Design of algorithm for creation of modular lines of special-purpose machines in the automotive industry

J Galík¹, R Kohár¹ and T Capák¹

¹ University of Žilina, Faculty of Mechanical Engineering, Univerzitná 8215/1, 010 26 Žilina, Slovakia
E-mail: jan.galik@fstroj.uniza.sk

Abstract. This article deals with modularity of special-purpose machines in the automotive industry. The Slovak economy, by its interconnection to engineering and most to the automotive industry, often solves the lowest costs, whether in the sphere of production or in the field of assembly. This question is associated with the question of special-purpose machines. The design and specificity of each such device results in high development and construction costs. It is important to mention the modularity that is very often used in the design of such devices. Due to the large variability of the automotive environment, it is a big prerequisite for the future rebuilding of equipment, which is usually expensive and time consuming. By looking for connections and bonds between elements, can be created some modules. By creating a modular construction of the device, it is possible, if a requirement comes, to reconfigure the device and prepare it for new production requirements, respectively. Certain algorithms and procedures are needed to design such devices and utilize the modular arrangement of the device. By creating such modular lines, whether in assembly or in production, we are able to save energy, work and money.

1. Introduction

The production of cars is the engine of the Slovak economy, while high demands are made and automation is supported, whether robotic automation or the placing of single-purpose machines in production and assembly. This is mainly due to requirements for production quality, greater flexibility and increased productivity. Automation is also the result of demographic change (the problem of finding enough qualified workers) and to ensure the competitiveness of companies.

The trend is to use dedicated devices for assembly closely related to man, while facilitating the handling of loads or performing more demanding activities, respectively one complex activity at one workplace. Single-purpose machines that do not need (need small) human presence are included in the production. Establishments should perform their function (Figure 1) and by modular construction we...
are able to design devices capable of performing specified tasks. Possible simple modification or inclusion of other module (s) in a dedicated device to meet the requirement for change in the production or assembly.

2. Conceptual design
For any design simpler or more complicated, the designer(s) comes out of conceptual design. The role of conceptual design is the specification of basic machine solutions. The basic step is to identify the main problem, construct functional structures, find work principles and combine them to create a working diagram [2]. The conceptual design specifies a more fundamental solution while providing answers to a few basic questions that arose during the concept approval process.

- Is there a clear definition of the task for the next design process?
- Is there a conceptual design or a well-known solution for realization and design of detail?
- If the conceptual design is used, to what extent should it be used?

The conceptual design and phases they have their succession and must not walk to the end to meet the need for the product [3]. Emphasis should be placed on the creation of product families, respectively products of a very related and modular nature, thus creating the future concept of a reconfigurable production system (RMS). This mode of production is closely related to the product and to the generation of profit and plays a major role in the integration of new products into production [4].

3. Conditions in the automotive industry
Modularly designed single-purpose equipment has a large share in the automotive industry, whether in the manufacturing or automobile assembly. The presence of such equipment in production or assembly indicates the degree of maturity of production. On the basis of this claim, it can be said that car production is one of the most technologically advanced productions.

The design of single-purpose machines is subject to a modular solution for future possible rebuilding, while their development and design is the cheaper matter of different purchased modules compared to robotic solution (depending on the complexity of the solved problem). From the point of view of the degree of automation, the price of equipment is also increasing. Advantages of such devices are lower costs, increased production efficiency, possibly increased equipment automation. The trend of different production changes results in an increasing number of special single or multipurpose modular construction machines. It can be said that the main requirements are:

- Modular solutions, whether manufacturing or assembly machines and equipment
- Development of higher automated machines without human or with little human presence;

Designers should, when designing equipment, place emphasis on concept creation and advancement in the design process to modularity. Purchased parts are used to make the construction cost-effective so that the cost of the equipment is as low as possible. Parts from well-known manufacturers and suppliers are used, while simple complaints are also a requirement.

a. Production
Manufacturers of any single-purpose production machines are subject to a trend of increasing automation and modular machine design. Despite the high price, the equipment is needed because of the growing volume of production and this trend will continue in the future. The need for such machines pushes on their prices, performance, accuracy, environmental and cost-effectiveness.

The concept of manufacturing equipment is, based on a possible transformation, designed to be of a modular type and capable of so-called. “Flexible automation” (module replacement by another module). The trend is set to multi-professional machines, with high dynamics, lightweight construction, reduced need for cutting fluids and the least amount of machining needed (almost
finished products from subcontractors). When designing such production machines, it is also necessary to consider the exchange of tools, the principles of automatic exchange, the presence of quick couplers, tracking gauges, magazine, feeders or other parts of the machine with regard to the degree of automation of the equipment [5].

Any design of a modular or modular system is an effective way to reduce production costs and produce a customer-friendly machine. It is advantageous for the customer if the machine is made of serial components. This assumes that spare parts and possible failures will be easily repairable and economically inexpensive. By using a modular structure and buying larger component units, it is possible to achieve lower prices for the constructed equipment as the purchased parts are produced in larger series and cheaper. With modular construction, it is possible to achieve a short time for a constructed device as well as quick commissioning, low operating costs. The user of such a single-purpose machine receives a machine that is built of tested and matching construction nodes [6].

The development of modular machining centers is directly linked to the development of cutting materials, which allow the work of so-called. High-Speed Cutting (HSC) technology. The HSC designation itself carries high cutting speeds (100 to 10,000 m.min⁻¹) when machining. By using HSC tools, we are able to shorten production times, increase the surface quality of the product, reduce the workpiece temperature and reduce the cutting forces. There is a trend that demand for machines capable of manufacturing HSC technology is growing [7].

The production of parts for the automotive industry is dominated by entire modular lines, which are designed to form a system of interconnected devices, individual manufacturing operations and do not need an operator. Typically, such lines are split, either to current (production sites in the series) or to multi-flow (parallel to series workstations). With the modular characteristics of the line, it is between the individual workstations via conveyors and conveyor systems. All functional relationships are secure and operate in an automatic cycle [7].

b. Assembly

Assembly single-purpose machines increase the degree of automation on production lines that replace people or make it easier for him. These include a variety of fully automatic, semi-automatic, manipulators, feeders, or a vision-checker and similar type control function.

The trend for the future is the concept of cellular production [8], so assembly will take place in a given cell, with the product being assembled going from cell to cell and acquiring new product contours for the customer. At such workplaces, the presence of modular single-purpose, but rather multi-purpose, devices will be required to fill multiple functions at once. Modular construction of such devices will be a necessity, for a possible or a very likely production reconfiguration [9].

4. Modularity

Modularity and design of modular components combine the use of the same or similar components to achieve a particular modular solution. Parts and components used in modular designs must ultimately be connectable and assembled. The creation of modular products can be perceived as a design of units fulfilling their function, making it possible to connect between them and to function as one complex product. At design parts, the emphasis is on making the interaction between the components as low as possible and making the proposed components independent. Each modularity component should support one or more function. When assembling parts together, a whole is created that supports one or more functions. By structuring the overall product, the resulting product should be able to support a larger function or a general function, it means the basic analysis of functions, which can be supported by different modules, is very important by creating modular products.

A good example of a comprehensive modular device is a car that, with its modular structure, has as its main objective to move the driver from point A to point B, and can perform several functions, such as transportation of other persons, goods, etc. It consists of a number of modules such as steering, brakes, body, chassis, tires, engine, and transmission. A customer buying a car can upgrade the car and configure it with additional modules (air conditioning, various steering, starting, tracking…) [10].
Figure 2. Module functions and modules and mixed production system [3].

a. Types of modularity

The modularity system can be applied in a number of sub-activities such as product design, process design, manufacturing system design, or combinations thereof. The best choice is to combine these three industries, their combinations and their simultaneous use, designing modular products, manufacturing them with modular processes and modular manufacturing processes.

- Product modularity- products that perform different functions through a combination of different building blocks or modules that perform the main function and this function can be subdivided into functions that can be filled by other components or modules. While the core should have sufficient capacity to handle all expected and unexpected variations.
- Modularity in product design- most design problems can be broken down into smaller, simpler sub-issues, where a small change in the problem can lead to a change in other higher-resolution solutions. An important part is the separation of individual problems and solutions so that they do not interact.
- Modularity in manufacturing systems- it should be said that it is primarily a focus on the construction of standardized modular machines. In practice, there is a large number of requirements that, together with the lack of agreement, has created a great deal of diversity in the design and building blocks of machines in this area - there are no standards in this area.

When creating any production system from dedicated devices, it is necessary that the production machines are defined in groups to form a modular system to meet the requirements of each group. The production machines can be divided into 4 groups and are basic or "primitive" parts, drives, modular basic elements, configurable control units. By using these parts, it is possible to build a diversifiable, efficient, automatic and integrated production system [10].
b. Category of modules
Any modular type device is built up of units with little or no dependency on each other. Two basic types of modules are function modules and production modules. For function modules, modules need to perform their function, either alone or in combination with other modules. Production modules are mainly subject to production requirements, so they need to be filled. The modules themselves can be based on different types of functions, and these functions are repeated throughout the system (basic, auxiliary, special, adaptive and customer) [10].

Modularity can be of a different character. If a modular series is created where the individual elements are similar and differ only in size, it is size modularity. When modularity elements are included in the system so that it is possible to use different types of modules per basic module, it is functional modularity.

c. Creating modular units
In modularity, it is important how individual sub-module assemblies are interconnected and can be based on different module combinations. The relationships between the modules are based on the interaction analysis with each other and with the final product. We have several variations of linking:

- Component interchangeability- type modularity that belongs to the same product family, combining two or more components with the same core component. Figure 3a shows the construction scheme of the aforementioned modularity and describes the interchangeability of the individual components with the ability to connect to the base module.
- Sharing components- this is a type of product linking when different products from different modular designs share the same core component. A very similar type of modular connection like the previous type (Figure 3b).
- Size variation- has several standardized components with one or more additional devices. Frequency is often associated with physical dimensions. (Figure 4a).
- Bus modularity- this is a type of modularity when one module can be exchanged for another module in the base assembly. This type of modularity allows for a large number of interchangeable variations (Fig. 4b).

![Figure 3.a Component interchangeability.](image1)

![Figure 3.b Sharing components.](image2)

![Figure 4.a Size variations.](image3)

![Figure 4.b Bus modularity.](image4)

d. Creating modular systems
The design of modular systems is possible only on the basis of a thorough analysis and division of the system into basic functional elements that characterize the basic physical principles and are integrated into the components of the modular system and capable of performing their function. The first key
The point in the creation of a modular system is the decomposition to basic problems. The second point is the integration of individual subsystems into an overall solution.

The structural problem decomposition system has at least two pros. The first is the simplification of the overall problem to smaller, solvable parts and the second is the possibility of a parallel solution of individual parts of the complex problem (to shorten the solution of the overall problem). Decomposition methods can be categorized according to where they were used, e.g. product decomposition, problem decomposition, process decomposition.

Product modularity is the ability to replace some component of the same or similar physical properties with other products of the same or similar properties. Modularity depends on physical properties between components. The system is divided into subsystems, sub-assemblies, assemblies, components leading to products and a particular design. The entire decomposition is captured in a hierarchical structure, along with dependencies between the subsystems.

The distribution of the whole system consists of constant simplification up to the basic ("primitive") element, which is independent of each other, respectively. Dependent as little as possible. The interrelationships between products should be taken into account as constraints on higher sub-issues. Problem decomposition is composed of decomposition of requirements, decomposition of constraint parameters and decomposition of basic design values. The requirements are constraints on solving a design problem. It starts with basic requirements and ends with specific (customer) requirements. The layout of the requests and the relationships between them are represented by a tree diagram.

5. Design algorithm of modular lines
In this part of the article, which deals with the creation of an algorithm for the design of single-purpose machines and devices in the automotive industry, it is necessary to say that the proposal is based on three key parts:

- Device planning (5.1)
- Concept creation (5.2)
- System design (5.3)

Subsequently, the whole algorithm is discussed in chapter 5.4, taking into account the fact that it is an automotive environment and what is often an environment that is subject to change and the construction of machines working there is an expensive matter.
a. Device planning
Designing using conventional methods does not give designers as many solutions as possible using new methods. By incorporating new materials, technologies, processes and other factors into the design process, we can design new combinations that will serve better solutions. Designers should occupy design points that need to be improved, summarized in the following points:

- Improvement of technical, quality, safety functions
- Weight and space reduction
- Reducing economic intensity
- Reduce delivery time
- Improving production methods

The importance of these points is different from proposal to proposal. While the impetus for improvement may be the need to improve one of the aforementioned points and create a new working principle on the basis of which the device will operate. New inventions include a fundamental solution, modifiable in manufacturing methods, based on lower prices and shorter delivery times. Therefore, the plan needs to be well thought out and to determine precisely what the facility is going to perform and to determine the exact working conditions together with the continuation of other working procedures, possible future changes [1].

b. Concept creation
Creating concepts can be said to be one of the most important parts of the equipment design process (often underestimated), because it is precisely in the creation of concepts that we are able to influence future equipment, its shape, cost of production, selling price, performance, and so on. By design, it is necessary to formulate the working principle of our modular product at first. The principles must meet the functional requirements, most of which are based on the competitor's experience, patents, and catalogs [11]. The formulation of construction requirements plays a role in mapping relationships between individual working principles. All the principles are evaluated in the table using important criteria, thereby separating the non-essential ones for the designer. The matrix itself is later decomposed and the design modules are defined. By systematically combining working principles, we are able to create variations of construction modules and then build upon them to build a modular design family scheme of the desired device [2].

c. System design
The design of the device is progressively made up of modules that are suitable for use in equipment, both economically and technically. After analyzing and evaluating the modules based on the criteria, the product structure is written and the modular product family is assembled. The final product is subjected to a practical assessment. If the design of a modular construction does not meet the requirements, a return to the design process is needed, and more specifically to the point of combination design and selection of device module variants. Subsequently, the design process proceeds to the next points, where the design of the device is detailed [1].

d. Algorithm design
The resulting algorithm is based on the previous chapters; their task was to bring the process of creating a device to a modular character, and this can be true not only in the automotive industry but also in other industries. The automotive industry has its rules and time plays a major role, along with other important conditions (see Chapter 3).
6. Conclusion
The article was intended to provide the reader with an insight into the design of machinery in the automotive industry, whether manufacturing or assembling. Mostly designed devices relieve people from labor, either work with it or replace it, thereby reducing costs. The proposed algorithm is the nature of a flowchart and gives the reader guidance on how to deal with the problem. Obviously, the design needs to take into account the requirements of the automotive industry and it depends on the designer/-s how to cope with the problem and what values (importance) they will give when creating classification schemes for individual requirements.
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