Production Management I

Principles and Planning for Manufacture and Assembly

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Structure of the lecture

8. Principles and planning of manufacturing and assembly

8.1 Introduction

8.2 Manufacturing

8.2.1 Functions and manufacturing equipment

8.2.2 Principles of manufacturing

8.2.3 Manufacturing type

8.2.4 Planning of manufacturing

8.2.4.1 Description of machining task

8.2.4.2 Derivation of technology requirements

8.2.4.3 Disposition of manufacturing sector

8.2.5 Result

8.2.6 Trends

8.3 Assembly

8.3.1 Characteristics and problems of assembly

8.3.2 Tasks of assembly planning

8.3.2.1 Definition of assembly tasks

8.3.2.2 Determination of assembly structure

8.3.2.3 Determination of assembly areas

8.3.3 Result

8.3.4 Trends

8.4 Summary of the lecture

8.5 References

8.6 Questions on the lecture

8.7 Exercise
**INDUSTRIAL PRODUCTION PROCESS**

<table>
<thead>
<tr>
<th>Targets</th>
<th>Problem Areas</th>
<th>Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Market Demand</td>
<td></td>
</tr>
</tbody>
</table>

**BUSINESS ENTERPRISE**

- **Programme Planning**
  - Supply
  - Production
  - Sales

- **Order Processing**
  - Design/Engineering
  - Operations Planning
  - Manufacture
  - Assembly

- Quality factors
- Knowledge
- Methods
- IT

**Subject**
- Production Management I
  - Fundamentals
  - General Problems
  - Tasks

- Production Management II
  - Methods
  - Management Tools
  - Procedures

- Focal Topics
  - Special Problems
  - Computer Use
Objectives of the lecture

The objective of the lecture is to impart the principles of manufacturing and assembly planning.

For this purpose, the basic functions of the production fields Manufacturing and Assembly are presented, the manufacturing equipment and types of organisation are described and the procedure of planning the two above mentioned fields is explained. This means in detail:

- to present the functions and manufacturing equipment of the manufacturing sector and the assembly area as well as their organisation in the operational process
- to characterise the different manufacturing types (individual production and series production)
- to show the systematic procedure of manufacturing and assembly planning
- to describe the tasks of planning
  - manufacturing and assembly structures
  - types of organisations
  - production means, personnel, material to be processed
- to explain the resources for manufacturing and assembly planning

In addition to that the future design trends are to be shown.
Main Points of the Lecture Principles and Planning of Manufacturing and Assembly

Business management / Controlling

- Purchasing
- Design
- Operations planning
- Manufacturing
- Assembly
- Sales

Types of organisation
Planning of facilities/
production means
Trends

Problems

Problems of the past
Technical, economical and organisational planning of production systems

Problems of today
Efficient operation and integration of technically matured production systems

Competition factor
Production Technology

Flexible production systems

Time

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Notes on figure 1:

8.1 Introduction

Notes on figure 2:
Effects of Manufacturing and Assembly on Previous Areas of Production

- **Manufacturing process**
  - Design
    - Drawing up of manufacturing documents
  - Operations planning
    - Operations planning
    - Operations management
  - Manufacturing
    - Manufacturing of single parts
  - Assembly
    - Assembly of single parts and modules

Products

The Significance of the Divisions Manufacturing and Assembly

<table>
<thead>
<tr>
<th></th>
<th>Purchasing</th>
<th>Design</th>
<th>Operations planning</th>
<th>Manufacturing</th>
<th>Assembly</th>
<th>Sales</th>
</tr>
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<tr>
<td><strong>Net added value [%]</strong></td>
<td>5</td>
<td>25</td>
<td>35</td>
<td>65</td>
<td>95</td>
<td>100</td>
</tr>
</tbody>
</table>

Supplier A  
Supplier B

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Notes on figure 3:

The value creation within the manufacturing chain is the biggest one in the fields of manufacturing and assembly. Therefore, these areas of the manufacturing process are of utmost importance.

Notes on figure 4:
Functions and Equipment of Manufacturing

<table>
<thead>
<tr>
<th>Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provision of information</td>
</tr>
<tr>
<td>Staging of workpiece</td>
</tr>
<tr>
<td>Buffering of workpiece</td>
</tr>
<tr>
<td>Tool change</td>
</tr>
<tr>
<td>Workpiece change</td>
</tr>
<tr>
<td>Machining</td>
</tr>
<tr>
<td>Process monitoring</td>
</tr>
<tr>
<td>Measuring, checking</td>
</tr>
<tr>
<td>Removal of chips</td>
</tr>
</tbody>
</table>

Manufacturing equipment

- Manufacturing System
- Machine Tools
- Tools
- Fixtures

Comparison of Different Manufacturing Principles

<table>
<thead>
<tr>
<th>Job shop manufacturing</th>
<th>Group manufacturing</th>
<th>Continuous flow manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical arrangement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Machine shop</td>
<td>Machining cell</td>
<td>Line of machines</td>
</tr>
<tr>
<td>Structure of the manufacturing sector</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raw materials stock</td>
<td>Raw materials stock</td>
<td>Raw materials stock</td>
</tr>
<tr>
<td>Finished-parts store</td>
<td>Finished-parts store</td>
<td>Finished-parts store</td>
</tr>
<tr>
<td>Criteria of structure: Combination of the same type of machine tools</td>
<td>Criteria of structure: Combination of the necessary machining procedures for one family of workpiece</td>
<td>Criteria of structure: Operation sequence of one family of parts determines the flow line</td>
</tr>
</tbody>
</table>
Notes on figure 5:

Notes on figure 6:
Suitability of the Use of Different Principles of Manufacturing

Criteria of machining

- Similarity of form
- Sameness of form
- Correspondence of range of dimension
- Technological similarity

Principles of manufacturing

- Job shop manufacturing
- Group manufacturing
- Continuous flow manufacturing

Legend: - Low suitability - Limited suitability - Good suitability

Job shop manufacturing

Group manufacturing

Continuous flow manufacturing

<table>
<thead>
<tr>
<th>Workpiece</th>
<th>Job shop manufacturing</th>
<th>Group manufacturing</th>
<th>Continuous flow manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Similarity of form</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sameness of form</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Correspondence of range of dimension</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technological similarity</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Job shop manufacturing</th>
<th>Group manufacturing</th>
<th>Continuous flow manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complexity of process per workpiece</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uniformity of processes per workpiece</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uniformity of process sequences per workpiece</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Big number of processes per workpiece</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Great differences in processing times</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Organisation</th>
<th>Job shop manufacturing</th>
<th>Group manufacturing</th>
<th>Continuous flow manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Big quantity of items per lot</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High lot frequencies</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Great demands on work contents</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Great demands on control and schedule monitoring</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Great demands on allocation of costs</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Kind of Production

Frequency of repetition = Average lot size

Produced annual quantity of items

Example: Machine tool manufacturers

Example: Plant construction

Example: Home appliance manufacturers

Example: Electronic hardware manufacturers

Example: Individual production

Example: Small-scale production

Example: Large-batch production

Example: Mass production

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Notes on figure 7:

Notes on figure 8:
Characteristics of Individual and Series Production

<table>
<thead>
<tr>
<th>Order data</th>
<th>Individual and small-scale production</th>
<th>Large-batch and mass production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lot size</td>
<td>small</td>
<td>big</td>
</tr>
<tr>
<td>Annual quantity of items</td>
<td>small</td>
<td>big</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Manufacturing equipment</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Changeover of manufacturing</td>
<td>frequently</td>
<td>rarely</td>
</tr>
<tr>
<td>Capacity utilisation</td>
<td>small</td>
<td>big</td>
</tr>
<tr>
<td>Space utilisation</td>
<td>low</td>
<td>high</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Manufacturing process</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Proportion of operating time</td>
<td>low</td>
<td>big</td>
</tr>
<tr>
<td>Proportion of side operation time</td>
<td>big</td>
<td>small</td>
</tr>
<tr>
<td>Proportion of changeover time</td>
<td>average</td>
<td>small</td>
</tr>
</tbody>
</table>

Fields of Application of Different Manufacturing Plans

- **Field of application:**
  - Minimum quantities of items
  - Little similarity of parts
  - Example: Prototype manufacture

- **Field of application:**
  - Frequent order change
  - Little similarity of parts
  - Example: Tool manufacture

- **Field of application:**
  - Frequent order change
  - Small quantities of items
  - Example: Aircraft construction

- **Field of application:**
  - Average or big quantities of items
  - Great similarity of parts
  - Example: Engine manufacturing

- **Field of application:**
  - Large-batch and mass production
  - Rare order change
  - Example: Automobile manufacturing

- **Field of application:**
  - Average quantities of items
  - Complex machining task
  - Example: Housing manufacturing
Manufacturing Planning

Manufacturing planning

Description of machining task
Description of machining task by means of geometric, technical and order-related parameters

Derivation of technology requirements
according to types and characteristics of necessary manufacturing equipment

Disposition of manufacturing sector
Determination of capacity requirements and of the arrangement structure of manufacturing equipment

Analysis of product
- product structure
- order data
- criteria of selection

Analysis of potential
- performance data
- degree of automation
- add-ons

Analysis of potential
- principles of manufacturing
- conveyance frequency
- priority rules

Accompanying evaluation

Essential Parts Belonging to a Comprehensive Description of a Machining Task

Derived machine requirements
- Precisions/ procedure
- Speed graduations
- Performance
- Rates of feed

Organisational data
- Parts families
- Quantities of items
- Number of variants
- Lot size/ frequency of repetition

Material: CK 45
Elementary form: Forging blank

Technological data
- Material/hardness/ machining property
- Tolerance requirements
- Heat treatment
- Pre-machining/ fine machining

Geometry of moulded elements
- Bends/ radii
- Tolerances
- Bevellings/ legs of trajectory
- Discontinuities of diameters

Geometry of workpiece
- Size
- Type and quantity of moulded elements
- Type of external form (e.g. uphill casted on one side)
- Rotational part with/ without deviations
Manufacturing of Family of Parts

- Geometric similarity with regard to:
  - Form
  - Dimension

- Technological similarity with regard to:
  - Chucking means
  - Machining
  - Measuring means

Workpiece system
Classification system
Manufacturing of family of parts

Higher productivity
- Rationalisation of design
- Adapted production means
- Higher degree of automation

Processing Requirements Overview – Machine Requirements Overview

Analysis of workpiece
- Organisational data
- Technology data
- Derived machine requirements

Processing requirements overview
Balancing

Machine requirements overview
- Maximum workpiece diameter
- Maximum workpiece length
- Maximum machine-tool output
- Maximum machine accuracy
Notes on figure 13:

If it is not possible to produce sufficiently big lots of components of one machining task, a formation and manufacturing of a family of parts should be realised. With this effect, the reduction of changeover, retooling and adaptation works is made possible.

Notes on figure 14:

The machine has to meet the requirements that are necessary to carry out the machining task.
Selection of a Suitable Type of Manufacturing

Requirements Profile of Batch Production

- Non-interlinked NC-machines
  - Short throughput time
  - Low investment
  - High flexibility
  - High quality
  - High productivity
  - Little manpower requirements
- Manufacturing island
- Machining centre
- Flexible manufacturing system
- Transfer line
- Flexible manufacturing line

Performance profile of manufacturing types

Legend:
- Requirements profile
- Performance profile
- Deficiencies

Derivation of the Machine Plan

Analysis of parts spectrum
- Quantity of items
- Machining requirements
- Representative workpiece spectrum

Determination of operation sequence
- Alternative operation sequences
- Clearing-up
- Standard operation sequence

Calculation of capacity requirements
- Capacity balancing

Calculation of number of machines
- Necessary capacity requirements
- Capacity availability per machine
- Capacity balancing
- Number of machines
Notes on figure 15:

The selection of manufacturing type depends on the criteria shown in the figure. The requirements profile has to be completely covered by the performance profile.

Notes on figure 16:

The steps shown in the figure have to be taken when selecting the machines. Should the situation arise, some corresponding iterative loops will have to be gone through.
Result of the Lecture Part Manufacturing

Automation Levels of Manufacturing

- **Company objectives**
  - Throughput time reduction
  - Reduction of personnel costs
  - Increase of production quality
  - Increase of system transparency
  - Increase of flexibility
  - Reduction of changeover times

- **Automation levels**
  - Starting point: Conventional production facilities
  - Workpiece conveyance system
  - Tool conveyance system
  - Disposal system
  - Workpiece changing system
  - Tool changing system
  - Warehouse system
  - Information flow control
  - Material flow control
  - Measuring system
  - Monitoring system
  - NC-control
Notes on figure 17:

Notes on figure 18:

Especially for small and medium-sized businesses it is very difficult to manage the technical, organisational and economical burdens that arise during the implementation of flexible production systems. On the basis of a presently conventional machine technology the production facilities can be automated in four stages.
Problems of Planning and Controlling the Assembly Compared with Machining by Stock Removal

Manufacturing

- Raw parts
- Finished parts
- For the most part clear operation sequence
- Sawing, turning, milling

Assembly

- Finished parts
- Assemble
- Product
- Networked operation sequence

Planning and control task

- Operation sequence
- Determination of time
- Coordination

- Average value tables
- Company-specific guideline values
- Standard time files
- Raw part
- Personnel Information
- Production means

- Single part
- Module
- Personnel Information
- Production means
- Area
- Time

Functions of the Assembly System

Input

- Single parts
- Modules

Assembly process

- Main function: Assembling
- Secondary functions: Storing, Conveying, Handling, Adjusting, Controlling

Output

- Products

According to:
- Kuka
- DEXION
- Renk
- Maho
- Gildemeister
- Eisenmann
Notes on figure 19:


Notes on figure 20:
Characteristics and Problems of Assembly with Different Production Conditions

<table>
<thead>
<tr>
<th>Parameters of assembly</th>
<th>Single part and small-scale assembly</th>
<th>Large-batch assembly</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiplicity of parts</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Parts geometry</td>
<td>Variable</td>
<td>Constant</td>
</tr>
<tr>
<td>Lot sizes</td>
<td>Small</td>
<td>Very big</td>
</tr>
<tr>
<td>Dependencies on customer requests</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Work instruction</td>
<td>Rough</td>
<td>Detailed</td>
</tr>
<tr>
<td>Material flow</td>
<td>Discontinuously</td>
<td>Continuously</td>
</tr>
<tr>
<td>Material to be processed</td>
<td>Dependent on order</td>
<td>Program-oriented</td>
</tr>
</tbody>
</table>

**External feature**
- Almost exclusively manual assembly
- Increasing mechanisation and automation of processes

**Typical problems**
- Single part and small-scale assembly:
  - long throughput times
  - many missing parts
  - Capacity constraints
  - regarding: Personnel Area
  - Test benches
  - longer breakdown and side operation times due to:
    - conveyance works
    - adaptation works

- Large-batch assembly:
  - time-consuming planning of procedure in case of
  - modifications of production conditions
  - design modifications or new products
  - material planning problems concerning staging
  - in case of station failure considerable effects on the productivity

Tasks of Assembly Planning

**Requirements for planning the assembly**

- Room
- Energy
- Information
- Constraints
- Aims
  - Sales
  - Market share
  - Costs

**Definition of assembly tasks**
- Product data
  - weight
  - dimensions
  - assembly
  - operation sequence

**Definition of assembly structure**
- Production data
  - product variants
  - quantity of items

**Determination of assembly levels**
- assembly phases
- final assembly
- module assembly
- pre-assembly
- main assembly
- subsequent assembly

**Determination of organisation form**
- Site installation
- Group assembly
- Planning of production means
- Planning of personnel
- Determination of assembly process

**Disposition of assembly**
- Site installation
- Group assembly
- Planning of production means
- Planning of personnel
- Determination of assembly process
Data for the Characterisation of Assembly Task

<table>
<thead>
<tr>
<th>Products to be assembled</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
</tr>
</tbody>
</table>

**Production-related data**

- Number of different products
- Gradients of quantity of items
- Production times

**Product capacity profile**

- Logical interdependence of assembly activities
- Capacity requirements
- Variant-specific capacity shares
- Single parts
- Weight

**Product-related data**

**Simplification of Assembly Automation by Means of Standardisation**

**Arm variants**

**Type-specific hinged joints**

- 90°
- 120°
- 150°

**Cup hinge variants**

**Constructive measure**

Standardisation of interfaces between the variant-independent hinged joints and the arm and cup hinge variants for three types of door hinges.

**Before**

- 18 arm variants
- 27 cup hinge variants
- Type-specific assembly

**Afterwards**

- 6 arm variants
- 9 cup hinge variants
- Different hinge types for one assembly equipment
Notes on figure 23:

Notes on figure 24:

The systematic standardisation of a product is an important condition for an economical assembly. The diagramme shows the main components of door hinges. By means of the standardisation it was possible to reduce the number of variants so much that a flexible and automated assembly of hinges is possible.
Subdivision into Pre-Assembly and Main Assembly

**Initial information**
- Quantity of items
- Variant code
- Lot sizes

**Product structure**

**Constraints**
- Technique
- Technology
- Separation of manual and automatic sectors
- Organisational

**Centralised**
- Line 1
  - Pre-assembly A
- Line 2

**Decentralised**
- Pre-assembly A
- Pre-assembly B

**Organisational**
- Order-oriented
- Programme-oriented
- Consumption-oriented

**Single-stage**
- MA
- PA 1
- PA 2

**Multi-stage**
- MA
- PA 1
- PA 2
- PA 3

Legend: PA: pre-assembly
MA: main assembly

Aims of Separating Pre-Assembly Areas from Main Assembly Areas

**Examples**
- Variant-independent PA
- Variant-dependent MA

**Aims**
- Reduction of throughput time
- Decoupling of subsystems
- Concentration of variant effect
- Simplification of automation possibilities in subsystems
- Interlinking equipment matched for basic components
- Good accessibility to assembly object in pre-assembly areas
- Possibility to shift assembly volumes to suppliers

**Examples**
- Staging of bought-in modules

Legend: PA = pre-assembly
MA = main assembly
Interrelation Between Product Structure and Assembly Structure

Efficient determination of product structure

Product structure

Assembly structure

Which part is assembled
When
Where
How
With whom
By whom

Legend: UN = Unit
CP = Component
SA = Subassembly
SP = Single part

Kinematic alternatives of organisational forms in assembly

Assembly organisation forms

Performance production arrangement

Site installation
Group assembly
Stationary assembly objects
Moving assembly objects

Continuous flow arrangement

Line assembly
Time-phased production line assembly
Continuous flow assembly
Stationary workstations
Moving work stations
Stationary objects
Moving objects

Advantages and disadvantages

Stationary workstations
Moving work stations

Legend: mechanical assembly equipment
manual work station
assembly object
object move
work station move

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Notes on diagram 27:

Notes on diagram 28:
Types of Production Means in Assembly Department

- Roller conveyors
- Chain conveyors
- Monorails
- Fork stackers
- Warehouse
- Bunker
- Hoppers
- Shelves
- Industrial robots
- Pick and place devices
- Screwdrivers
- Riveting devices
- Presses
- Wrenches
- Optical sensors
- Inductive tracers
- ...
Notes on diagram 29:

Notes on diagram 30:

While in the field of manufacturing the personnel employment could be reduced, there is still some potential of rationalisation in the field of assembly. Therefore, the manufacturing resource Personnel is of great importance for the assembly.
8.4 Summary of the lecture

In the first part of the lecture, the functions of manufacturing equipment were explained. The differences of the principles of manufacturing were pointed out and the different manufacturing types were described with examples.

The planning sequence of manufacturing planning was presented and the derivation of the machine plan was dealt with.

In the second part, the characteristics of assembly and the individual planning phases of assembly were presented. The different types of organisation of assembly were explained and the significance of the resources Personnel and Production Means were pointed out.

The objective of the lecture was to explain the following terms and to delimit them from one another

- functions of manufacturing
- manufacturing equipment
- types of organisation of manufacturing
- manufacturing types
- principles of manufacturing
- processing requirements overview and requirements profile
- formation of family of parts
- functions of assembly
- production-related data
- product-related data
- pre-assembly
- main assembly
- types of organisation of assembly
- types of staging of material
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