6.1 AUTOMATIZED PRODUCTION SYSTEMS

The manufacturing means determined for the mass and large lot production are the attendant phenomenon of globalization which surrounds us. Their abilities i. e. to produce a great quantity of identical parts quickly, precisely and cheaply are their indisputable advantage, therefore the production lines and single purpose machine tools have their justification on the market with manufacturing technologies. Automation of manufacture is the natural process motivated by the increase of production and manufacturing quality as well as by the elimination of people of the direct service activities in the manufacturing process.

Macroeconomics is based on a lot of principles. On this place it is suitable to mention four of ten generally respected principles [Mankiw 1999]:

- trade can make everyone better off (fifth principle);
- markets are usually a good way to organize economic activity (sixth principle);
- governments can sometimes improve market outcomes (seventh principle);
- a country's standard of living depends on its ability to produce goods and services (eight principle).

Especially the eight principle (reality of the country, of the nation, of the individual person) is directly related to macroeconomics of the company and its ability to manufacture the objects of final consumption.

Automation of technological processes cannot be limited only on the machine itself. Automation also includes automatized transport, manipulation with material, inspection and measuring, etc. Intensification of manufacture is connected inseparably with the replacement of the physical participation of people in the manufacturing process by the automatized production systems (i. e. by the combination of machineries for technological processes, e. g. machining centres with manipulation, with transport). The current state and development trends in the production manufacture field are influenced considerably by computer technology which has the influence on the numerically controlled machine tools, automatic lines and robotic workplaces as well as on the unattended workplaces.

Automation is considered to be one of the ways how to keep the manufacturer on the world markets in the conditions of sharp competition which the manufacturer can stand only if it is able to manufacture more cheaply, more quickly and with bigger quality than the other ones. At the current time the automation development takes place in these directions:

- transition from the semi automation of the particular technological operations and interoperation manipulation with workpieces to the complete automation of manufacturing processes – origination of production systems (especially of flexible production systems);
- computer support of the still and still bigger share of the human creating activity which is necessary for the manufacturing course (designing, procedures, data sharing, cloud applications for manufacture and others);
- development of new manufacturing principles and technologies (this need not concern directly the chip machining but they have an impact on the chip machining technologies).

The first two mentioned directions mingle in so called CIM (Computer Integrated Manufacturing), the third direction changes the manufacturing procedures established up to now. The numerous applications confirm that the development (within the particular manufacturing enterprises as well as in the branch of manufacturing technology) takes place in three stages:

- 1st stage – the unit built arrangement of all machine tool types having a different automation degree (conventional machine tools (CMT, operated manually);
- numerically controlled machine tools (NCMT), machining centres (MC), multiple spindle machining centres (MSMC), single purpose machines (SPM);
- 2nd stage – a higher automation level in the form of flexible production cells (FPC), flexible production (manufacturing) systems (FPS, FMS), flexible production lines (FPL) and hard automatic lines (HAL) utilizing dedicated single purpose stations/machines;
- 3rd stage – automated production systems (APS) on the level of a workshop or of the factory (see Fig. 6.1.1).

We are now in modern world Industry 4.0. Industry 4.0 has a lot of content and is very close to APS. It adds to automated production systems new technologies such as virtualization, simulation, digital prototyping, internet of things etc.

Not all manufacturers pass from the conventional machines to the single-purpose machines in the first stage. Transition to the CNC machines appears in the most often cases, even in the second decade of the 21st century. There is a huge quantity of the conventional machines in the world which are replaced step by step in dependence on the possibilities, plans and strategies of the particular companies.

This book deals with the machining centres extensively in the particular sections. There are special design solutions of the machining centres available which can be compiled to the line. The text of this section will return later to these centres. Thanks to the electronic control and – besides other things – to the development of tooling systems, the single purpose machines can be more easily reconfigured than at those

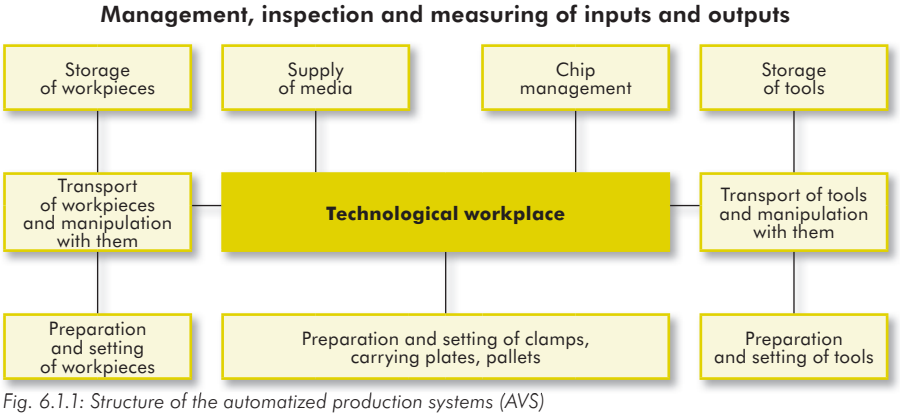


Fig. 6.1.1: Structure of the automatized production systems (AVS)

times, when only the cams and replaceable gears represented the base of technical solutions for manipulation devices. The term "automatized production system" includes one or more technological workplaces, where all material and information flows are automatized and they form the comprehensive system. Fig. 6.1.2. shows the structure of the automatized production system. In principle it consists of four workplace types: flexible production cell (FP), flexible production system (FP), flexible production line (PVL) and hard production line (HA).

The automatized production system is distinguished by the controlled manufacturing process determined to make various parts or products according to the particular possibilities of the arrangement, in dependence on the plan specified in advance. The manufacturing enterprise decides to use the automatized production system, because it wants to have higher production, smaller manufacturing costs and the stable manufacturing quality. The input costs for implementation of the automatized production system are considerable up to huge. The automatized production system is the efficient manufacturing tool which is able to ensure the position of the industrial enterprise regarding to the productivity increase. In many cases this is the only tool how to provide the mass production with the top quality (there are not so many qualified workers on the labour market in the particular region, etc.). The automatized production system leads to the higher capacity utilization of machine tools and at the same time, its application is the prerequisite for the unattended operation – CIM. The flexibility of the automatized production system enables to manufacture such workpieces which are needed on the consumer market.

The automatized production systems have big impacts on the changes of the employment structure. The new manufacturing technologies and principles including the operation of the automatized production systems cause the origination of new professions and completely different qualifications of employees, than it was when the conventional machine tools and the CNC machine types were used. The manufacturers of machine tools dealing with the development and manufacture of the automatized production systems also need the engineering designers as well as e. g. specialists in logistics, databases, computer networks, etc.

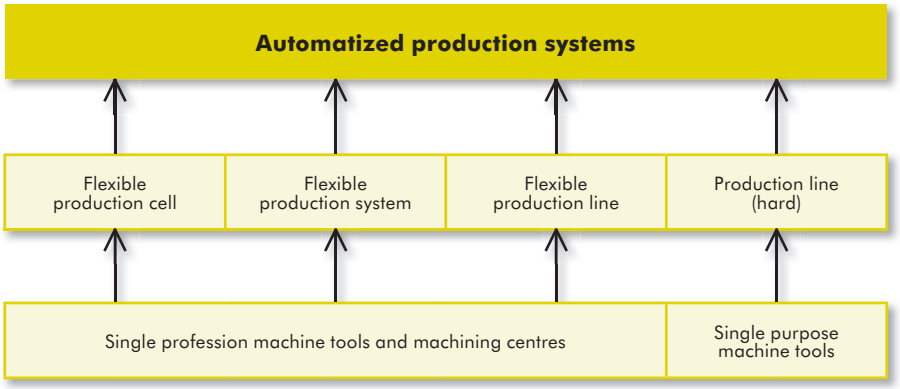


Fig. 6.1.2: Utilization of machine tools at the particular types of the automatized production systems

The technological subsystem is formed by various machine tool types (Fig. 6.1.2). The automation development results in the fact that all machine tools used in this technological subsystem should have the unit built concept (the machine itself, machine control and its connection with the manipulation device). This enables the manufacturer of the production machinery to deliver a big number of modifications (so called supplier's flexibility) for the particular product and the particular manufacturing type in the optimum technical and economic variant. The economic assessment what manufacturing type and what machinery shall be used must create the inseparable part of every project. The term "economic review" is used for this activity. Fig. 6.1.3 shows the graphic expression of the costs needed for the product and the manufacturing volume. When a particular machine (a unit-built module) is chosen, it is possible to use the criterion: manufacturing time, number of operations performed on the product and its size. The implementation of the automatized production system has its benefits in the considerably bigger number of working hours (Fig. 6.1.4) and in the quick economic payback period (Fig. 6.1.5). These machine tool types are used to implement the automatized production systems:

- single profession CNC machine tools (CNC M);
- single spindle machining centres (SSM);
- multiple spindle machining centres (MS);
- single purpose machines (SPM).

In the 21st century the automatized manufacturing systems are predominantly based on the machining centres and

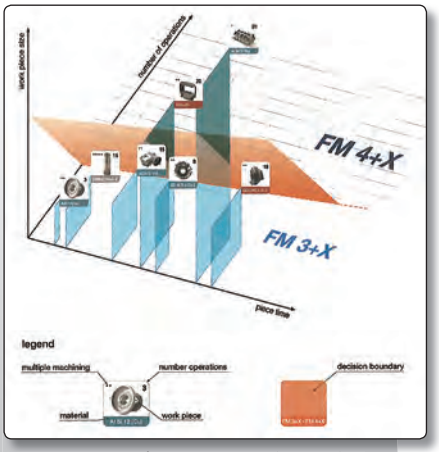


Fig. 6.1.3: Manufacturing time, the number of operations and the workpiece size serve to choose the manufacturing machinery [Elha]

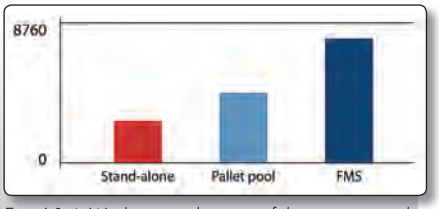


Fig. 6.1.4: Working productivity of the automatized production system expressed by the number of spindle operating hours [Fastems]

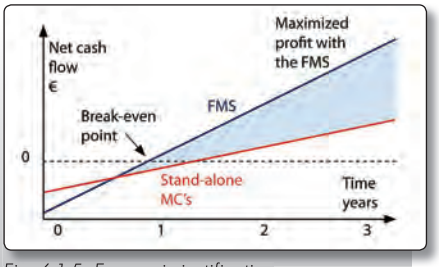
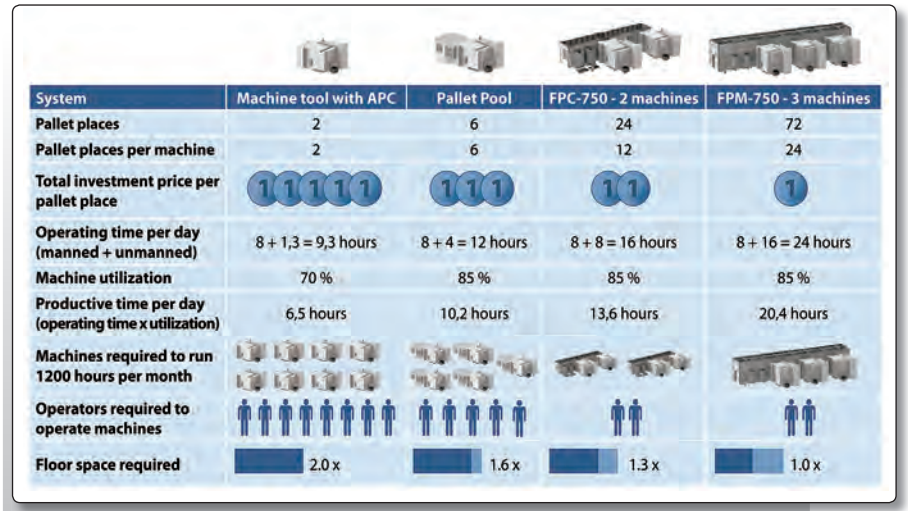


Fig. 6.1.5: Economic justification of the automatized production system [Fastems]



System	Machine tool with APC	Pallet Pool	FPC-750 - 2 machines	FPM-750 - 3 machines
Pallet places	2	6	24	72
Pallet places per machine	2	6	12	24
Total investment price per pallet place	1 1 1 1 1	1 1 1	1 1	1
Operating time per day (manned + unmanned)	8 + 1,3 = 9,3 hours	8 + 4 = 12 hours	8 + 8 = 16 hours	8 + 16 = 24 hours
Machine utilization	70 %	85 %	85 %	85 %
Productive time per day (operating time x utilization)	6,5 hours	10,2 hours	13,6 hours	20,4 hours
Machines required to run 1200 hours per month				
Operators required to operate machines				
Floor space required	2.0 x	1.6 x	1.3 x	1.0 x

Fig. 6.1.6: Benefits of transition from the machine having two pallets to the more sophisticated automation ways [Fastems]

numerically controlled (single profession) machines, even in the case when there are no requirements on the quick change of the manufactured product. The benefits can be seen in Fig. 6.1.6. This section will say more about the adaptation of the machine tools for their utilization in the automatized production systems. It is valid for the numerically controlled machine tools – and the same is valid for four mentioned machine types including the up to date single purpose machines – that they eliminate the human factor from the machining process and they can use the tools for the active check of the machining process. The design of the CNC machine tools is adapted for work in the unattended workshops, which is especially caused by the fact that they have the automatic tool exchange and the automatic workpiece exchange available, they work in the automatic cycle and moreover, they are equipped with diagnostics. The independent sections deal with the machines and with their possibilities in more details. A part of this section deals with the single purpose machine tools.

The single profession machine is understood as the machine using one kind of the chip machining technological operation, e. g. milling machines, turning machines, etc. Another possible division is to divide the machines into the machines specified to make rotary workpieces and into the machines specified to make non rotary workpieces.

The single spindle machining centres enable to implement more technological operations. The workpieces can be machined at one chucking from one side or from all sides, in dependence on their design. The single spindle machining centres are divided into the machining centres specified to make rotary workpieces and into the machines specified to make non rotary workpieces. In both cases the spindle can have the vertical axis as well as the horizontal axis.

The multiple spindle machining centres opened the efficient production rationalization for the branch of the middle sized lot production. They can be in the type with fixed spindles or they are equipped with operation heads. The operation head is transported according to the sequence determined by the program into the working position to perform the technological operations. The operation head size determines the working figure size. The concept results from the proven principles of the single purpose machines. The distinguishing criterion is the motion type of the operation head at its exchange. It can be the rotary one (around the vertical axis or the horizontal axis) or the straight one (reversible continuous).

The single purpose machines are determined to machine the workpieces in the branch of the large lot production and the mass production. The single purpose machines are designed in the simple way and they have the following advantages:

- in order to machine small workpieces, the working units are arranged to the rigid frame creating the working area at the same time;
- in order to machine middle sized or larger workpieces, the working and position setting units are located in the lower part (on the supporting frame);
- they are formed by the unit built structure of the working, position setting and additional units located in the lower part creating the machine frame;
- the assembly groups which the machines are compiled of are made in series (lower price, higher quality, reliability);
- if the production program is changed, the unit built elements can be used for the composition of a new machine. More often, in the automobile industry case, after the series production is finished, they are moved (re-sold) to the companies dealing with the manufacture of spare parts.

The following subsections mention the essential terms which are important for the unified terminology.

Mechanization – it means the utilization of the technical tools whose mutual cooperation is provided by the human factor. The operations are performed by transfer of the mechanical, electrical, pneumatic or hydraulic energy, or – may be – by their combinations. The selection of operations, their start, the process control and the working cycle end are provided by people. Mechanization serves to eliminate the exhausting human work.

Automation – it means the utilization of all measures (e. g. of technical tools), with the help of which the partial processes or the whole processes (e. g. manufacturing processes) run automatically according to the previously entered program. The automation target is most of all to bring economic and technical advantages. Said shortly, automation is the replacement of human work with automats having the aim to replace people.

Flexibility – the term "flexibility" appeared with the automation development. We recognize altogether eight degrees of flexibility [Borský 1992b]:

- mechanical flexibility – ease by means of which it is possible to perform the changes necessary to manufacture the particular set of workpieces;