MODULAR DESIGN OF UNCONVENTIONAL CUTTING MACHINE TOOLS

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Abstract: Modular design provides development and implementation in different stages of the products during the whole life cycle. In this paper, based on the principle of modular design, an unconventional cutting machine concept is presented. The modular design strategy of the unconventional machine includes water jet, laser beam and plasma arc cutting. The developed modular system of the unconventional cutting machine and its modules are illustrated as an example. The result is a competitive cutting machine which gives a sustainable market solution and answering customer requirements for various options with reduced expenses of the manufacturing.

Keywords: unconventional machining processes, cutting, modular design

1. INTRODUCTION

Today's manufacturing is facing ever-growing requests on a daily basis. System flexibility, productivity, quality, reliability and cost savings of manufacturing are the most vital requests facing the market-oriented company. If manufacturing firms are to meet these high market requests, the imperative is to adopt new production methods.

Modular design method is one of the significant solutions to realize modern product solutions. The concept was first presented by Star in 1965 [1], where the use of modular product in manufacturing processes was proposed. This is an issue that was constantly investigated and today modular design concept has been presented in many fields of design and manufacturing.

In this work is presented investigation of the modular design of machine tools for unconventional machining processes in terms of cutting operations. The objective of this research is to investigate development trends of the modular design of unconventional machines for Water Jet Cutting (WJC), Laser Beam Cutting (LBC) and Plasma Arc Cutting (PAC).

2. MODULAR DESIGN

Modular design is simple, flexible and reliable construction method, which modernized production by introducing more efficient ways to build the products, especially those with many complex parts and assemblies. The modular design is a new trend of designing complex systems as a series of standalone objects. Each of these can be built by themselves and stand on their own until the system is ready to accept them. It involves separating a product into definable smaller units.

2.1 Benefits of the modular design

Modular design has many benefits. The modular design is economical because it allows production of safe parts which find their way into a strong market requests. Also, there is efficiency in production. The modular design means that it is now possible design and manufacturing implemented in parallel. This means that building the product is just a series of finished modules that come together to become a unity.

Besides reduction in cost of development, design and manufacturing, modular design offers other benefits such as adding new solution by merely plugging in a new module, reusable parts and assemblies, transparency and manageability of modules etc. An especially benefits of the modular design are standardization of components and processes.

2.2 Modular design of machine tools

Modern manufacturing systems are leading to considerable changes in the way of design and manufacture of machine tools. Bases to this change are the adoption of modular methods of machine tool construction. The benefits include shortening machine design time, improved machine reliability, reduced construction costs and simplifying service. Furthermore, modular machine tool construction is increasingly becoming an important mean of flexible manufacturing automation.

Engineering research and development into the modular design for machine tools was first launched by Koenigsberger in 1968 [2] and since then these technologies have been further advanced. Thereby, the modular principle into machine tools design has not been sufficiently studied so far in the academic sphere.
but has already been developed on the basis of long standing practical experience. Various examples of modular machine design have been seen in modern manufacturing systems like machining centres, transfer lines and flexible manufacturing systems. The developing history of the modular design for machine tools can be found in [3].

In order to improve manufacturing efficiency, methods of designing machine tools must be simple and practical. In this context, it is suitable to use modular design of machine tools, in which manufacturing consists of components and controllable processes. In machine tools analysis, a module is understood as a group of elements of the system which may be used autonomously or in combination with other modules. The use of the modular design concept allows the machine tool system to be regarded as consisting of a number of modules. Thereby, modules are subsystems that functionally and structurally are independent and perform controllable executive motion in manufacturing [4-6].

3. UNCONVENTIONAL CUTTING TECHNIQUES

There can be little doubt that production technologies will remain important in today's manufacturing industry. Especially important are material cutting operations as the integral part of manufacturing and assembly processes [7-10].

Modern world largely implements cutting operations which are supported by novel technologies, which are based on completely new machining principles. These manufacturing processes are defined as a group of methods that remove the material by various techniques involving mechanical and thermal energy, but do not use a cutting tools as it needs to be used for traditional manufacturing processes. Among them are extracted unconventional technologies which produce precise and high-quality cuts on all sorts of materials: difficult to machine materials, very fragile materials, complex-shaped parts, etc. In the first place [11-13], they are Water Jet Cutting (WJC), Laser Beam Cutting (LBC) and Plasma Arc Cutting (PAC).

Observed unconventional methods of cutting utilize high-power kinetic or thermal energy of the working flow (water jet, laser beam or plasma arc) to remove the material. The basic principle of the unconventional cutting techniques is shown in Fig. 1.

These machines have a similar structure, designed for processing a wide variety of plate materials. Basic structure of the unconventional cutting machine consists: base of the machine tool, working table, extraction system, motion system, drive, cutting head and nozzle, energy source and controller unit.

In this paper will not be considered which of these three unconventional techniques is best suited for cutting materials. These techniques and their comparisons are illustrated in Fig. 2, where are seen cutting area and some of the differences between them.

3.1 Water Jet Cutting

Most theories explain water jet cutting as a form of micro erosion used material. Through a small orifice in the nozzle extreme pressure of the accelerated pure water or together with abrasive particles, in a small area of the workpiece develops small cracks. Water jet machining is in use more than half century. Due to the uniqueness of water jet cutting, there are many applications where it is more useful and economical than standard machining processes. Pure water jet cutting is used mostly to cut softer materials such as wood, plastics and aluminium. Together with abrasive means this method is successfully used for cutting strength materials such as steel, ceramic and composite material.

3.2 Laser Beam Cutting

Laser beam cutting is a thermal process that utilizes a high energy of light beam to melt and vaporize material particles on the surface of the workpiece. Advantage of laser beam cutting are: no limit cutting of hard and fragile materials, cost effective and flexible process, high accuracy parts, narrow heat affected zone, no tool wear, etc.

This process is used widely for cutting, drilling, welding and marking of metallic and non-metallic materials. Laser beam cutting is being used extensively in the mechanical, electronic and automotive industries.

3.3 Plasma Arc Cutting

Plasma arc cutting is a thermal material removal process via the heat generated from an ionized gas, which is produced by applying an electric current. The plasma arc cutting has always been seen as an alternative to the oxy-fuel process. Plasma arc cutting is characterized: low capital cost, high speed of cutting, increased quality of the cut, low finishing costs, mobility, cutting of all positions, etc.
Plasma arc cutting is used for industrial production cutting of all materials. This process is chiefly used for cutting bulky sections of electrically conducive materials. Plasma is the fastest cutting process on carbon steel, aluminium or stainless steel.

4. MODULARITY OF THE UNCONVENTIONAL CUTTING MACHINE

The modular design for unconventional machine tools is the real example for mode of complex technical systems standardization. This means composition of great number of common modules, produced from standard or non-standard elements composed in a functional composition of complex unconventional machines. Efficiency and reliability of the modular design of these machines allows designing complex modules from different elements which are checked in design and technology meaning.

4.1 Modular strategy for design

In industrial practice a variety of unconventional cutting machines exist, yielding a number of different technical, technological and economical levels. As with any purchase, the wants and needs must be weighed well. Closely examining machine needs can minimize unnecessary expenditures.

There are different criteria for classification of unconventional cutting machines. Selection of these machine tools includes: power, size of the work area, number of cutting heads, level of controlled axles, etc.

These requirements most effectively modular design strategy implement. The modular system offers optimum technology of design for different types of the unconventional cutting machine, while having to meet the specific conditions of the cutting process. All requirements have to be covered with detailed analysis of various options, combined with extensive engineering expertise.

Due to the specifics of each of the unconventional processes, there are elements, objects and systems that are common, as well as those that are unique to a given case. The main composition of the modular system of unconventional cutting machine is shown in Fig. 3.

Fig.3. Modular system composition

4.2 Modular conception

Because of high price of unconventional cutting machines and specific production conditions, modular design is one of the significant solutions to implement these machines. This modular design is complicated, but flexible and considerably cheaper.

The developed standard variant of the modular design of unconventional cutting machine is illustrated in Fig. 4.

Fig.4. Modular design of the unconventional machine

If customer designs unconventional cutting machine, manufacturer can produce part of equipment or to order it from another supplier. For most of the production conditions it is possible to produce basic parts of machine tools structure. Energy source, drive system, control unit and nozzle are usually ordered from specialized producer of equipment parts.

The unconventional machine structure is usually produced according to own flexible system needs. Shown in Fig. 5 is upgradeable bed of the machine tool with slide and guide rails. The scalable modular motion system is shown in Fig. 6.

Fig.5. Bed of the unconventional machine

Fig.6. Modular motion system

Shown in Fig. 7 is possible variant of the modular design unconventional cutting machine with extended working table. This concept uses the flexible bed of the machine and a replaceable transverse bar with more cutting heads.
The presented modular design of unconventional cutting machine allows that all standard options are easily installable as a module afterward and enabling a machine upgrade to the customer’s wishes. This is a perfect example of how a modular design concept makes it possible to make small changes to existing designs to create an unconventional cutting machine with custom capabilities.

5. CONCLUSION

Modular design of machine tools is completely different substantially from traditional approaches to design. Historically, modular principle of design has been based on experience. The modular design of unconventional cutting machine, because of the high price of equipment, economically is much approved procedure. The presented modular design of unconventional machine allows efficient construction of elements and systems to be ensured a good design. It is flexible machine which allows answering customer requirements for various options. This modular composition of the machine offers optimum value of technology for various types of machining sheet materials.

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7. REFERENCES