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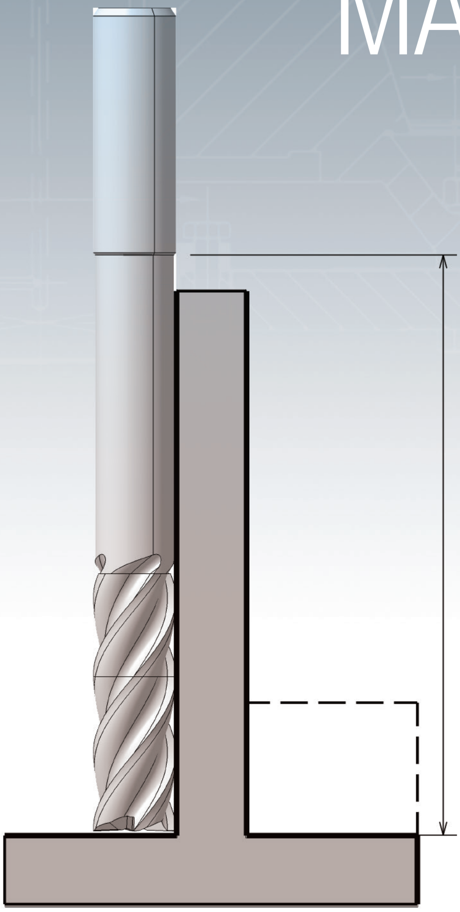
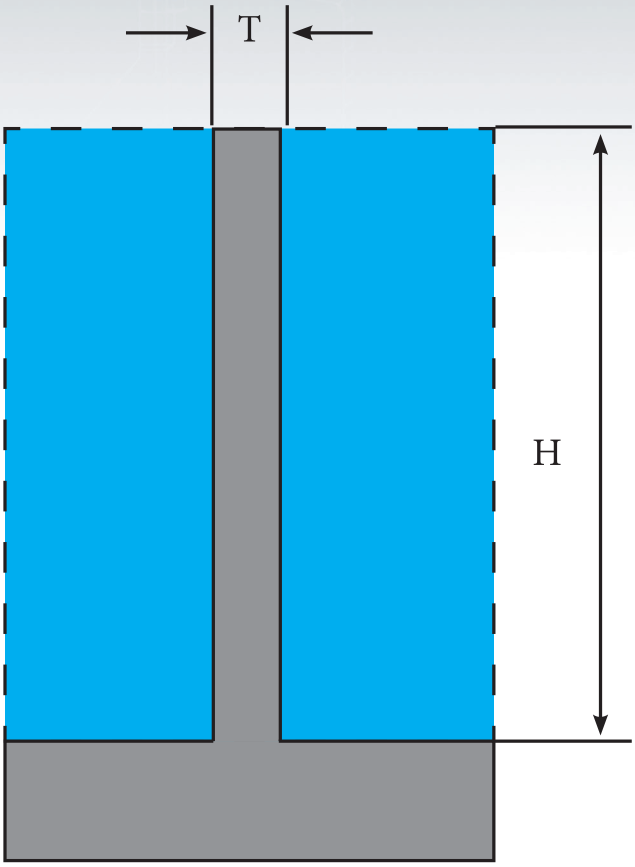
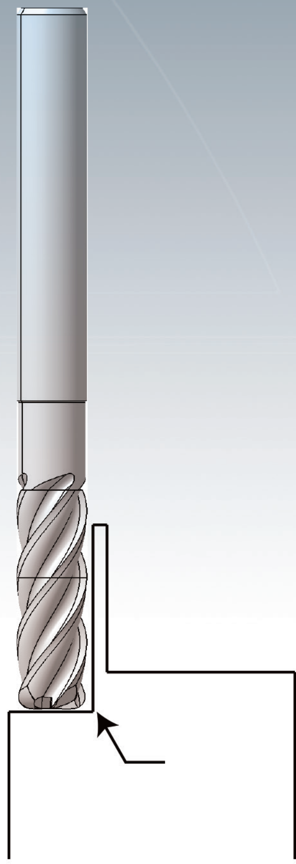
High Performance Cutting Tools

THIN WALL
MACHINING GUIDE







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THIN WALL MACHINING GUIDE- ESSENTIALS

PROPER TOOLING

A long length tool, combined with a long length of cut, cannot be used due to deflection, chatter and breakage. It is essential to keep the tool as stable as possible while maintaining the ability to reach to the desired depth. It is essential to look at necked-down tooling when reaching depths more than 3 times the diameter.

UNDERSTANDING AXIAL DEPTH OF CUT (ADOC)

Keeping a wide cross-section behind the wall for support on the way down is vital. Below, we recommend producing a “stepped down” approach dividing the total wall height to manageable depths while working each side of the wall. The ADOC dimension can/will vary depending on the material (and its hardness) being cut.

UNDERSTANDING RADIAL DEPTH OF CUT (DOC)

A progressive radial depth of cut (RDOC) strategy is of equal importance as wall height is being established. Reducing tool pressure while support stock is disappearing is equally important to keep wall stable.

OTHER IDEAS

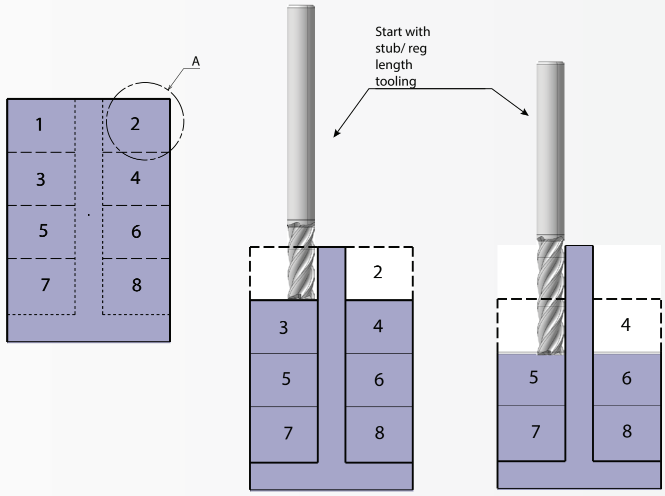
- Climb milling will help to keep tool pressure to a minimum.
- Vibration dampening/wall stabilization can be achieved in “hard to fixture thin wall situations” by using thermoplastic compounds or wax - which can be removed (thermally).
- The use of ultra-high performance tool paths can optimize tool performance, work with lighter depths of cut and offer less tool cutting pressure.

THIN WALL MACHINING CAN BE CATEGORISED INTO 3 TYPES

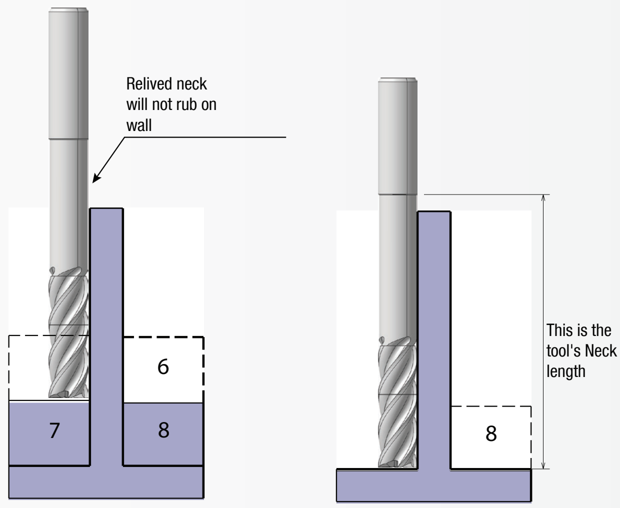
Ratio H:T of 15:1	Ratio H:T between 15:1- 30:1	Ratio H:T >30:1

STRATEGY

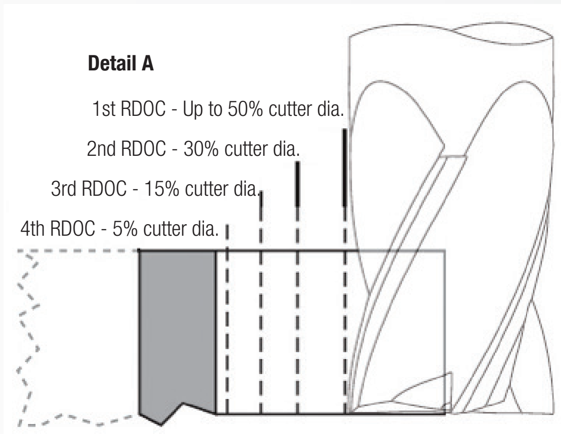
4:1 for Non Ferrous	8:1 for Steel/ Stainless Steel/ Super alloys



(Figure 1)



(Figure 2)



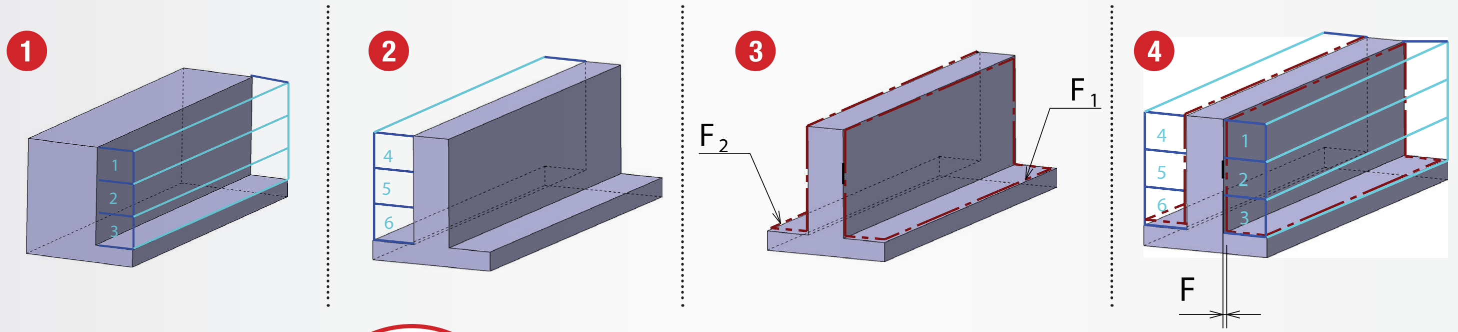
Detail A represents a 5-step progressive radial approach. The number of passes will depend upon your particular application, material/hardness & final wall thickness/height.

Note:
Thin walls deflect under pressure so separate machining passes are required to minimize friction and vibration.

Milling part features with thin wall characteristics while maintaining dimensional accuracy and straightness can be difficult at best. Although multiple factors contribute, some key components are discussed below and can help turn these types of applications around.

High Performance Cutting Tools

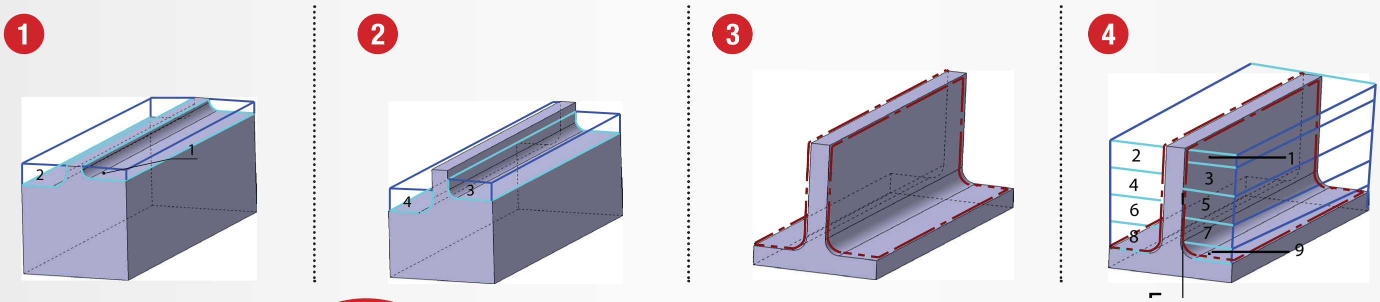
RATIO H:T OF 15:1



STABILITY
RELATIVELY STABLE

- Machine each side of the wall in overlapping passes
- Leave clearance on the faces for finishing passes
- When machining 15:1 and lower please ensure that you follow the above flow of steps

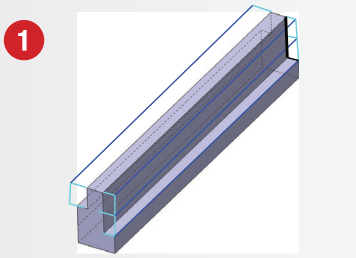
RATIO H:T OF 30:1

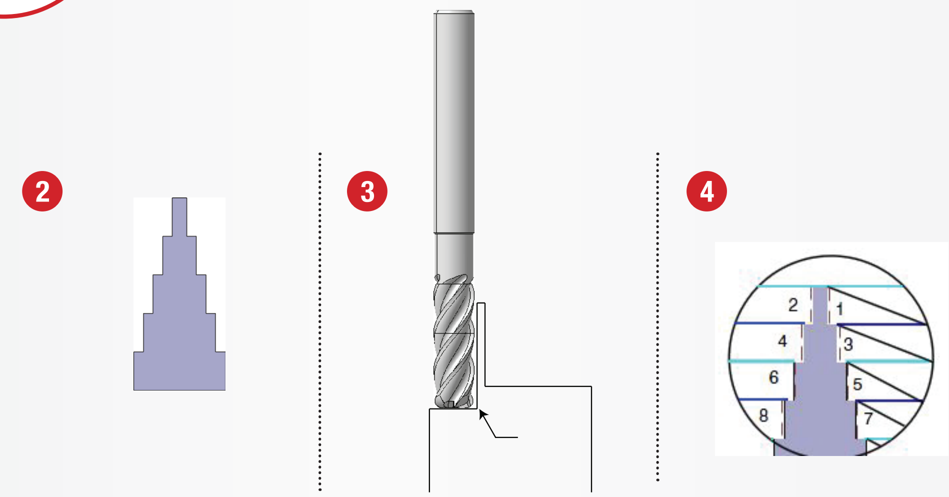


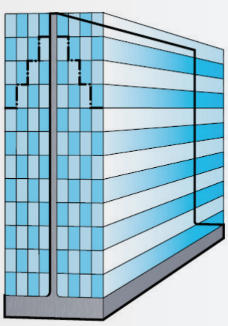
STABILITY
LESS STABLE AND PRONE TO DEFLECTION

- Choose step-support milling, with passes on alternate sides of the wall
- Overlapping passes provide material support to add stability
- Less than 30:1 for Non ferrous structures ensure that the last machining pass takes out 80% of the material and For high strength materials like super alloys keep 0.2mm as a finish stock. For ferrous materials you can keep stock between 0.2mm-1mm

RATIO H:T >30:1





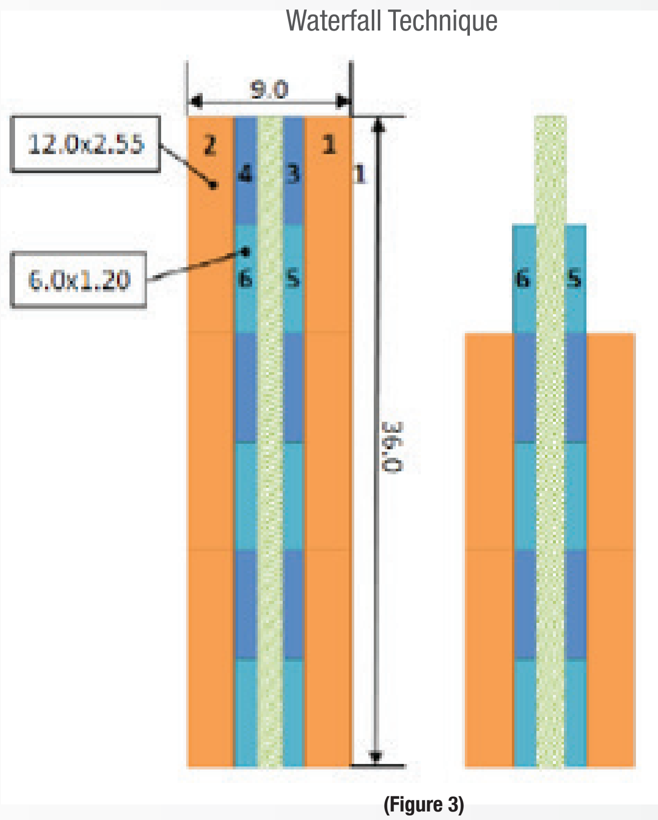


STABILITY
VERY UNSTABLE

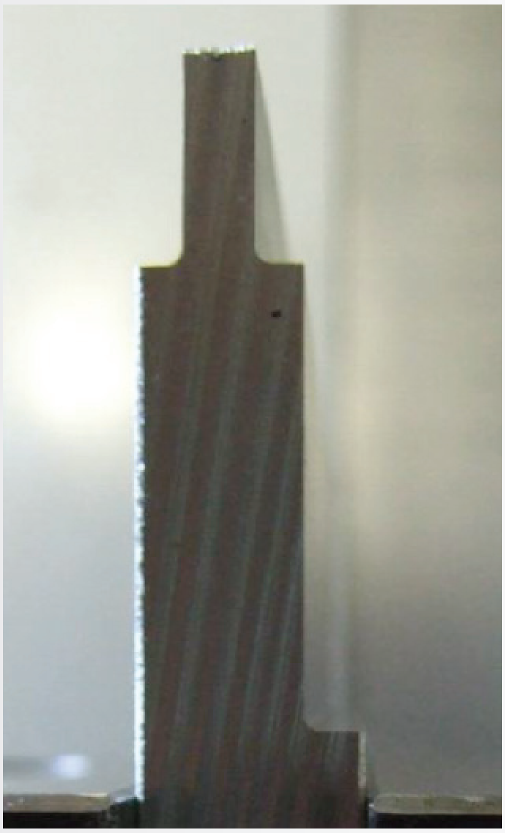
- Machine passes on alternating sides of the wall
- Approach the wall thickness in stages
- The material support of thicker sections is crucial as thinner sections are being machined
- Move passes down the wall in a step formation moving outwards

STRATEGY 4:1 FOR ALUMINIUM

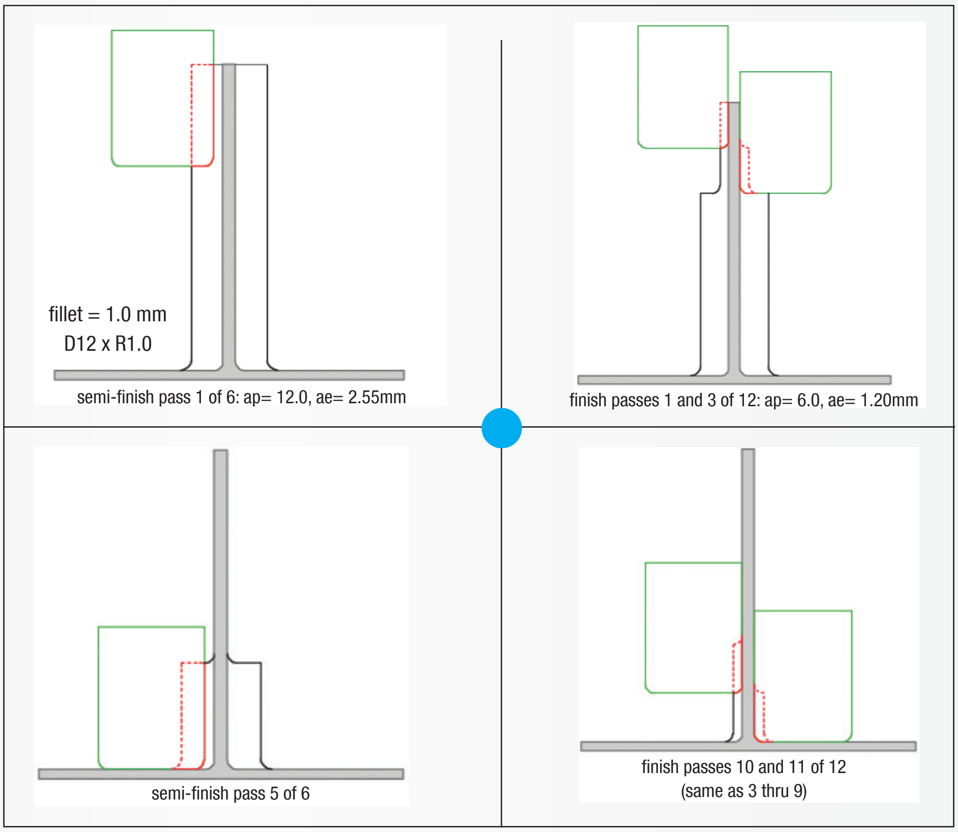
- 4:1 rule – ratio of wall height to wall thickness
- In our case the wall is 36 mm tall, hence in roughing we reduced the wall to 9 mm thick
- During finishing too the axial DOC cannot be larger than 4 x wall thickness
- In our case finished wall thickness is 1.5 mm, hence max. axial DOC is 6 mm
- Finishing is typically done in 2 radial passes, with the last pass removing ~80% of final wall thickness, i.e. a radial DOC of 1.2 mm
- Hence wall is 3.9 mm thick before final finishing, i.e. a pre-finish will remove 5.1 mm.
- Apply the 4:1 rule again, i.e. 4 x 3.9 = 15.6 mm axial DOC for pre-finish cut. (Practically take as 12 mm)
- Applying the 4:1 rule results in 18 passes to finish each wall.
- Wall is divided into three levels, each level requiring 2 pre-finish cuts and four finish cuts.



(Figure 3)



(Figure 4)



(Figure 5)

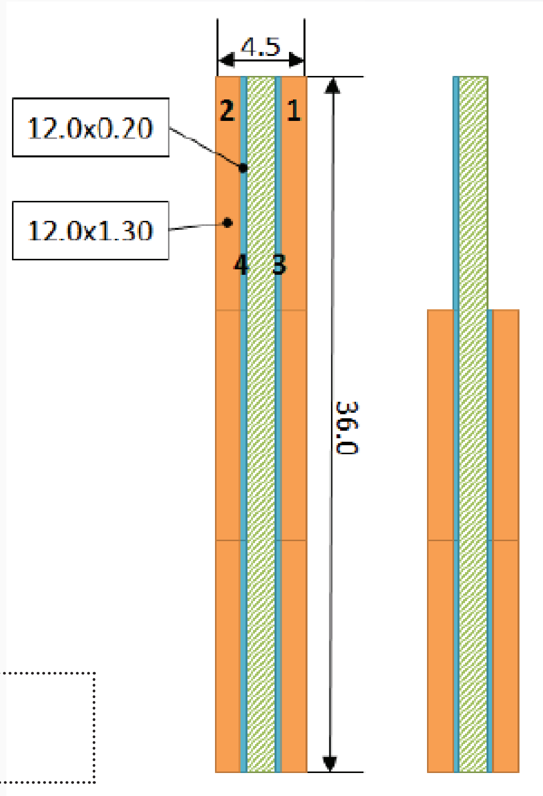
THIN WALL MACHINING GUIDE- TITANIUM 8:1

In order to machine thin pocket walls in titanium without vibration problems, the eight-to-one rule (8:1) can be used to devise the machining plan. This approach, ensures the part is always stiff enough to machine, avoiding part vibrations.

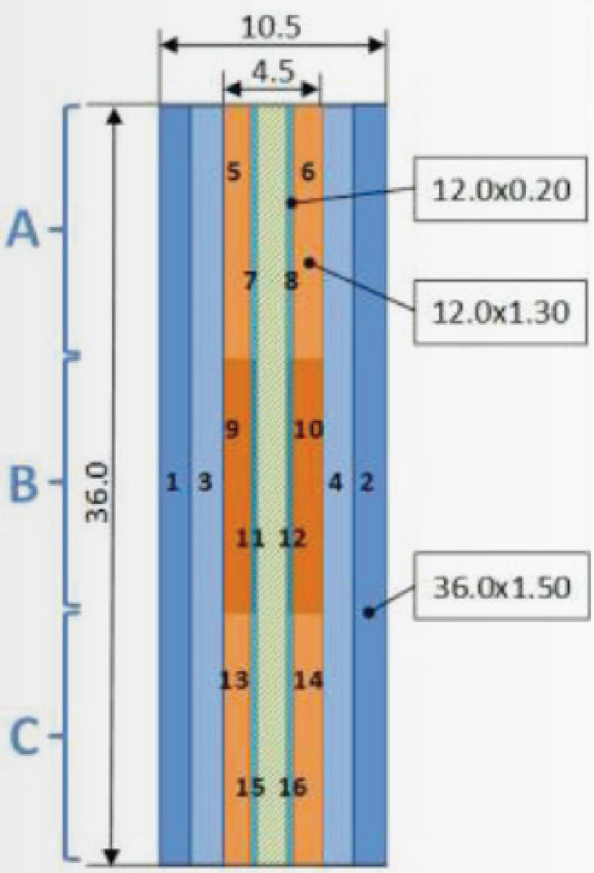
Aircraft structural parts have complex shapes, hence work piece chatter is difficult to eliminate as natural frequencies change constantly during machining.

Using the 8:1 rule makes the titanium part “rigid”, allowing you to focus on only optimizing your cutters to be able to achieve the cuts resulting from the method (smaller cuts can be taken but will slow down machining). Hence, titanium behaves as a stiffer material than aluminium where the ratio is 4:1.

The application of the rule is done in reverse order (Figure):
Example :- thin wall 36.0mm high, 1.5mm thick (ratio of height to thickness



(Figure 6)



(Figure 7)

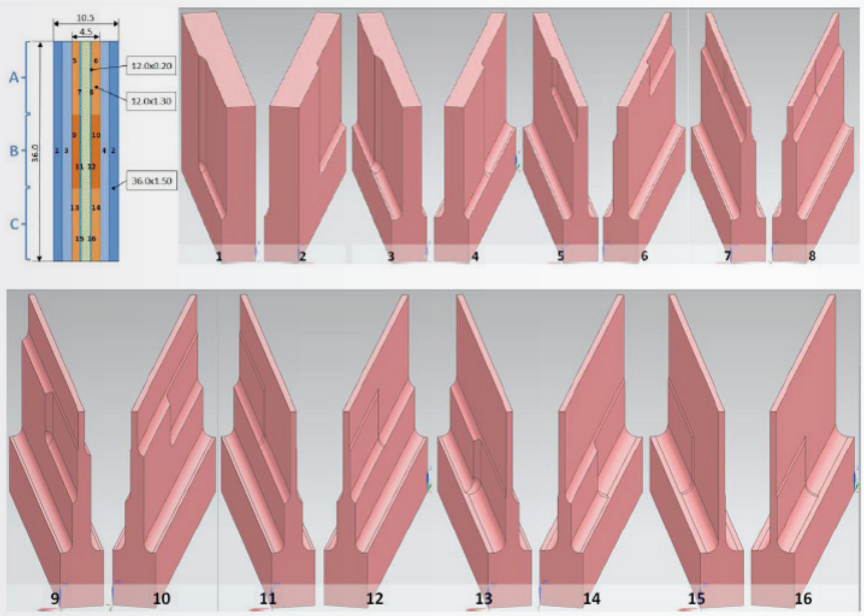
The result of roughing and semi finishing needs to result in a ratio of wall height and wall thickness of 8:1 (no more); Example: for a 36.0mm wall, the thickness after roughing and semi-finishing should be 4.5mm or more.

When taking the final finishing pass, the axial depth of cut cannot be larger than 8 times the finished wall thickness; Example: for a 1.50mm thick wall, the maximum cutting depth is 12.0mm

Finishing is typically done in two radial passes (depending on wall height), the last one removing 0.20mm; this wall will measure 1.50+2x0.20=1.9mm thick before final finishing.

As the wall measures 4.5mm thick after rough/semi-finish, there is 1.30mm to remove before final finishing to obtain a 1.9mm thick wall, which is done by a pre-finish cut.

Repeated application of the 8:1 rule allows to take us 8x1.9=15.2mm axial depth of cut. In this case it’s practical to use 12.0mm depth, which will then be followed by finishing at the same depth.

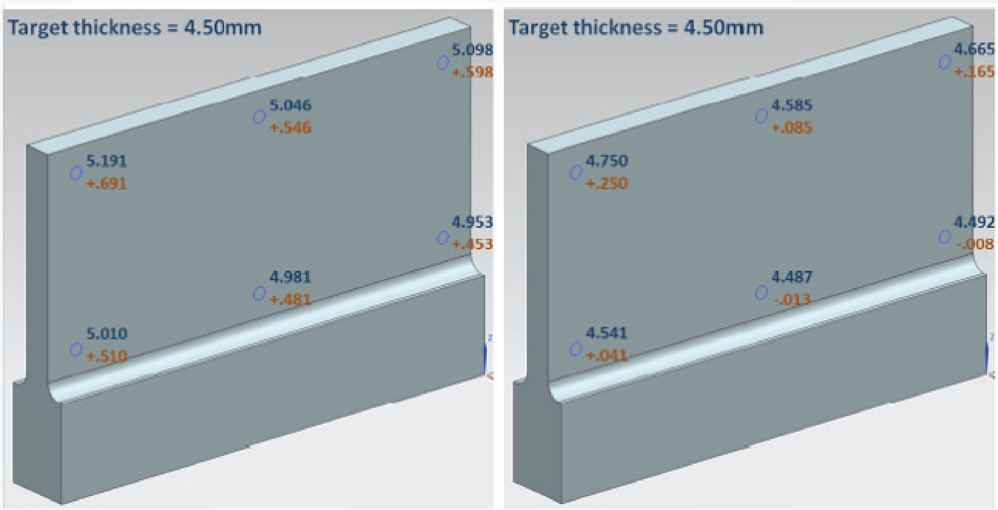


(Figure 8)

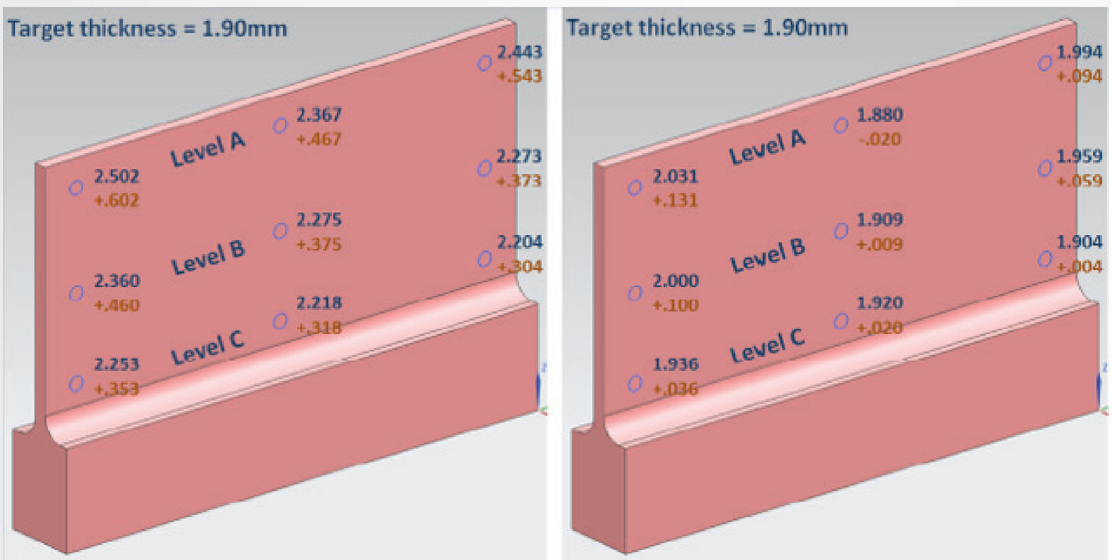
Figure 8 Titanium plate machining steps; 1-4 roughing; 5-6 semi-finish, 7,8 finish; Images of the partially machined work pieces were generated using Unigraphics NX7.5

First Stage

Roughing Wall thickness readings



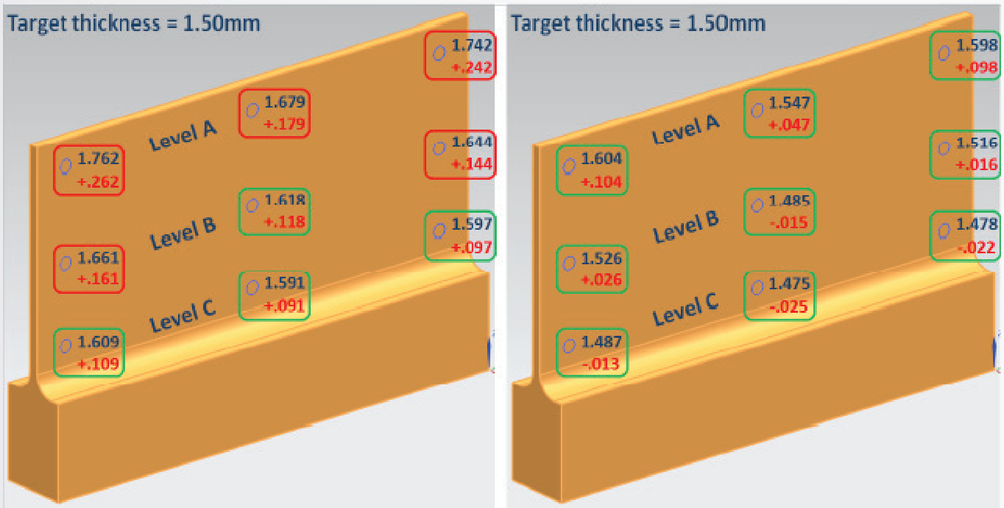
(Figure 9)



(Figure 10)

Second Stage

Semi Finish wall thickness readings



(Figure 11)

Third Stage

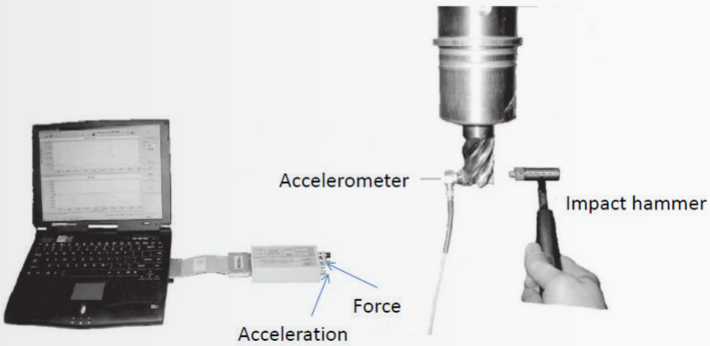
Finish Wall thickness Readings

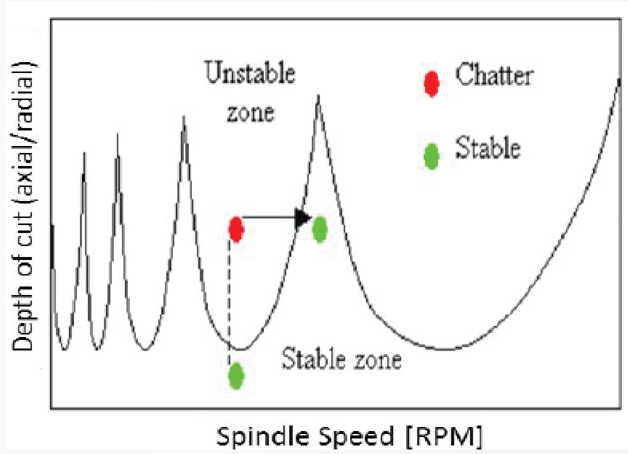
THIN WALL MACHINING GUIDE- TITANIUM 8:1 (ACTUAL READING)

Machining Step	Location	Part deflection (μm)	Tool deflection (μm)	Total deflection (μm)	NC program Compensation (μm)
Step 1 Roughing	Top	42	130	172	250
Step 2 Roughing	Top	52	130	182	250
Step 3 Roughing	Top	69	130	199	250
Step 4 Roughing	Top	114	130	244	250
Step 5 Semi-finishing	Top	108	117	225	250
Step 6 Semi-finishing	Top	131	117	248	250
Step 7 Finishing	Top	37	28	65	50
Step 8 Finishing	Top	41	28	69	50
Step 9 Semi-finishing	Middle	44	117	161	180
Step 10 Semi-finishing	Middle	60	117	177	180
Step 11 Finishing	Middle	20	28	48	50
Step 12 Finishing	Middle	23	28	51	50
Step 13 Semi-finishing	Bottom	12	117	129	140
Step 14 Semi-finishing	Bottom	25	117	142	140
Step 15 Finishing	Bottom	14	28	42	50
Step 16 Finishing	Bottom	15	28	43	50

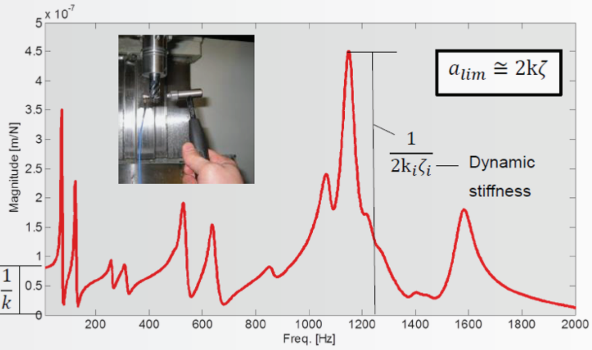
The below readings were further dealt with using an accelerometer and the vibrations were resolved. (Figure 12)

THIN WALL MACHINING GUIDE- TITANIUM 8:1 (FRF)





$$\text{Frequency response function (FRF)} = \frac{\text{Displacement}}{\text{Force}}(\omega) = \frac{x}{F}(\omega)$$

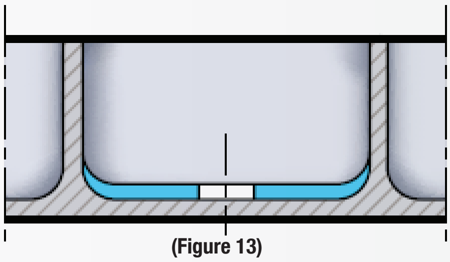


Identifying the FRF Frequency Response Function of the machine using an accelerometer and a Impact hammer Identifying stable cutting zones/ Safe zones for the setup Incorporating those Stable cutting zones and cutting with those revised parameters

(Figure 12)

THIN POCKET FLOOR MACHINING GUIDE

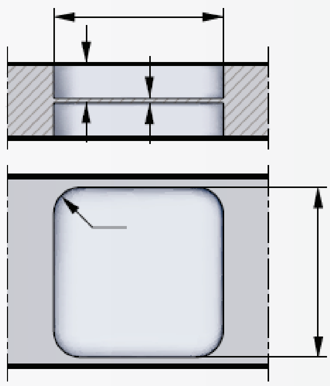
If a thin pocket floor is fully supported by fixturing one sided web, see (Figure 13), radial step-over and feed are adjusted to obtain the required surface finish, by pocketing from the center to the walls. You start by opening it from the center and then going outward towards the walls



(Figure 13)

If you have a two-sided web that is not supported (Figure 14) when the second side is being finished, you have to leave a thicker floor on the last side to finish. The first side can be finished as if it was supported. The last side is stepped down in small axial passes until the finished floor before you step out radially (“down and over” technique). This method will take longer to machine but has the advantage of simple and cheap fixturing. For very large production runs, vacuum tooling maybe more cost-effective.

Note :- When machining the final pass of first side keep Ae 30% of D. This will ensure that the Surface does not attract too much of Axial force but more radial force. When machining the final pass of the second side ensure that the Ae is 60% of D. It may not give you the best surface finish but will ensure least vibrations and warpage



(Figure 14)

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