CHAPTER 4

EXPERIMENTAL WORK ON MONITORING HARD TURNING

The second phase of experiments was designed, with the objective to evolve an AE based monitoring technique for hard turning. The experimental set up, the data acquisition method employed, the parameters measured, and the experimental procedure are discussed in this chapter.

4.1 EXPERIMENTAL SET UP

The turning experiments were conducted on a Quest 8/15SP Hardinge CNC turning center of 15kW capacity (Figure 4.1).

Figure 4.1 Quest 8/15SP Hardinge CNC Turning Center
The specifications of the machine tool are given in Table 4.1. The schematic arrangement of the experimental setup is shown in Figure 4.2 and the close up view of the cutting tool and sensor is given in Figure 4.3.

**Table 4.1  Machine Specification of Quest 8/51 SP Hardinge**

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. w/p hardness</td>
<td>62 HRC</td>
</tr>
<tr>
<td>Control system</td>
<td>Fanuc 210i- T</td>
</tr>
<tr>
<td>Max. spindle speed</td>
<td>4500 rpm</td>
</tr>
<tr>
<td>Part surface finish</td>
<td>0.2 µm</td>
</tr>
<tr>
<td>Over all axis repeatability</td>
<td>0.76 µm</td>
</tr>
<tr>
<td>Power rating</td>
<td>15 kW/ 20 Hp</td>
</tr>
<tr>
<td>Axis resolution</td>
<td>0.1µm</td>
</tr>
</tbody>
</table>

**Figure 4.2  Schematic Diagram Showing AE Measurement System in Hard Turning**
4.1.1 Tool and Work Material Specification

The cutting tool material used was Cubic Boron Nitride (CBN) of commercial specification MB 8025 (Mitsubishi), having a nose radius 0.8mm. MB 8025 has a low CBN content and particles are dispersed in the ceramic matrix. It is then sintered at a pressure above 5GPa and a temperature of 1200° or higher. The ISO designation of the cutting tool insert is DNMA 15 04 08. The tool holder used in the experiment was DDJNL 2525 M15. While mounting the tool, care was taken to align the tool tip along the axis of the rotation of the workpiece.

The workpiece was a 55 mm diameter cylindrical rod of about 130 mm length, made of high carbon, high chromium steel (AISI-D3, UNS No.T30403). The chemical composition of the work material is given in Table 4.2. The workpiece was hardened to the hardness of 60 HRC. The
micro hardness at the surface of the workpiece material was measured to be Vicker’s hardness number 694.2 HV.

Table 4.2 Chemical Composition (% by weight) of the Workpiece Material

<table>
<thead>
<tr>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Cr</th>
<th>Mo</th>
<th>Ni</th>
<th>Al</th>
<th>Co</th>
<th>Cu</th>
<th>Ti</th>
<th>V</th>
<th>W</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.12</td>
<td>0.48</td>
<td>0.37</td>
<td>0.02</td>
<td>0.02</td>
<td>10.84</td>
<td>0.06</td>
<td>0.03</td>
<td>0.02</td>
<td>0.04</td>
<td>0.04</td>
<td>0.01</td>
<td>0.04</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

# - The remaining percentage is Fe

4.1.2 Cutting Conditions

The experiments have been carried out mainly to devise a tool wear monitoring method. Tool wear is primarily influenced by the cutting speed. Hence, experiments were conducted by varying the cutting speed alone. The cutting speeds used are 70, 100 and 130 m/min. The feed used in all the experiments was 0.05 mm/rev and the depth of cut was 0.1 mm, which are typical values used in hard turning. All the experiments were conducted under dry cutting conditions without any coolant.

4.2 THE DATA ACQUISITION METHOD

During the experiments the AE emitted from the wear zone had to be captured with minimal loss. The Piezotron AE Sensor, shown in Figure 4.4 consists of the sensor housing, the piezoelectric sensing element and the built-in impedance converter. The sensing element, made of piezoelectric ceramic, is mounted on a thin steel diaphragm. The sensing element is acoustically isolated from the housing by design and therefore, well protected against external noise. The Kistler AE sensors feature a very high sensitivity for surface and longitudinal waves, over a broad frequency range. A miniature
impedance converter is built into the Piezotron AE Sensor, giving an output low-impedance voltage signal.

The AE Piezotron Coupler Type 5125B1, is used to supply power to the sensor and for signal processing.

The AE sensor is mounted on the tool holder by means of a mounting stud close to the cutting edge (Figure 4.3). Silicone grease was applied at the interface between the sensor and the tool holder to ensure proper acoustic coupling.

![Figure 4.4 Kistler AE Sensor](image)

The signal from the sensor was pre amplified and processed by the Kistler Piezotron coupler (Kistler 5125B1, Figure 4.5). The AE-Piezotron Coupler processes the high frequency output signals from the AE Sensors. The AE-Piezotron coupler with a built-in RMS converter and limit Switch, has been specially designed for the processing of high-frequency sound emission signals from the Piezotron AE Sensors. The type of filter (high-pass or low-pass) as well as the frequency limit are freely selectable. A bandpass filter is obtained by the series connection of one high-pass and one low-pass
filter. The gain, filters and the integration time constant of the built-in RMS converter are designed as plug-in modules, which allow the best possible adaptation to the particular monitoring function concerned. The coupler has provision to select suitable band pass filters and the time constant for obtaining the RMS signal.

![Figure 4.5 Kistler 5125B1 AE Piezotron Coupler](image)

In all the experiments a band pass filter of 50 kHz to 500 kHz was chosen. This filter eliminated structure borne vibrations and other acoustic and electrical noises. A time constant of 0.12 ms was chosen for computing the root mean square value of Acoustic Emission signal ($AE_{RMS}$). This low value time constant facilitated capturing the intensities of AE burst. The filtered and $AE_{RMS}$ signals were available at the output point of the coupler for subsequent signal processing.

The $AE_{RMS}$ and AE filtered signals were fed to a high speed digital storage oscilloscope, Agilent 54621A shown in figure 4.6. The oscilloscope is
capable of processing high frequency signals, which is a prerequisite for processing AE signals.

The output from the AE piezotron coupler is feed to the oscilloscope. An 8-bit analog to digital converter converts the waveform into an evenly-spaced series of voltage readings. These readings are made for both channels, and are stored in memory as an array of voltages with implicit times. The Digital to Analogue Converter continuously scans through the recording, producing a repeating analogue signal representing the contents of the memory, which is sent to the Cathode Ray Tube (CRT) for display. The oscilloscope has additional trigger modes that allow the user to make better use of the available storage space. One of the most important of these is the Pre-Trigger mode, which allows the user to capture events that occur before the trigger pulse. This is achieved by the oscilloscope DSO continuously recording the analogue signal until the trigger pulse is detected.

Figure 4.6 The Digital Storage Oscilloscope (Agilent 54621A)
The 82357A GPIB interface available with the oscilloscope facilitated the fast transfer of signals to computer for subsequent signal analysis. With the help of the data capturing software in the computer the AE signal can be discretised into required number of data points and stored in the computer as a data file for subsequent signal processing. In all the experiments the filtered and AE\textsubscript{RMS} signals were discretised into 2,000 data points and stored. The typical filtered AE signal and AE\textsubscript{RMS} signals are shown in Figures 4.7 and 4.8.

![Figure 4.7 Typical Filtered AE Signal Captured during machining](image-url)
4.3 PARAMETERS MEASURED

During the experiments, at pre-determined time instants, the tool flank wear and the surface roughness of the workpiece were measured. The tool wear and the final image of the worn tool were obtained, using a tool maker’s microscope, shown in Figure 4.9. The surface roughness of the workpiece was measured using a Taylor Hobson surface roughness tester, shown in Figure 4.10.
Figure 4.9 The Tool Maker’s Microscope
Figure 4.10 Close up view of Taylor Hobson Surface Roughness Tester and the Workpiece

Figure 4.11 Displaying the Measured Values of the Surface Roughness from the Taylor Hobson Surface Tester.
4.4 EXPERIMENTAL PROCEDURE

For all sets of cutting conditions, tool wear experiments were conducted. Care was taken to mount the AE sensor close to the cutting edge to minimize acoustic loss. Silicone grease was applied at the interface between the tool shank and the sensor, to ensure proper acoustic coupling.

During each experiment, the machining was interrupted approximately every five minutes or ten minutes, of machining depending on the expected rate of wear. When the wear rate was expected to be steep, the interruptions were frequent. At each periodical interruption, the tool flank wear and surface roughness were measured. Just before the interruption the AE_{RMS} and AE filtered signals were captured. Experiments were continued till the tool flank wear land clearly crossed the limiting flank wear land value of 0.3 mm.

4.5 CHAPTER SUMMARY

This chapter dealt with the details of the experimental setup used for monitoring hard turning using acoustic emission signals. It also explained the various parameters measured and measuring systems used.