Simultaneous In-process Roughness Control and Tool Wear Monitoring

Problem:

Surface roughness of machined parts is a key attribute in determining product quality. It affects several functional attributes of parts such as fatigue life, contact surface friction, wear, contact stress distribution, and paintability. Due to the lack of a robust in-process roughness monitoring scheme and the isolation of the monitoring schemes from control schemes in industry, it is difficult to control surface roughness based on in-process feedback. During machining processes, tool wear is one important factor which contributes to the variation of the cutting force, surface finish, tool life, and others. It is highly desired to develop an in-process roughness control and tool wear monitoring scheme which will allow 100% roughness and tool wear monitoring and immediate roughness feedback control.

Research Objectives:

Design and develop a monitoring and control scheme which will predict the tool wear in-process and achieve a constant surface roughness throughout the life of the tool for a given combination of cutting tool and workpiece.

Approach:

A roughness model which describes the relationship between surface finish, cutting parameters, and tool flank wear has been developed and used as the basis of roughness control and tool wear monitoring. Tool wear is monitored by surface roughness indirectly. Surface roughness is controlled in-process by a model-based control scheme as shown in Figure 1. The strategy of control is to regulate either speed or feed to maintain a desired surface roughness under the presence of continually increasing tool wear and other disturbances.

Accomplishments:

The in-process roughness control and tool wear monitoring scheme has been implemented within a Distributed Open Architecture Controller (DOAC) for a three axis-milling machine. The system setup is shown in Figure 2. Experiments have been conducted on hot wrought alloy steel 4140 blocks (3x2x1 inch) for both speed and feed adjustment methods. The predicted tool wear and actual, measured tool wear are plotted in Figures 2 and 3, while Figure 2 is for speed adjustment and Figure 3 is for feed adjustment. To compare the experimental results with that of the uncontrolled cuttings, another set of experiments has also been performed with a fixed speed and feed. The uncontrolled surface roughness values along with those of controlled cuttings are shown in Figure 4. All the results show that the tool flank wear can be monitored accurately in-process and a relatively constant surface roughness can be achieved throughout the life of the cutting tool.

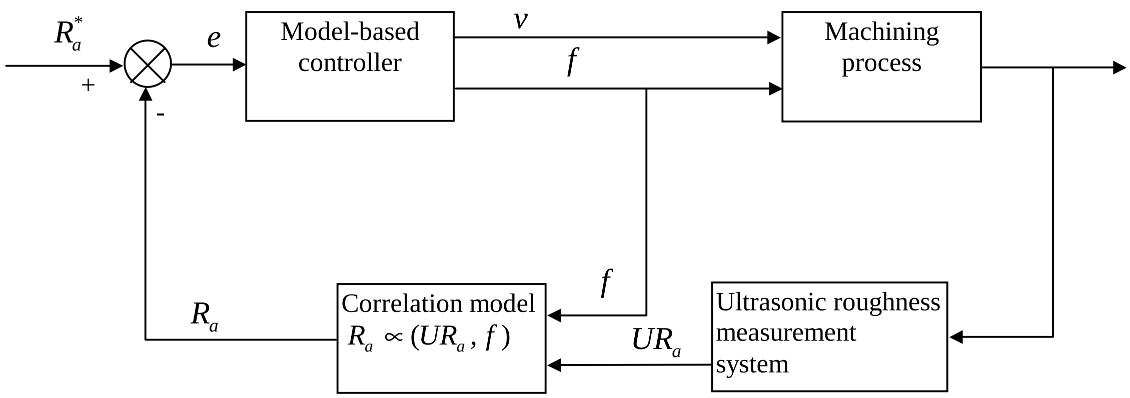

Figure 1: Model-based roughness control.

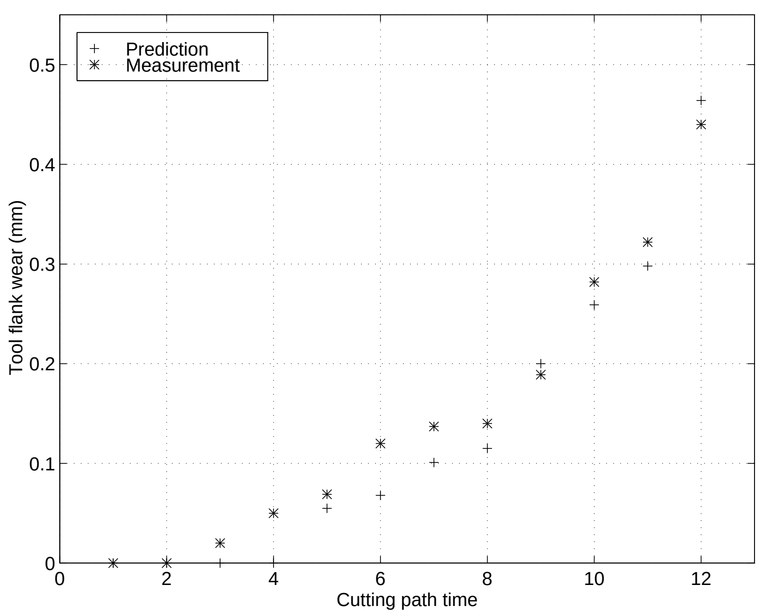

Figure 2: Tool wear within speed adjustment control scheme.

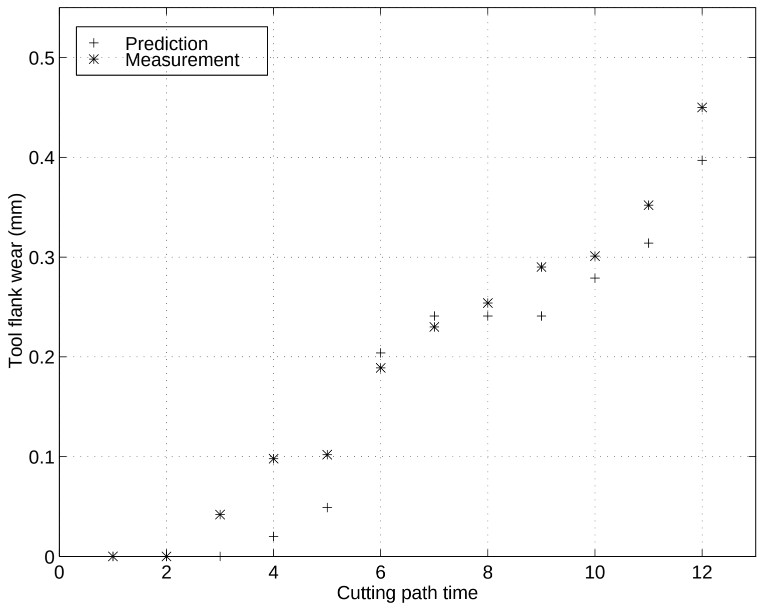

Figure 3: Tool wear within feed adjustment control scheme.

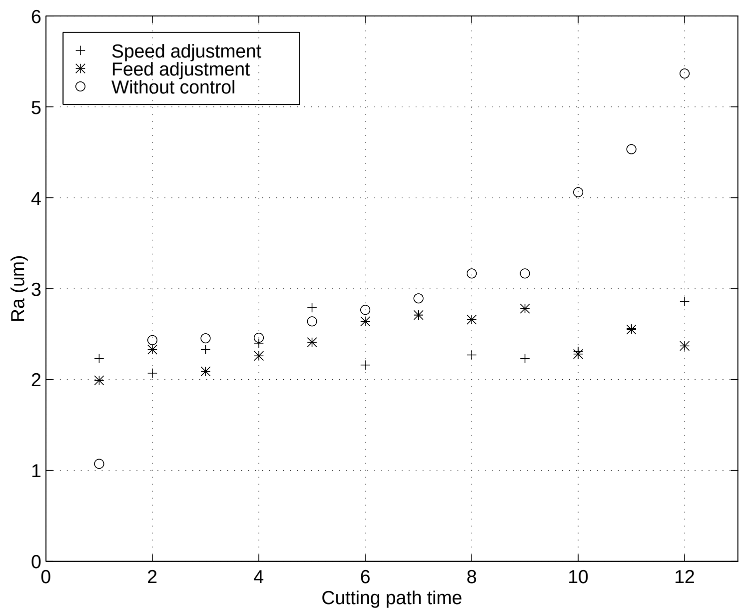

Figure 4: Surface roughness comparison between controlled and uncontrolled cuttings.