The research on high precision machining of vertical wall

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Keywords: vertical wall , tool rigidity , tool deflection , cutting force ,chatter vibration ,down cut , up cut

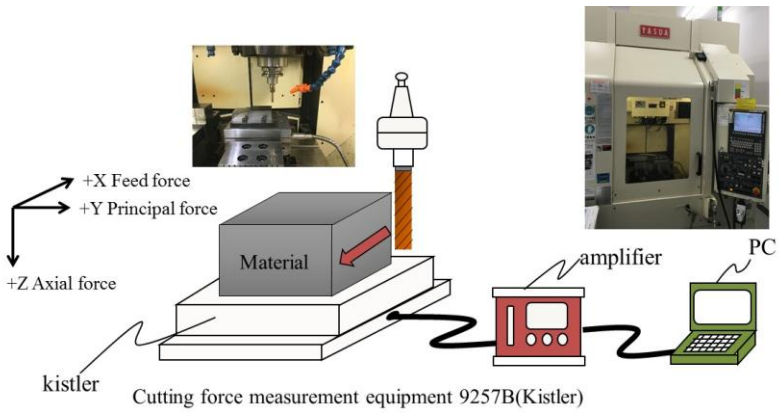
Abstract. In order to investigate the influence of cutting condition to the wall precision in finishing process of high hardened steel , we conducted some experiments changed cutting parameters(cutting speed *Vc*, feed rate *fz* , axial depth of cut *ap*) . The result is that the most impact factor is the axial depth of cut . It was few changed of the wall precision in changing *Vc* and *fz* . On the other hand , by decreasing *ap* , the cutting force is tend to be reduced dramatically . Therefore , we surmise that the tool deflection is suppressed , and the wall deflection is also improved . The result compared with cutting direction is that the wall precision machined by up cut milling is higher than down cut milling . In the case of small *ap* , when *ap* and flute length of the endmill is the same , it is possible to machine the higher wall precision than the machining by using the long flute length endmill , without contacting the cutting edge of the tool shank side with the wall surface .

1. Introduction

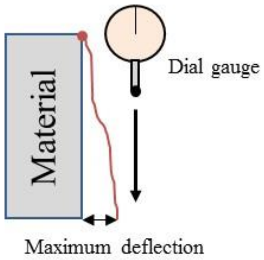
There are many problems in the direct machining of high hardened material , especially in the case of machining deeply work material by end milling process . Vertical wall is on the die and mold, the mold base , slide surface and mold core . In general , vertical wall is finished by endmill of long flute length machining process and the precision of vertical wall is required high quality . But , it is difficult to realize the high precision in only one pass machining because of endmill deflection . So , it is need to machine many times of same surface for high quality and precision . Many researchers made studies to clarify the mechanism of end milling . [1-7] But , the most of their research is concerning with mild steel and aluminum by using a big diameter endmill made of high speed steel . There are rarely studies about wall machining of high hardened steel or wall machining by using small diameter endmill . Therefore , in this paper , the influence of cutting condition to the precision and the quality in the wall machining of high hardened steel has been studied to realize high precision of vertical wall in one pass machining .

2. Experimental procedure

Fig .1 shows a experimental equipment to evaluate the influence of cutting condition to wall precision . Table .1 and Table .2 shows cutting tool specification and cutting condition . Cutting material is high hardened steel SKD61(H) 45HRC , and machining center is YBM640V (YASDA) for high precision machining . Evaluation point is wall precision (deflection , cutting surface) and cutting force .Cutting force is measured by using cutting dynamometer (Fig 1 (a)) . Wall deflection is measured by dial gauge on the machining (Fig 1 (b)) , and wall surface is measured by surface roughness meter of contact type（TOKYO SEIMITSU）(Fig 1 (c)) .



(a) Cutting force measurement



(b) Wall deflection measurement

(c) Surface roughness meter

Fig 1 Experimental equipment

Table .1 Cutting tool specification

Tool diameter	6mm
Flute number	4NT
Flute length	25mm
Overall length	70mm
Helix angle	43°
substrate	Cemented carbide
coating	TH coating

Table .2 Cutting condition

Cutting speed *Vc*	25m/min～250m/min
Feed rate *fz*	0.01mm/t～0.2mm/t
Axial depth of cut *ap*	25,12.5,5mm
Radial depth of cut *ae*	0.1mm
Overhang *OH*	30mm
Cutting direction	Down cut , Up cut
Coolant	Dry with air blow
Material	SKD61(H) 45HRC
Holder	Shrink fit（MST)
Machining center	YASDA YBM640V(BBT40)

3. Results and discussions

3-1 Relation between cutting condition and wall deflection

Figure 2 , figure 3 and figure 4 show measurement results of wall maximum deflection and cutting force . In this case , cutting force *Fy* is selected , because *Fy* is most affected force to the deflection of the cutting tool . *Fy max-min* means that the difference maximum *Fy* and minimum *Fy* , so if *Fy max-min* is big , it occurs chatter vibration .

Fig 2 shows the influence of *Vc* . We can see almost same wall deflection with the increases of *Vc* . But , over *Vc*100m/min , *Fymax-min* became bigger . Therefore , it occurred chatter vibration in *Vc*200m/min . We can find chatter vibration mark on the surface picture .*Fy ave* decrease from *Vc*100m/min because of chatter vibration . So ,*Vc* is needed to adjust within the range it doesn’t occur chatter vibration .

Fig 3 shows the influence of *fz* . We can see the increases of wall deflection with the increases of *fz* , and cutting force is also same tendency . In case of *fz* 0.1mm/t over , it occurred chipping on the peripheral edge . I guess that cuting force to periphral edge is too big .In case of fz 0.2mm/t , *Fymax-min* is increasing rapidly . So , I guess that it is caused by chatter vibration .

Fig 4 shows the influence of *ap* . We can see the increases of wall deflection with the increases of *ap* , and cutting force is also same tendency . But , *Fymax-min* is different tendency . In spite of the differnce *Fy* in *ap*25mm and *ap*12.5mm , *Fymax-min* of *ap*12.5mm is almost same value in *ap*25mm and *ap*12.5mm . I guess that this cutting phenomenon is concerned with simultaneously working cutting edge number in the machining [1] . In the machining by using helix endmill , normally simultaneously working cutting edge value is large when ap is big , and then , it occurs swing of cutting force , as simultaneously working cutting edge number is changed in the one revolution . In case of *ap*12.5mm , simultaneously working cutting edge number is changed from two cutting edge to three cutting edge in the one revolution . Therefore , in spite of *ap*12.5mm , it occurred big swing of cutting force almost same with ap25mm .

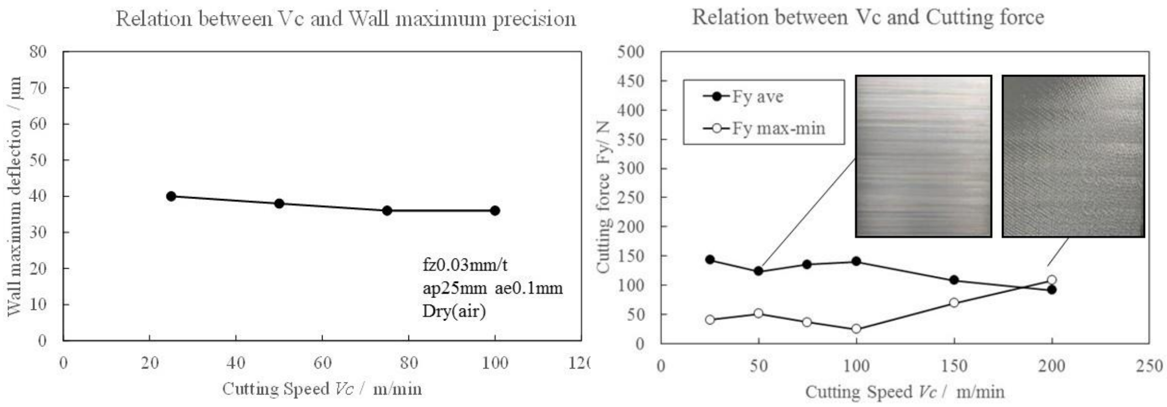


Fig 2 Measurement result of wall deflection and cutting force (the influence of *Vc*)

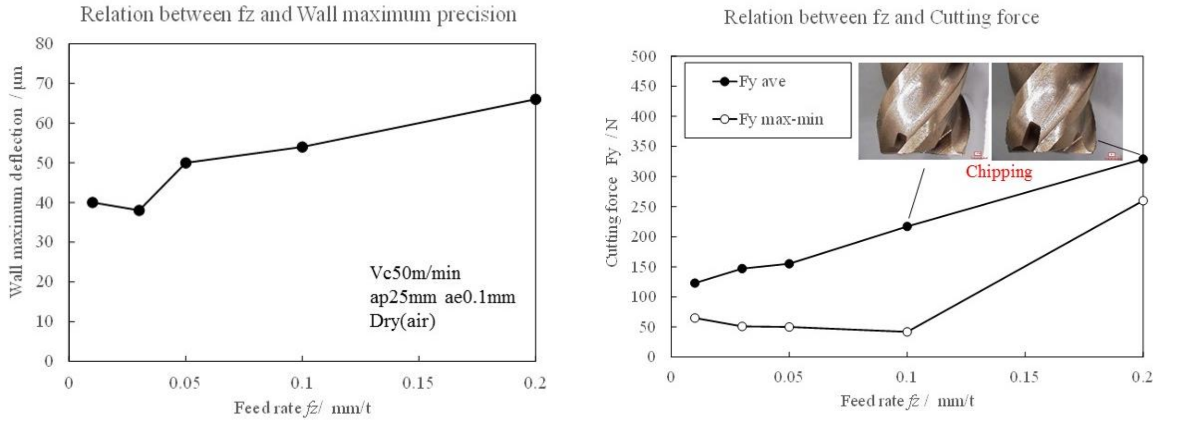


Fig 3 Measurement result of wall deflection and cutting force (the influence of *fz*)

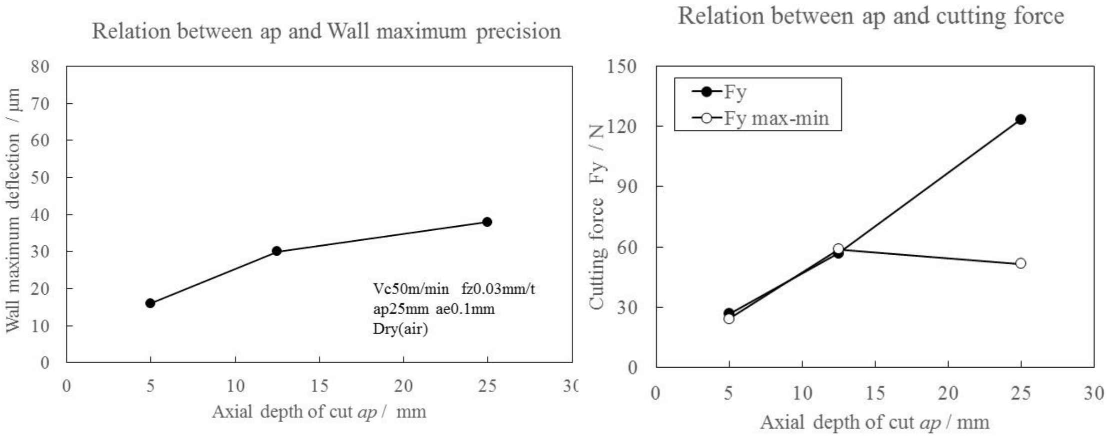


Fig 4 Measurement result of wall deflection and cutting force (the influence of *ap*)

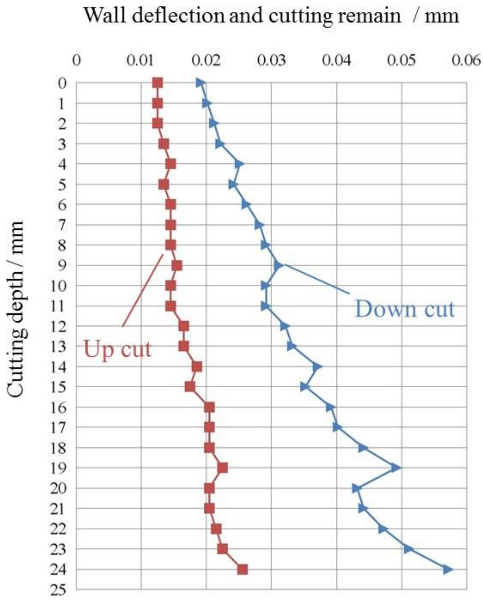
In summary , most impact factor of cutting condition (*Vc* , *fz* ,*ap*) in this cutting test is axial depth of cut *ap* . This cutting test results means that in order to achieve small wall deflection , it needs to suppress cutting force and swing of cutting force .Axial depth of cut *ap* has a strong correlation with cutting force . Therefore , it must be controlled *ap* to less wall deflection .

3-2 Comparison down cut and up cut

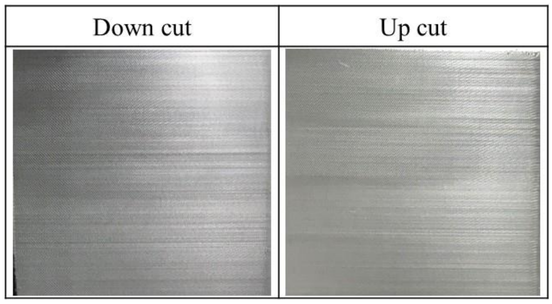
Fig 5 shows wall deflection result compared with down cut and up cut . Cutting condition is *Vc*50m/min , *fz*0.03mm/t , *ap* 25mm . In case of *ap* 25mm , up cut is smaller wall deflection than down cut . About surface roughness , it is measured three position of the surface , upper ,middle and lower .The results is that up cut is better roughness than down cut . Surface roughness is upper roughness better than lower . Totally , up cut is better result than down cut . This is reason that cutting force is different , especially *Fy* . Fig 6 shows cutting force measurement result compared up cut and down cut . *Fy ave* of down cut is 123.2N , and *Fy ave* of up cut is 58.2 N . Up cut can reduce cutting force Fy . Therefore , wall deflection of up cut is better than down cut . Cutting surface roughness is larger with near the lower position . I guess that lower position is cut by end area of endmill . Tool rigidity of end area is smaller than shank side of endmill . Therefore , it occurs vibration end area of endmill . So , Cutting surface roughness is larger with near the lower position from the upper position .

3-3 Comparison with flute length in up cut machining

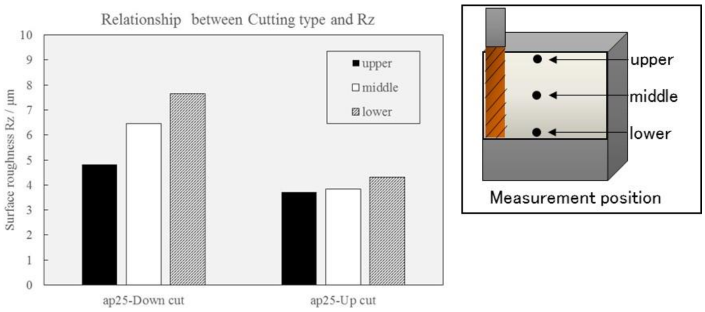
In this experiment, flute length is evaluated in up cut machining . Fig 7 shows cutting tool . This experiment is used two type , long flute length 25mm and flute length 5mm shown in Fig 7 . The reason using tool added grinding to flute length 5mm is to prevent to touch cutting edge of shank side to cutting surface by tool deflection . Fig 8 shows measurement result of wall deflection and cutting reamin . *Ap* 5mm by using flute length 25mm and *ap*5mm by using the tool added grinding are better precision than long flute length 25mm . By using the tool added grinding , cutting edge of shank side do not touch to cutting surface . Therefore , *ap*5mm by using the tool added grinding result shows almost straight wall compared with *ap*5mm by flute length 25mm . In order to achieve the high precision wall condition , up cut is effective method , in addition in case of flute length equal ap , this prevent to touch cutting edge of shank side to cutting surface and it can machine the high precision wall



(a) Wall deflection and cutting remain



(b) cutting surface



(c) surface roughness

Fig 5 measurement results of down cut and up cut

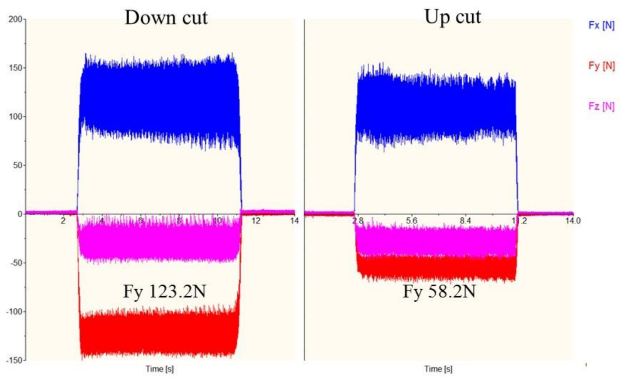


Fig 6 Cutting force

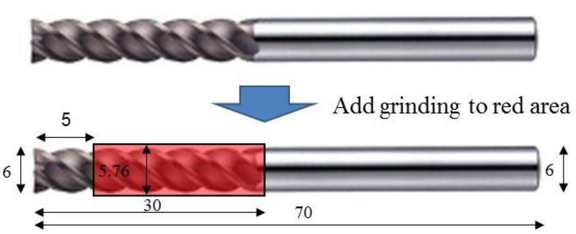


Fig 7 Cutting tool

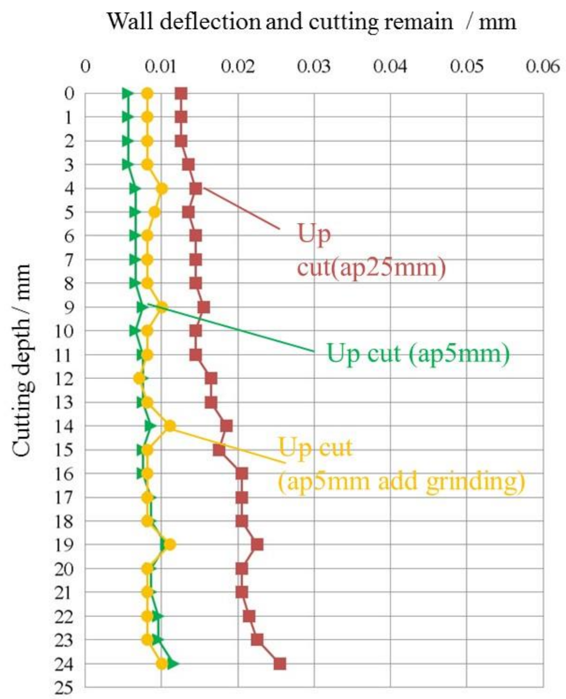


Fig 8 measurement results of up cut

4. Conclusions

(1) In order to suppress the wall deflection , most impact factor of cutting condition (*Vc* , *fz* ,*ap*) is axial depth of cut *ap* . It needs to reduce cutting force and swing of cutting force . This cutting phenomenon is concerned with simultaneously working cutting edge number in the machining Axial depth of cut *ap* has a strong correlation with cutting force . Therefore , it must be controlled ap to suppress wall deflection

(2) Up cut is very effective cutting method to achieve high precision wall . Cutting force (*Fyave*) of up cut is reduced compared with down cut . So , tool deflection is much reduced than down cut and up cut can machine high precision wall .

(3) As flute length equal ap in up cut , cutting edge of shank side do not touch to cutting surface by tool deflection . Therefore , we can machine better straight wall than ap5mm of long flute length .

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