methods can be used in the development of control programs together with MDC systems to obtain a complete picture of the current status of the implementation of tasks.

Acknowledgments
We would like to thank the Ministry of Science and Higher Education of the Russian Federation supported in the frame of grant NO. 05.601.21.0019 of 2019 with unique identification number RFMEFI60119X0019.

References

[1] Industry 4.0 Capturing value at scale in discrete manufacturing. McKinsey & Company, Advanced Industries 2019.
[2] Next frontiers for lean. McKinsey Quarterly, 2014
[3] Agile manufacturing: a management and operational framework H Shari®1 , G Colquhoun2 Barclay2* and Z Dann2 First Published June 1, 2001, Sagepub
[4] Browne, J. Future integrated manufacturing systems, a business driven approach. *In Organisations, People and Technology in European Manufacturing* (Ed. P. T. Kidd), 1992,

IOP Conf. Series: Materials Science and Engineering **971** (2020) 052034 doi:10.1088/1757-899X/971/5/052034

pp. 17±30 (Luxembourg Commission of the EEC).

[5] Petr Nikishechkin, Nadezhda Chervonnova, Anatoly Nikich. Approach to the construction of specialized portable terminals for monitoring and controlling technological equipment. *In: MATEC Web Conf*. Volume **224**, *International Conference on Modern Trends in Manufacturing Technologies and Equipment (ICMTMTE 2018)*. Sevastopol, Russia, September 10-14, 2018. pp.1-9.

[6] Martinov, G.M., Nikishechkin, P.A., Grigoriev, A.S. et al. Organizing Interaction of Basic Components in the CNC System AxiOMA Control for Integrating New Technologies and Solutions. *In: Automation and Remote Control*, 2019, Vol. **80**, No. 3, pp. 584–591.

[7] Martinov, G. M., Kovalev, I. A. and Chervonnova, N. Y. (2020). Development of a platform for collecting information on the operation of technological equipment with the use of Industrial Internet of Things. *In IOP Conference Series: Materials Science and Engineering* (Vol. **709**, No. 4, p. 044063). IOP Publishing.

[8] Kovalev I.A., Nikishechkin P.A., Grigoriev A.S. Approach to Programmable Controller Building by its Main Modules Synthesizing Based on Requirements Specification for Industrial Automation. *International Conference on Industrial Engineering, Applications and Manufacturing (ICIEAM)*, 16-19 May, 2017.p.1-4.

[9] Petr A. Nikishechkin, Ilya A. Kovalev and Anatolii N. Nikich. An approach to building a cross-platform system for the collection and processing of diagnostic information about working technological equipment for industrial enterprises, *MATEC Web Conf*. Volume **129**, 2017 *(International Conference on Modern Trends in Manufacturing Technologies and Equipment (ICMTMTE 2017)*.

[10] Martinov, G., Martinova, L. and Ljubimov, A. (2020). From classic CNC systems to cloud-based technology and back, *Robotics and Computer-Integrated Manufacturing*, 2020, Vol. **63**, June.

[11] Martinov, G. M., Pushkov, R. L. and Evstafieva, S. V. (2020). Collecting diagnostic operational data from CNC machines during operation process. In *IOP Conference Series: Materials Science and Engineering* (Vol. **709**, No. 3, p. 033051). IOP Publishing.

[12] Martinova, L., Sokolov, S. and Babin, M. (2020). Organization of Process Equipment Monitoring. In: *2019 XXI International Conference Complex Systems: Control and Modeling Problems (CSCMP)*. Samara: IEEE.

[13] Nezhmetdinov, R., Nikishechkin, P. and Nikich, A. (2018). Approach to the Construction of Logical Control Systems for Technological Equipment for the Implementation of Industry 4.0 Concept. In: *2018 International Russian Automation Conference (RusAutoCon)*. Sochi: IEEE. pp. 1079-1083.

[14] Martinova L. and Martinov, G. (2018). Automation of Machine-Building Production According to Industry 4.0. In: *3rd Russian-Pacific Conference on Computer Technology and Applications*. Vladivostok, pp.1 - 4.

[15] Grigoriev, S. and Martinov, G. (2018). An Approach to Creation of Terminal Clients in CNC System. In: *3rd Russian-Pacific Conference on Computer Technology and Applications*. Vladivostok, pp.1 - 4.

[16] Martinov, G. and Kozak, N. (2015). Numerical control of large precision machining centers by the AxiOMA contol system. *Russian Engineering Research*, 35(7), pp.534-538.