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Letter to the Editor

Comment on 'Optimal grey-fuzzy controller design for a constant turning force system'
By Shinn-Horng Chen, Jyh-Horng Chou and Jin-Jeng Li, International Journal of Machine Tools & Manufacture 42 (2002) 343–355

Chen, Chou and Li present a nice grey-fuzzy control scheme to control the turning process with constant cutting force under various cutting conditions [1]. The writers of this Letter to the Editor are particularly interested in the design of the grey-fuzzy control system and the computer simulation results.

Although the increase of cutting force will reduce the workpiece precision, their statement in the Introduction section that, "maintaining the cutting force on the tool tip at the appropriate value despite variation in depth of cut is one method of guaranteeing that the dimension error is permissible and the production rate is maximum" deserves some comment.

A machining system is an elastic system consisting of machine, fixture, workpiece and tool (MFWT). Elements of the MFWT system deflect elastically under the cutting force and clamping force. The deflections change the relative positions between tool and workpiece, and then reduce the workpiece precision.

MFWT system deflection is usually expressed as the ratio of the cutting force to the resulting MFWT system stiffness between tool and workpiece. Thus, the deflection varies invariably because: (1) the cutting force varies due to a variable allowance on the blank to be machined and consequently due to the variable depth of cut; (2) the cutting force varies due to wear of cutting tools; (3) the cutting force varies due to variations in cutting conditions such as cutting speed variations occurring in profile turning a stepped-shaft; and (4) the system stiffness could vary due to the varying position of the cutting point in the machine structure during the feed motion of the tool and/or of the workpiece. These effects usually act simultaneously. The deflections due to the variation of the cutting force and of the resulting stiffness between the cutting tool and the workpiece have been discussed in good detail in [2].

Much research has been undertaken to study workpiece deflection in turning operations since 1960s [3–9]. For example, when a slender workpiece which is held solely at one end only by a chuck is machined on a lathe, the workpiece can be simplified usually as a cantilever beam (see Fig. 1). The workpiece stiffness k_{wp} continuously changes as the cutting point traverses the tool path according to the following equation:

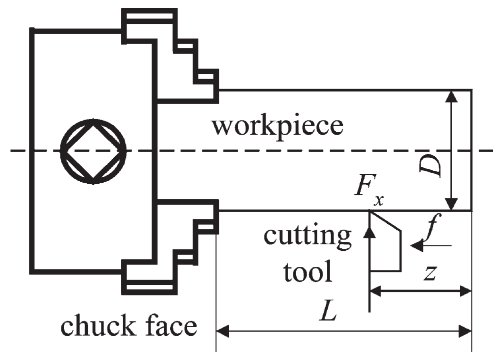

Fig. 1. Turning a workpiece held at one end in a chuck.

$$k_{wp} = \frac{3EI}{(L-z)^3} \quad (1)$$

where:

E is modulus of elasticity of workpiece material,
I ($= \pi D^4/64$, D is workpiece diameter) is the second moment of area of the workpiece,
L is the distance between the free end of workpiece and chuck face, and
z is the instantaneous distance between the free end of the workpiece and the cutting point position.

The solution for the workpiece deflection due to the radial cutting force component F_x is then given by:

$$\delta_{wp} = F_x/k_{wp} = F_x(L-z)^3/(3EI) \quad (2)$$

Eq. (2) indicates that even if a very precise controller maintained a constant cutting force, the deflection is still not constant due to the variation of distance between the free end of the workpiece and the cutting point position, and leaving the machined workpiece with non-uniform dimension.

Thus, it is shown that a control system which maintains a constant ratio of the cutting stiffness to the resulting stiffness needs to be developed to guarantee the workpiece dimension precision in turning operations.

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