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Proposal of a new burnishing method utilizing a flank face of a turning tool

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Abstract

As a measure to perform a burnishing processing easily on an NC lathe, the authors propose a new and simplified burnishing method, i.e. to feed in a flank face of a cutting tip radially into a workpiece. In the experiment, the flank face located in a few millimeters lower part of the tool cutting edge was fed radially toward the carbon steel workpiece (S45C) of ϕ30mm at a given rate (t=1-4μm/pass) and burnished axially along the workpiece length. As a result, the surface roughness improved to Rz≈2.5μm from Rz≈10μm measured after turning. Utilizing the accurate feed control of the NC lathe, an attempt to control a dimensional accuracy of the workpiece diameter was also made. As a result, the workpiece radius came down constantly by 0.8μm in proportion to the tool feed-in rate (t=1μm/pass), which reveals that the dimensional accuracy of the workpiece diameter could be controlled by the proposed burnishing process.

Keywords: burnishing, tool flank, nose radius, surface roughness, dimensional accuracy, circularity

1. Introduction

Many of rod-shaped parts used as a jig for manufacturing aircraft components have a small diameter of below ϕ10mm, and requirements for dimensional accuracy and surface roughness of those components are strict. There is a method using a burnishing tool [1-3] as a measure to improve a surface roughness easily on a turning machine without using cylindrical grinding method. The existing burnishing method using a specialized tool such as a diamond indenter with a curved surface or a roller tool produces an effect, but its application area is limited [4,5]. Also, dimensional control by the above method is difficult. The authors have made a study on a measure to actualize a required finish with a good surface roughness and high accuracy at low cost without grinding.

2. Simplified burnishing method utilizing a tool flank face

In this research a burnishing processing method utilizing a flank face of the tool nose is proposed (**Fig.1**). The proposed method is characterized by a burnishing processing that can be achieved right away after turning by just controlling a position of the tool edge in the height direction (Y axis) and the cutting-in direction (X axis). In addition, it is expected that the dimensional control of the workpiece becomes easier since the new method employs an accurate NC feed-in system differently from the conventional burnishing processing employing a constant pressure system.

3. Positional relation between tool flank face and workpiece

Relation of the contact position between a tool flank face and a workpiece surface was searched. Providing that the workpiece radius, the clearance angle of the turning insert and the chip thickness are r, ϑ and t, respectively, as shown in **Fig.2**, X direction distance (PQ_X) and Y direction distance (PQ_Y) from a tool tip position after turning (P) to a tool tip position when a tool flank face makes contact with a workpiece periphery (Q)

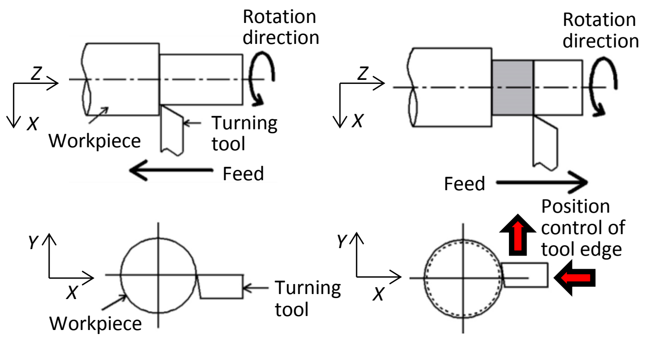


Figure 1. Schematic of burnishing processing method utilizing a flank face of tool nose

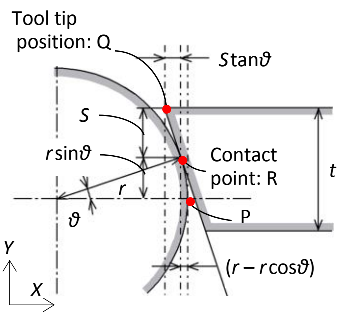


Figure 2. Positional relation between tool flank face and workpiece

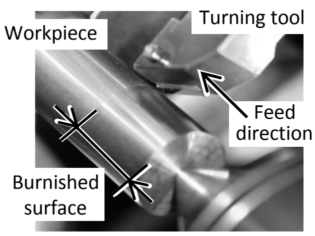


Figure 3. Experimental setup on NC lathe

can be expressed by the formula as below.

X direction: $PQ_X = S\tan\vartheta + (r - r\cos\vartheta)$ ---- (1)

Y direction: $PQ_Y = S + r\sin\vartheta$ ---- (2)

Note, however here, that S represents a distance toward Y axis from a tool nose Q to a contact point R and is determined arbitrarily within a range of $S<t$.

Since a required transfer amount of the cutting edge can be determined from the above formula, the burnishing processing utilizing a flank face can be performed right away on the 5 axis turning center just after the turning by automatic adjustment of a height and a nose position of the cutting edge only if the corrective program for the transfer amount is set in preliminarily.

4. Experimental device and conditions

The experiments were performed on the NC lathe as shown in **Fig.3**. The workpiece material is a carbon steel S45C with a diameter of ϕ30mm and ϕ10mm and an aluminum alloy A5056 with a diameter of ϕ30mm. The turning tool used was a triangle insert of uncoated WC (thickness 4.7mm, nose R0.8mm). A clearance angle of the insert fitted in the holder was set at γ=2°. An edge position of the tool for burnishing was set 3mm higher preliminary. Conditions used for the finish turning were V=200m/min, f=0.15mm/rev and t=0.5mm/pass. The burnishing experiments were performed at V=57m/min in the positive rotation identically to the turning, shifting a feed-in rate to the workpiece radius direction (X axis) per pass in the range of t=1-4μm/pass. The feed rate was set constant at f=0.05mm/rev which is equivalent to 1/3 of the rate used in the turning.

5. Results of the burnishing processing

Taking a reference at the position where the flank face of the tool insert was made contact with the workpiece after the turning process, burnishing processing was performed. The total amount of the radial feed-in was set at up to 20μm.

5.1. Surface roughness and surface condition

Changes in the surface roughness to the total feed-in amount are shown in **Fig.4(a)**. The roughness value after turning was *Rz*≈10μm. The surface roughness achieved slightly varied depending on the radial feed-in rate per pass, but the roughness value improved in proportion to the total feed-in amount at any feed-in rate. When the total feed-in amount was 20μm, the surface roughness improved to *Rz*≈2.5μm at any feed-in rate.

Figure 5 shows a transition of the workpiece surface condition when radial feed-in rate was t=2μm/pass. Gradual improvement of the roughness can be seen here. This seems to be due to the crush of the convex parts of the roughness by plastic deformation.

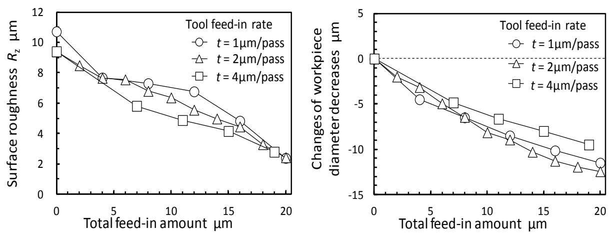
5.2. Changes of workpiece diameter

Figure 4**(b)** shows a transition of changes in the workpiece diameter at varied feed-in rate. At any feed-in rate, the workpiece diameter decreases in proportion to the total feed-in amount. More precisely, the workpiece radius came down constantly by 0.8μm in proportion to the tool feed-in rate (t=1μm/pass), which reveals that the dimensional accuracy of the workpiece diameter could be controlled by the proposed burnishing process.

5.3. Burnishing of small diameter steel and aluminum bars

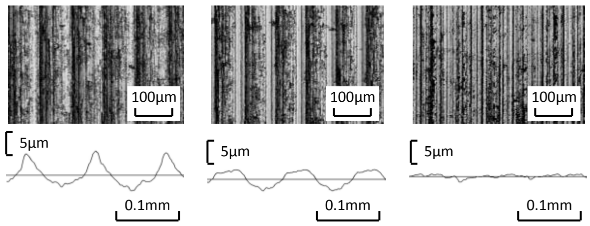
Figure 6 shows a result of the burnishing processing on a small diameter (ϕ10mm) round bar of S45C. Here again, the surface roughness improved in proportion to the total feed-in amount and resulted in the value of *Rz*≈2.5μm.

Results of the burnishing processing on a round bar of aluminum alloy with a diameter of ϕ30mm are shown in Fig.7. Improvement effect on the aluminum alloy was found higher in comparison with the carbon steel resulting in the uniformized surface obtained when the total feed-in amount was 5μm. The surface roughness value shifted in the range of *Rz*=1-3μm through the experiment.



(a) Changes of surface roughness (b) Changes of workpiece diameter

Figure 4. Relation between feed-in rate and burnishing processing properties (S45C, V=57m/min (N=600min^{-1}), f=0.05mm/rev)



(a) After finish turning (b) Total feed-in amount: 12μm (c) Total feed-in amount: 20μm

Figure 5. Transition of the workpiece surface condition at t=2μm/pass (S45C(ϕ30mm), V=57m/min (N=600min^{-1}), f=0.05mm/rev)

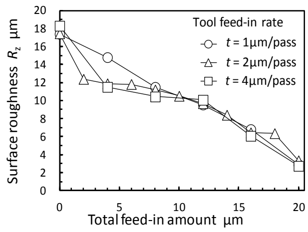


Figure 6. Application to a small diameter S45C bar (ϕ10mm)

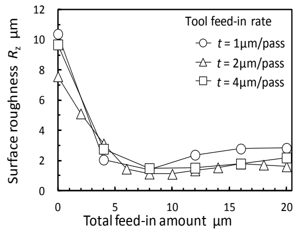


Figure 7. Application to an aluminum alloy (A5056, ϕ30mm)

6. Conclusion

As a measure to perform the burnishing processing simply on the NC lathe, the authors proposed a method to feed-in the flank face of a turning tool radially toward a workpiece. It was made clear that roughness improvement and dimensional adjustment to a level of micron meter could be possible by optimizing the tool feed-in amount.

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