Automation of machining

- Is connected with the rising demands of society and industry development.
- Is the way to intensification of manufacturing – increasing productivity, improving quality and lowering costs.
- Is the way to improvements in manufacturing technology, spreading the technological possibilities and way to make the innovation cycle faster.
What we need to automate?

- Tool management
- Tool change
- Tool movements
- Spindle start, devices start
- Material loading
- Finished piece remove
Automation Of Machining

**Machine tools:**
- general-purpose, manually operated (conventional);
- *The leading power is the worker*
Automation Of Machining

**Machine tools:**

- **automated:**
  a) *fixed automation* – mechanisms: cams,
  gear wheels, links, levers, arms;
  mechanical stops, limit switches, etc.
  b) *flexible automation* – program control, numerical control
Fixed automation elements

a) cylindrical cam

b) disc cam
Cam

Is a disc or cylinder with a curve shaped path. A boss in support is in the path and as the cam turns the support moves. Cam are connected together to provide complex movement of support, feed, rotation and other.
Cylindrical cam use – automatic lathe carriage
Disc cam use –
automatic lathe cross slide
Fixed automation machine tools

- **automatic general-purpose machine**
  e.g. a semiautomatic or an automatic lathe

- **single-purpose machine** (usually unit-built)
  workpiece oriented function design

- **transfer line**
  integrated workpiece transport system
Video – CAM lathe
Unit-built machine
Feed drive unit - EV
Drilling spindle unit - BO
Slide unit - SE
Circular indexing table unit - TA
Modular units design
**Single purpose machine**

- Just one operation, of op. Step is done.
- Sometimes a batch of operation steps
- Special machine designed to maximize the production:
  - Multiple spindles
  - High feed drives
  - Multiple clamping
  - Automatic part in feed
  - Special tooling usage
Single-purpose machine efficiency
Transfer line – a concept

An illustration of a typical transfer line
Transfer line – a schema

Workpart transport system

Starting work units

Stations: 1 2 3 n-1 n

Partially completed work units

Workstations

Finished parts or products
Transfer line – a design
Engine block machining transfer line

Inner motion transfer line
Transfer line station – an example
2) Flexible Automation

- (soft, programmable automation) is aimed at piece and small batch production due to easy reprogramming.

Two basic forms
- Program sequence control
- Numerical control
Program sequence control

The sequence of motions and switchings is controlled by relays, timers, switches, perforated tape, programable cylinders, plugboards and other controllers.

Easier reprogramming, limited program options, almost no adjustments
Perforated tape

Each line presents a different movement or switch. It has to be printed correctly, no error control.

FYI:
8 line perforated paper tape can contain one byte of information in one column of holes. Normal pitch of columns is 2,54 mm. That means you need 2,6 m of tape to store 1kB of data. A dual-layer DVD is then approx. 22100 km of perforated tape.
Numerical control

- The most important type of automation. Almost all of new machines are numerically controlled.

Principle:
Machine and all of its movements are controlled by a program. Program is a list of instructions written in a specific syntax and having specific format.
Mechanical vs. numerical

- Limitations – speed, length of program, possible motions on cams.
FLEXIBLE AUTOMATION

1. Conventional machine tool
2. **NC machine tool** (stand-alone)
FLEXIBLE AUTOMATION

3. NC machine tool with tool magazine
4. CNC machine tool
Mechanization vs. automation

- Mechanization – human power is replaced by machines, drives, hydraulic or mechanic devices

- Automation – human control is replaced by sequentional machine, cams, computer, PLC controller
Automation degree

- **Semiautomatic run** – tools are changed automatically, blank or finished workpiece is renewed by operator

- **Automatic run** – both the tool and pieces are placed and removed automatically by robot (line, tables)
NC / CNC definition

Originally only NC control was used. Program was stored on tape or disc and read one line after another.

Influence of rapid development of computers resulted to CNC control (Computer numerical control). Now the program is loaded into computers memory and executed from here.
## CNC advantages

<table>
<thead>
<tr>
<th>Option</th>
<th>NC control</th>
<th>CNC control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Program length</td>
<td>Limited by data storage capacity (tape)</td>
<td>Unlimited (limited by data storage capacity – HDD drives over 1TB)</td>
</tr>
<tr>
<td>Program sequence</td>
<td>One line after another</td>
<td>Allows jump forward, backward, subprograms.</td>
</tr>
<tr>
<td>Jump to other programs</td>
<td>N/A</td>
<td>Yes</td>
</tr>
<tr>
<td>Canned cycles</td>
<td>N/A</td>
<td>Yes</td>
</tr>
<tr>
<td>Coordinates correction</td>
<td>Manually only</td>
<td>Yes, automatically</td>
</tr>
<tr>
<td>Tool length compensation</td>
<td>Manually only</td>
<td>Yes, programable</td>
</tr>
<tr>
<td>Tool diameter compensation</td>
<td>N/A</td>
<td>Yes, programable</td>
</tr>
<tr>
<td>Reading in advance</td>
<td>N/A</td>
<td>Yes, continual mode</td>
</tr>
<tr>
<td>Start after breakdown</td>
<td>N/A</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Program sequence

Subprograms

- A link to another then the following line is entered into main program.
- This subprogram is executed.
- After finishing this program we return to main program and we continue until end of main program (M30)
Basic principles of CNC machines

- NC/CNC machine consist of 3 basic elements.
  List of instructions – NC code – a mix of alphabecial and numerical information. Contain information about movements, feed, speed, tool change and other machine functions (cooling, measuring)
  Control unit - control system – converts the program into signal for machine and send them to machine (PLC controller)
Basic principles of CNC machines

- NC/CNC machine consist of 3 basic elements. Machine tool – fitted with drive motor to operate slides, support and spindle. Also with switches to start/stop specific functions.
- Sensing device – optional (closed circuit) - sensing device control if a specific demand was fullfilled. Support feed, Table position etc.
CNC machine tool
Motions

Three types of motion

1) point-to-point motion – tool is moved to specific location, path or speed of move between location is not controlled. (drilling)

2) Linear control – movement along one of the axes of the machine.

3) Contouring control – movement can be made in two or more axes simultaneously. (interpolation)
Motions

- **Point-to-point control**
  - drilling

- **Linear control**
  - milling machines, lathes

- **Contouring control (continual)**
  - machining c. (milling, turning)
Motions for...

- Generative process
  - Using simple tool with difficult toolpath
Interpolation

- In 2D or 3D machining
- Different precision of machines
- Calculations and price
CNC machining centre (MC)

- MC combine a number of different machining processes in one operation
Modular tool set
Modular tool set – tooling system

All manufacturers around the world

Basic concept:
1) Holder with standardized connecting part – ISO, BSK cone, CAPTO system etc.
2) Extension bar – active (vibration elimination) adjustable and balanced
3) Quick change tooltip/insert
SECO - Combimaster
Tool exchange
Tool exchange

Fig. 1 - Sequence of the Tool Change cycle.

1 - Rest position.

2 - Engaging of the toolholders (rotation of the arm by $+60^\circ$ / $+90^\circ$).

3 - Extraction of the toolholders from their couplings (linear downward motion).

4 - Exchange of tool positions (arm rotation by $+180^\circ$).

5 - Insertion of the exchanged toolholders into their couplings (linear return motion).

6 - Release of the toolholders (rotation of the arm by $-60^\circ$ / $-90^\circ$).
Flexible cell – a concept

Machine worktable

Robot

Machine tool

Parts carousel

Motoman robots
Flexible manufacturing system
Conveyors

Device used for transportation of blank and semiproduct in production

Types:
Belt conveyor
Pulley(rolls) conveyor
Cradle conveyor
Conveyors – Belt conveyor

- Used for small parts and loose material
- Endless belt made of rubber, plastic particles, short boards (grids)
Conveyors – pulley(roller) conveyor

- For large solid parts and products
- Low force needed (gravity slide ways)
- Use of pallets
Pallet

Board used for transportation

Equipped with jigs and other positioning elements

Together with pallet changer is used for automatic blank material loading and parts unloading
Pallet changer

aka Switch table

2-4 pallets in one machine
Loading of blank/semiproducts

- **Manual**
- **Accumulation conveyor**
  - Accumulating pieces to balance production
- **Robot loading**
  - For single standing, large production usage (common machine tools)
- **Line(conveyor) loading**
  - For FMS and large batch production (special machine tools)
Loading
Flexible manufacturing system

Flexible manufacturing system for 4 types of automobile cylinder heads (GM 3801 – 3811)

- Flexible to suit various part variants
- 9 Flexible transfer machines (some incorporating BZ 400 machining centers), and 16 high-dynamic BZ 500 machining centers
- Completely automated
- Approximately 500,000 parts p.a.
Process automation and integration levels

**NC MACHINE TOOLS**
- cutting data adjustment
- workpiece/tool positioning
- tool path control
- tool change
  (- measurement)

**FLEXIBLE CELLS**
- cutting data adjustment
- workpiece/tool positioning
- tool path control
- tool change
- measurement

**TRANSFER LINES**
- cutting data adjustment
- workpiece/tool positioning
- tool path control
- tool change
- measurement

- workpiece handling and storage
- tool setting
- material and information flow control
- workpiece location,
  clamping and unloading
- workpiece location,
  clamping and unloading
AUTOMATION OF MACHINING
Effects of automation

- Cost reducing (per piece)
- Higher investments
- Speed improvement
- Productivity improvement
- Repeatability improvement

![Graph showing the effects of automation on machining costs and productivity.](Graph).
Links:

CAM Lathe

https://youtu.be/VS7GeKBbnSU
Links:

Motoman robots in press transfer line
http://youtu.be/j4-F8EZZGAg

Inner motion transfer line
http://youtu.be/YX5YpC0Oemc

MAZAK company – CNC machine manufacturer
https://www.mazak.com