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Cutting forces during turning with variable depth of cut☆,☆☆

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Summary The purpose of this paper is to investigate the problems with increasing the efficiency of turning cycles. This paper also describes and suggests the possibility of using effective strategies and their application in programming CNC turning centers. It proposes new roughing turning cycles where variable depth of cut is applied. Suggested roughing cycles with the use of variable depth of cut will ensure increasing the durability of the cutting tool and the efficiency during turning.

The proposed research for the paper is an experimental work — measuring cutting forces and monitoring of the tool wear on the cutting edge. It compares the turning where standard roughing cycle is used and the turning where the proposed roughing cycle with variable depth of cut is applied.

Roughing tool path in turning

CAD/CAM systems produce the technological basis for computer-controlled production. For standard programming of rough turning tool paths online programing SFP — Shop Floor Programing is commonly used. For specific programming of tool paths (non-linear tool path and cycles that are not in cycles at the workshop) it is appropriate to use CAM systems (Hatala, 2007; Svetlik and Dobransky, 2005; Sadílek et al., 2011).

The conventional roughing cycles in turning, where a cutting tool performs constant depth of cut, can be adapted and extended with the cycles when the tool cuts with variable depth of cut. The proposed roughing cycles are as follows:

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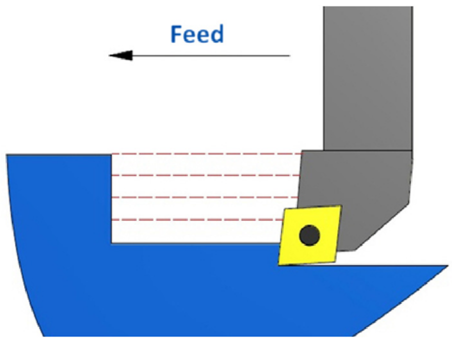

Figure 1 Roughing cycle with constant depth of cut. Figure adapted from Sadílek et al. (2013).

- Tool paths ''decreasing of engagement'', see Fig. 2.
- Tool paths with creating conic surface, see Fig. 3.
- Tool paths with the use of nonlinear methods, see Fig. 4.

Fig. 1 shows commonly used roughing cycle. In Fig. 1 it is possible to see a constant depth of cut, which is used in this roughing cycle. The machining process results in wear that prevails in one point of the cutting edge only.

During the roughing strategy — cut decrement, each chip removal is performed with a different depth of cut so a different cutting part of the tool is under stress during each cutting operation. This method of machining can be time consuming due to more passes. This is compensated for by increased tool life, lower loading of the machine spindle and reduced machine noise. The depth of cut is reduced when the final diameter is being approached. The maximum wear point is therefore moved outwards from the cut, prolonging by doing so a longer cutting tool durability. This type of roughing cycle is already contained in some CAM systems (for example Mastercam and Edge CAM). Application of this feature when longer parts are turned is advantageous for the elimination of ever-decreasing workpiece stiffness.

The cutting where a conical surface is formed starts with the greatest depth of cut which decreases in the feeding direction, see Fig. 3. The second cut is programmed to be parallel with the workpiece axis. This provides for efficient removal of the conical surface formed in the previous cut. Thanks to this strategy, the tool wear moves along the cutting edge from the maximum to minimum depth of cut (a_{pmax} to a_{pmin}).

The non-linear roughing cycle method also ensures the variable depth of cut. For example, the tool path's wavy profile (Fig. 4) will achieve the same effect as the previous methods. In the first cut and the second cut, the machined material is on gradual increase and decrease and a variable depth of cut is thereby achieved. It is also possible to shift the machined surface and, in doing so, change the depth of cut. However, this requires an advanced CAD/CAM system joined with the CNC cutting machines.

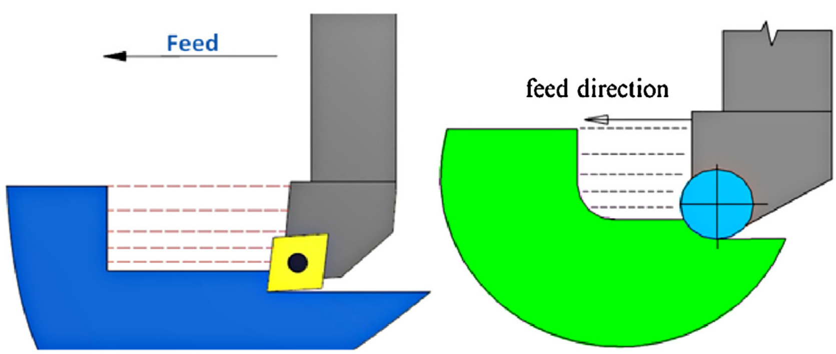

Figure 2 Tool paths — decreased cut with two types of insert (ramping). Figure adapted from Sadílek et al. (2013).

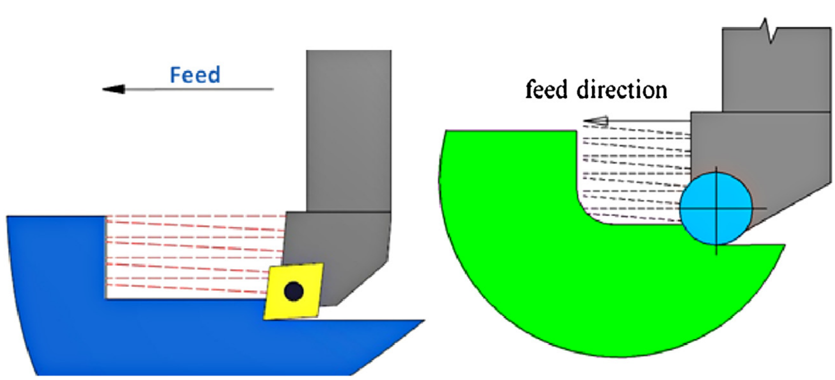

Figure 3 Tool paths creating a conic surface with two types of insert. Figure adapted from Sadílek et al. (2013).