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To cite this article: D A Zakoldaev et al 2020 IOP Conf. Ser.: Mater. Sci. Eng. 734 012123

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Hardware reservation of cyber-physical production of the Industry 4.0

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Abstract. An actual task has been studied to increase the Industry 4.0 production companies functioning safety with methods of cyber and physical systems machine reserving. The production machine reserving shall include some additional components to the technological equipment, which in their functions and properties duplicate the existing low-reliable components. With the method of cyber and physical systems reserving in production they can realize different schemes of assembly units transportation within the smart factory technological lines. Cyber and physical systems reserving schemes could be described as equivalent schemes (chains) to calculate the parameters and evaluate company duplicating efficiency are done according to the methods of the reliability theory. There is a scheme of typical technological line of cyber and physical production. There is a way of low-reliably cyber and physical systems reserving. There is a way of machine reserving of cyber and physical production with a pool of reserved cyber and physical systems. There is a scheme of the Industry 4.0 cyber and physical production transport system duplicating.

1. Introduction

Cyber and physical systems (CPS) machine reserving is [1, 2] an effective way to increase the Industry 4.0 production division reliability. In the production division they apply the CPS reserved components on purpose to maintain the proper condition of technological equipment in the item manufacturing [3, 4].

A single technological equipment component failure or the control computerized system failure lead to failure of the whole cyber and physical production which is unacceptable. Each component of cyber and physical production has their own values of reliability which defines how good they are at their functions completion with necessary level of quality during a period of time [5]. So each CPS failure may define the characteristics of the CPS failure and the item manufacturing technological cycle must be continuous which can be achieved with different schemes of production components reserving which may fail randomly [6, 7].

CPS machine reserving scheme implementation into the Industry 4.0 cyber and physical production structure is an instrument to provide smart factory functional safety where all technological operations
of item manufacturing are being done autonomously [8, 9]. Smart factory functional safety is a part of company security system in general and it defines anti-failure properties of the production infrastructure [10] to minimize the risks and consequences of CPS failure for the personnel, technological equipment, items being done and other [11, 12].

2. Technological lines level reserving
In matrix or cluster production structure there are two ways how to reserve CPS:

- to reserve a CPS of low reliability within a single technological line;
- to create a pool of reserved CPSs as an independent technological section.

Machine reserving in a separate technological line level is a way of low-reliability CPSs reserving where a reserved CPS is engaged to the technological section. From all CPSs in the section, they choose the one with the lowest values of reliability. Such an approach to reserve CPSs may preserve classical organization linear structure for the production division equipment. A reserved CPS could be in this case in the cold state or a hot reserve, which affects directly production preparation values should a technological equipment fails.

A scheme how to reserve a CPS of low reliability within a single technological line is given in figure 1.

To increase reliability and production efficiency by low reliability CPSs reserving leads to the short delays of technological lines during the production tasks re-assignment and small distances to which the transport system transports the assembly units during the item manufacturing. Low reliability CPSs reserving disadvantage is impossibility to repair a technological line if an unreserved CPS has failed.

![Figure 1. Low reliability CPS reservation scheme within a technological line (AWP – Automatic Work Place, IoT – Internet of Things).](image)

3. Reserved CPSs pool level reserving
The creation of reserved CPSs pool as an independent technological section helps to reserve CPSs of all types being used in production. A function of any failed CPS will be substituted by a functioning analogue one from the reserving technological section. The production division increased reliability scheme based on the reserved CPSs pool is given in figure 2.

To increase reliability and production division efficiency the reserved CPSs pool must be placed in closed proximity to the technological line, which is realized in the technological equipment radial placement scheme. CPS placement radial scheme minimizes the production site, which has the CPSs to guarantee short distances of assembly units transportation from the technological line to the reserved CPSs pool.

If a CPS fails the assembly unit being manufactured in it is transported by the transportation system to the scrap isolator and the technological cycle for this item is renewed with a reserved CPS.

![Figure 2. Reserved CPSs pool level reserving scheme.](image)
An important feature of cyber and physical automatic production is a possibility of machine reserve in the level of CPSs if the being manufactured product nomenclature is changed. The item manufacturing route from the technological documentation is not just a consequence of technological operations but also the classes of CPSs engaged in those technological processes. If the technical documentation of a smart factory from a digital factory do not include the full set of CPS, which are available in a cyber and physical production the computerized control system views the non-engaged CPSs as the reserved ones to duplicate the CPSs being used. In this case, the smart factory CPS reserve level in its design just to duplicate the CPSs in some cases could reserve them three times which increases the general reliability of cyber and physical production.

4. Transport CPS reserving
The most important task in cyber and physical production projection is to reserve the robotized transport system. The transport system configuration and longitude and its dynamic properties affects the efficiency of the entire smart factory. The duplicating transport system must transport the production parts for its own technological lines but also for a line the transport system of which is failed. Under such working conditions the cyber and physical production must apply special industrial robots with extended manipulators. An example of cyber and physical production structure with a duplicated transport system is given in figure 3.
the nearing CPSs from the technological line to complete the production tasks. Should one of the transport systems fail the second one is engaged for the both nearing technological lines. The calculation of dynamic properties of both transport systems is for the maximum load, which is appeared during the item manufacturing technological routes completion in the production. If both transport systems work properly the production item transportation is being done with a lower speed and for the shorter distances. This way of the production components duplicating may as well reserve some technological equipment in the matter of time of technological operations completion.

Transport system duplication is a necessary condition to project a cyber and physical production because its failure may shut down the entire automatic technological line.

5. Conclusion
The machine way of reserving cyber and physical production components may increase the Industry 4.0 smart factory functioning reliability. The machine reserving is done for cyber and physical systems and industrial physical lines of production data transmission. The machine way of CPS reserving is a number calculated with the methods of the reliability theory.

Machine way reserving of cyber and physical production main problem is a problem to choose the number of CPSs necessary and sufficient to provide production division continuous functioning. Redundant number of duplicating CPSs application makes the smart factory architecture more complicated and creates additional redundancy in production. Insufficient number of duplicating CPSs may provide cyber and physical production reserving not fully. So they must develop methods of CPS machine reserving to provide the necessary values of digital production functioning reliability.

The Industry 4.0 cyber and physical production reliability functionality values are formed in the technical task requirements and shows the level of reserving of cyber and physical systems (duplicating, tripling and other). Smart factory designer main problem how to increase reliability of an automatic production is to define the low-reliable and highly-loaded cyber and physical systems which in fact are probability characteristics where the technological line in general may fail. Such production components must be reserved in the first hand.

The machine reserving for production reliability increasing make better the level of the Industry 4.0 smart factory protection against failure but does not affect its measures against failure (the personnel and production components protection against the consequences of a CPS failure). To increase smart factory cyber and physical production protection level and measures against failure, which must be done with some special means of protection and some organization means to increase the personnel culture in production.

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