DMV 4242 – ADVANCED MANUFACTURING PROCESSES

6.0 HIGH SPEED MACHINING
LEARNING OBJECTIVES

After completing the unit, students should be able to:

1. Define High Speed Machining (HSM)
2. Explain the potential of HSM
3. Describe the requirement of HSM
4. Discuss some common applications of HSM
5. Explain the HSM processes
6. Discuss some advantages of HSM.
INTRODUCTION

- Machining with high speeds (HSM) is one of the modern technologies, which in comparison with conventional cutting enables to increase efficiency, accuracy and quality of workpieces and at the same time to decrease costs and machining time.

- The first definition of HSM was proposed by Carl Salomon in 1931.

- Practically, it can be noted that HSM is not simply high cutting speed. It should be regarded as a process where the operations are performed with very specific methods and production equipment.
WHAT IS HSM?

- Definition of **high-speed machining** (**HSM**) means using **cutting speeds** that are significantly higher than those used in conventional machining operations.

- The term **high speed** is relative. As a general guide, an approximate range of cutting speeds may be defined as follows:
  1. **High speed**: 600-1,800 m/min,
  2. **Very high speed**: 1,800-18,000 m/min,
  3. **Ultrahigh speed**: > 18,000 m/min.
WHAT IS HSM?

<table>
<thead>
<tr>
<th>Work Material</th>
<th>Solid Tools (end mills, drills)¹</th>
<th>Indexable Tools (face mills)²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Conventional Speed</td>
<td>High Cutting Speed</td>
</tr>
<tr>
<td></td>
<td>m/min</td>
<td>ft/min</td>
</tr>
<tr>
<td>Aluminum</td>
<td>300+</td>
<td>1000+</td>
</tr>
<tr>
<td>Cast iron, soft</td>
<td>150</td>
<td>500</td>
</tr>
<tr>
<td>Cast iron, ductile</td>
<td>105</td>
<td>350</td>
</tr>
<tr>
<td>Steel, free machining</td>
<td>105</td>
<td>350</td>
</tr>
<tr>
<td>Steel, alloy</td>
<td>75</td>
<td>250</td>
</tr>
<tr>
<td>Titanium</td>
<td>40</td>
<td>125</td>
</tr>
</tbody>
</table>

Comparison of cutting speeds used in conventional versus high-speed machining for selected work materials.
WHAT IS HSM?

- One popular HSM definition is by the **DN ratio** — the bearing bore diameter (mm) multiplied by the maximum spindle speed (rev/min).
- For high-speed machining, the typical DN ratio is between 500,000 and 1,000,000.
- Other definitions emphasize **higher production rates and shorter lead times**. In this case, important noncutting factors come into play, such as high rapid traverse speeds and quick automatic tool changes ("chip-to-chip" times of 7 s and less).
WHAT IS HSM?

- Another HSM definition is based on the ratio of horsepower to maximum spindle speed, or \( \text{hp/rpm ratio} \).
- Conventional machine tools usually have a higher \( \text{hp/rpm ratio} \) than machines equipped for high-speed machining.
- By this metric, the dividing line between conventional machining and HSM is around 0.005 \( \text{hp/rpm} \). Thus, high-speed machining includes 50 hp spindles capable of 10,000 rpm (0.005 \( \text{hp/rpm} \)) and 15 hp spindles that can relate at 30,000 rpm (0.0005 \( \text{hp/rpm} \)).
APPLICATIONS OF HSM

Applications of HSM seem to divide into three categories.

- **Aircraft industry**, in which long airframe structural components are machined from large aluminum blocks. Much metal removal is required, mostly by milling. The resulting pieces are characterized by thin walls and large surface-to-volume ratios, but they can be produced more quickly and are more reliable than assemblies involving multiple components and riveted joints.
APPLICATIONS OF HSM

- **Machining of aluminum by multiple operations** to produce a variety of components for industries such as automotive, computer, and medical. Multiple cutting operations mean many tool changes as well as many accelerations and decelerations of the tooling.

- The third application category for HSM is in the **die and mold industry**, which fabricates complex geometries from hard materials. In this case, high-speed machining involves much metal removal to create the mold or die cavity and finishing operations to achieve fine surface finishes.
APPLICATIONS OF HSM

- Much research and development work has been carried out on high-speed machining (turning, as well as milling, boring, and drilling) of aluminum alloys, titanium alloys, steels, and superalloys.

- Considerable data have been collected regarding the effect of high speeds on the type of chips produced, cutting forces, temperatures generated, tool wear, surface finish, and the economics of the process.
APPLICATIONS OF HSM

- These studies have indicated that high-speed machining can be economical for certain applications, and consequently, it is now implemented for machining aircraft turbine components and automotive engines with five to ten times the productivity of traditional machining.

- Important factors in these operations are the selection of an appropriate cutting tool, the power of the machine tools and their stiffness, the stiffness of toolholders and the workholding devices, spindle design for high power and high rotational speeds, the inertia of the machine-tool components, fast feed drives, and the level of automation.
HSM PROCESSES

- The following are important machine factors in high-speed operations:
  1. Power and stiffness of the machine tools,
  2. Stiffness of tool holders and workholding devices,
  3. Spindle design for high power and high rotational speeds,
  4. Inertia of the machine-tool components,
  5. Fast feed drives,
  6. Level of automation, and
  7. Selection of an appropriate cutting tool.
MACHINING PROCESS CAPABILITIES

- The surface finish and dimensional accuracy obtained in turning and related operations depend on factors such as the characteristics and condition of the machine tool, stiffness, vibration and chatter, process parameters, tool geometry and wear, cutting fluids, machinability of the workpiece material, and operator skill.

- As a result, a wide range of surface finishes can be obtained.
HSM SPECIAL FEATURES

Cusps produced by ball nose end mill
HSM SPECIAL FEATURES

Headlamp reflector mold
HSM SPECIAL FEATURES

Copper electrode for EDM
HSM SPECIAL FEATURES

 Dies for forging operation
HSM SPECIAL FEATURES

Typical workpieces for HSM, forging die for an automotive component, moulds for a plastic bottle and a headphone.
HSM SPECIAL FEATURES

Thin wall EDM electrode
HSM SPECIAL FEATURES

Landing gear bulk head for a C-17 cargo plane.

Photo courtesy Boeing.
HSM SPECIAL FEATURES

Aluminum fuel control housing
Spindle tradeoff
HYBRID BALL BEARING

- Hybrid ball bearings take the place of all-steel ball bearings in most high speed spindles.
- In a hybrid ball bearing, the race is still steel but the balls are ceramic.
- Ceramic balls deliver more stability at high speeds.
- The balls are lighter and stiffer, so they deflect less from centrifugal force.
- This improves efficiency and quiets vibrations.
- Ceramic balls also deliver longer life.
HYBRID BALL BEARING

- In any high speed spindle using ball bearings, the bearing is generally the component that fails first.
- Some machine tool and spindle makers offer spindles with non-contact bearings that overcome some of the limitations of traditional bearings.
- Many of these non-contact spindle designs are still being proven.
HYBRID BALL BEARING

- There are three non-contact bearing types:
  - Hydrostatic Bearings
  - Air bearings
  - Magnetic bearings
HYBRID BALL BEARING

Hybrid bearing photo courtesy Fadal Machining Centers.
ADVANTAGES OF HSM

- Faster production rates,
- Shorter lead times,
- Reduced costs, and
- Improved part quality.
SUMMARY

In this unit we have studied that

1. Hard competition causes rapid development of the machining technology and design of new solutions. High Speed Machining is proposed as an example.

2. HSM ensures high metal removal rates, boost productivity, improve surface finish and eliminates the need of coolant.

3. In spite of high requirements of machining tools, HSM gives numerous benefits. It allows shortening the production time and eliminates some treatment (e.g. manual finishing) besides simultaneously retaining the accuracy.
4. These advantages are decisive for the use of HSM for machining the press dies.

5. Even though HSM has been known for a long time, the research is still being developed for further improvement of quality and minimization of costs.
SELF TEST

1. List three common application of HSM.
2. Important machine factors in high speed machining.
3. List three types of non-contact bearing.
4. What are the advantages of high speed machining?
REFERENCES


