

機械系教科書シリーズ28

CAD/CAM

工学博士 望月 達也 著

コロナ社



9

サーフェスとCAM



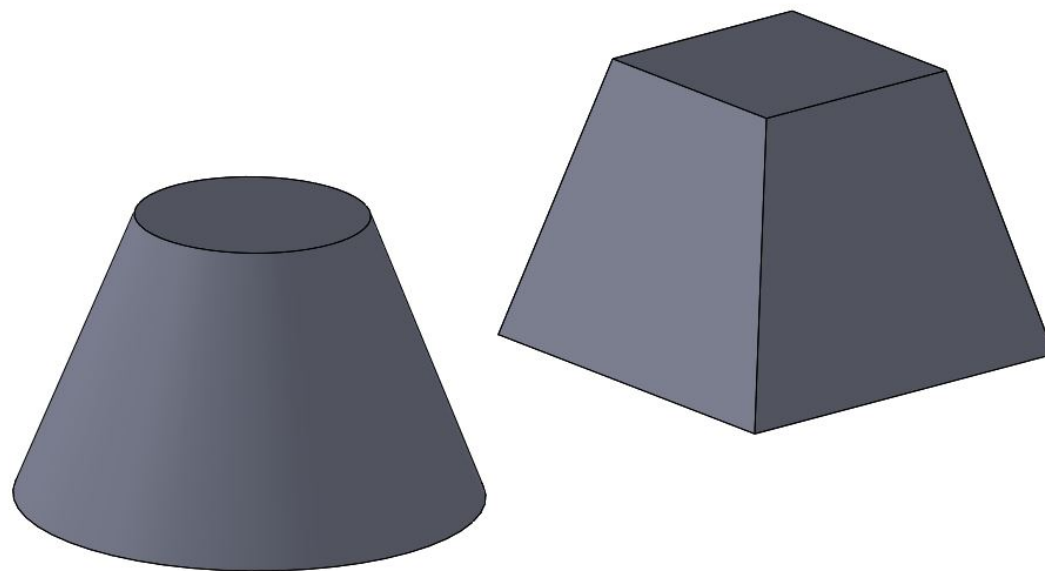


図9.1 円錐台，角錐台



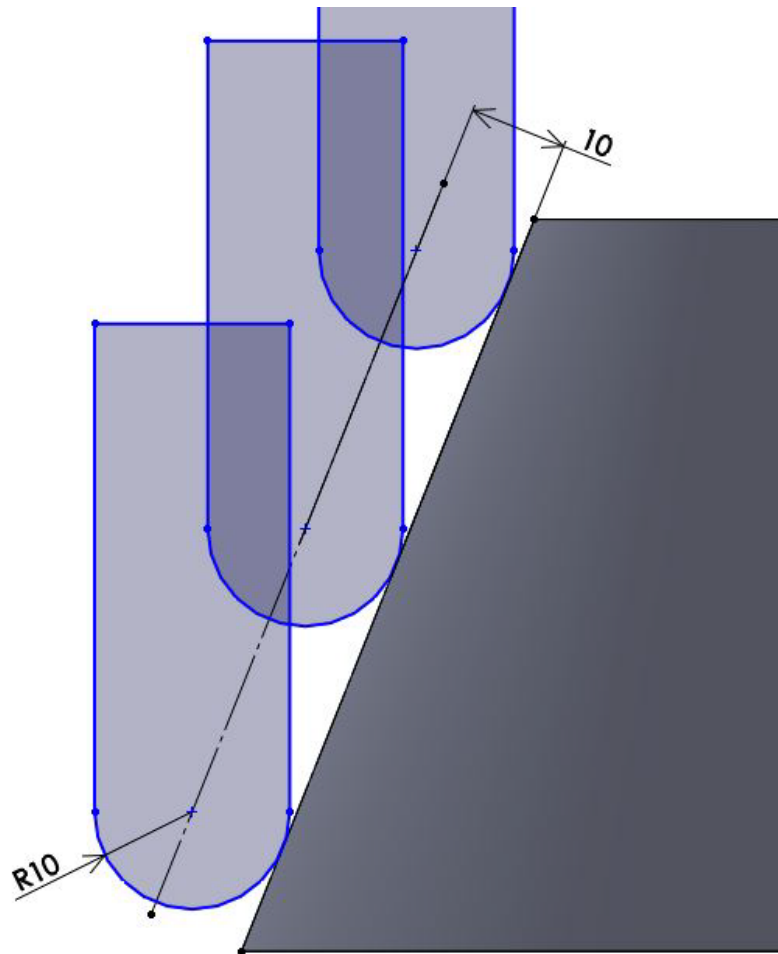


図9.2 側面の加工



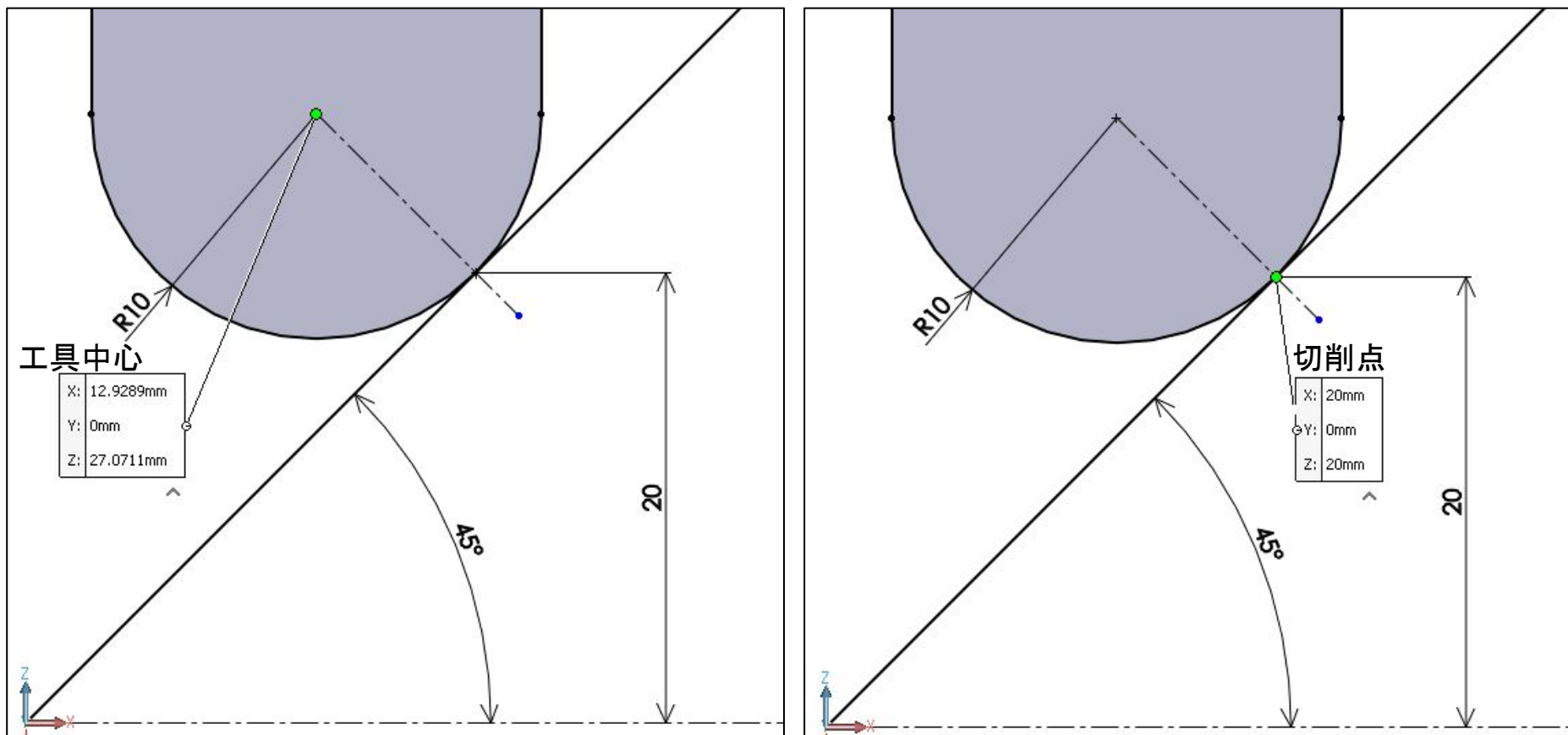
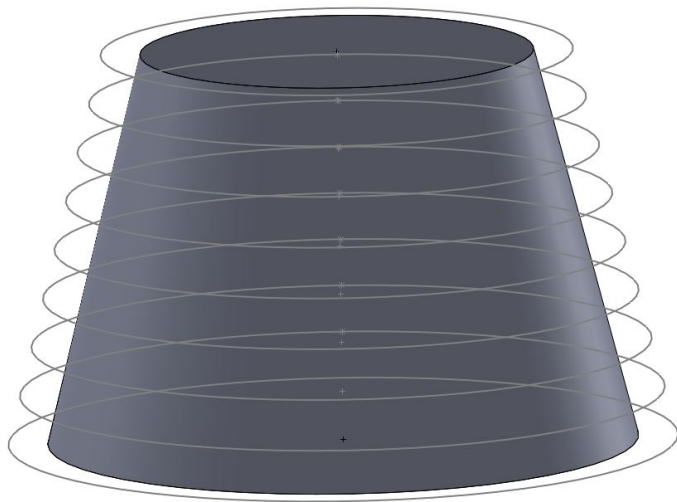
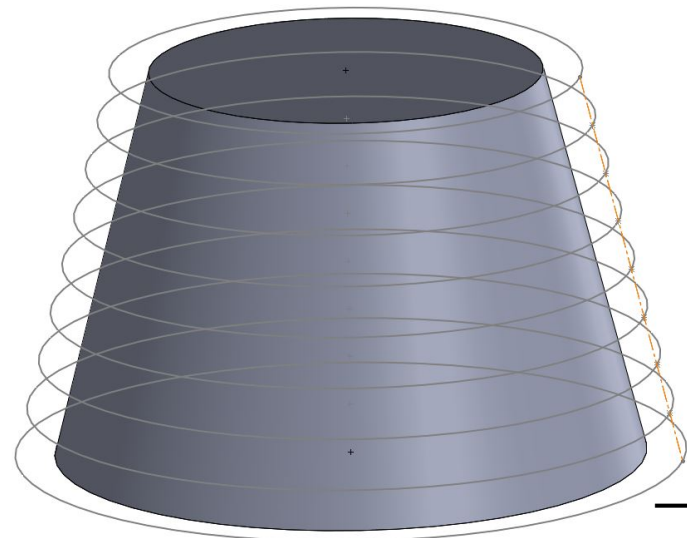


図9.3 切削点と工具中心

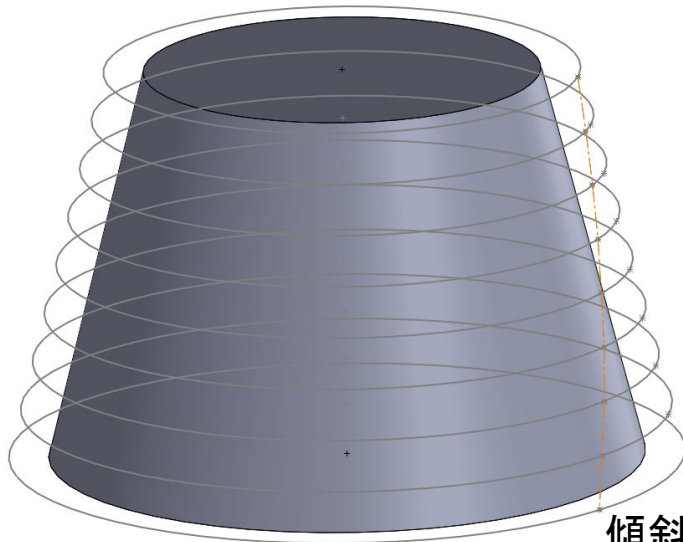




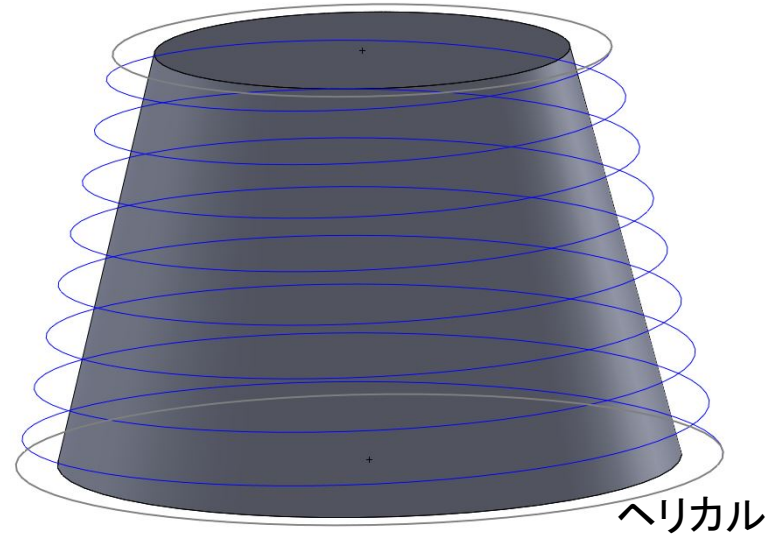
アプローチとリトラクト



一定



傾斜



ヘリカル

図9.4 円錐台を3軸加工する工具軌跡の例



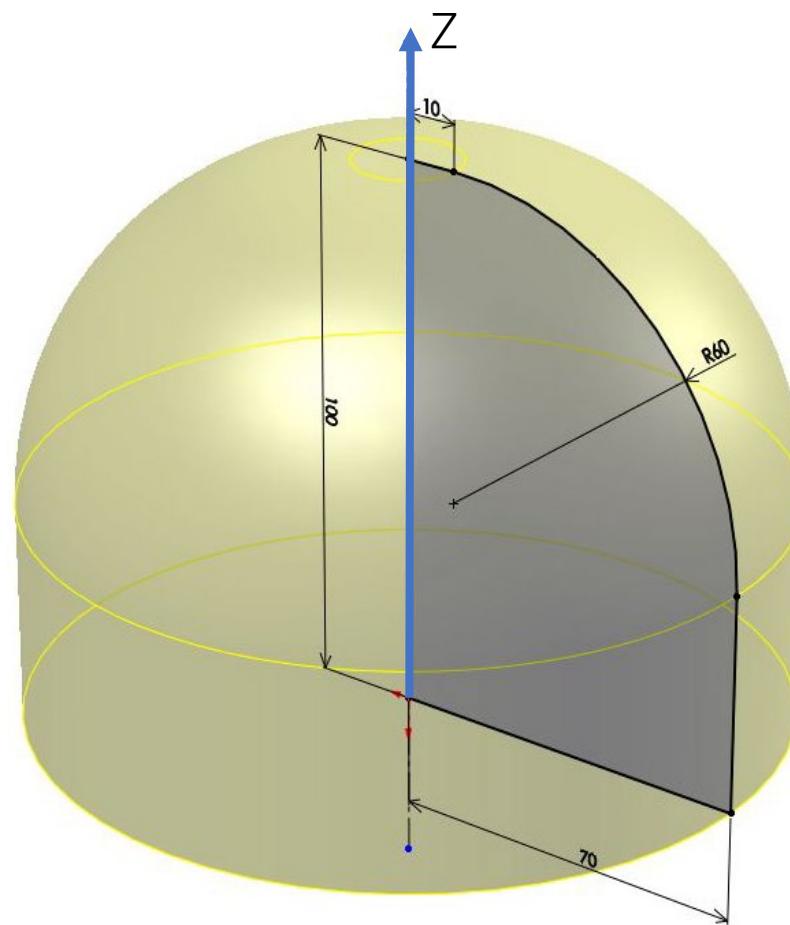
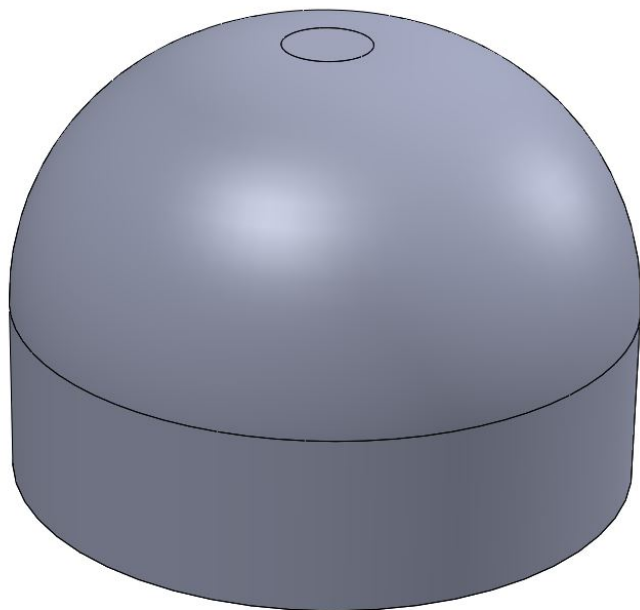
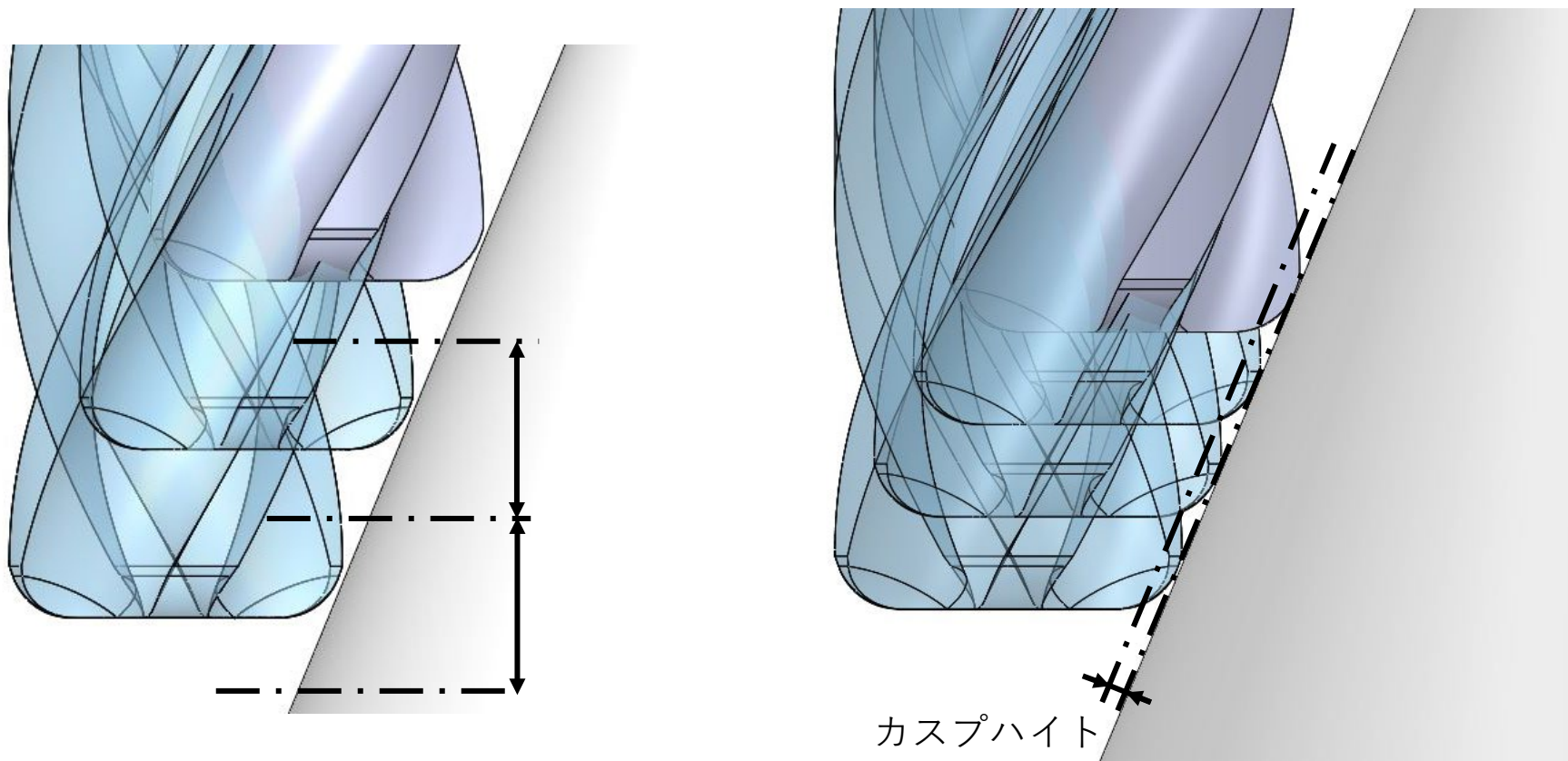


図9.5 加工形状





(a)一定

(b)カスプ

図9.6 深さ(z方向)のパラメータ



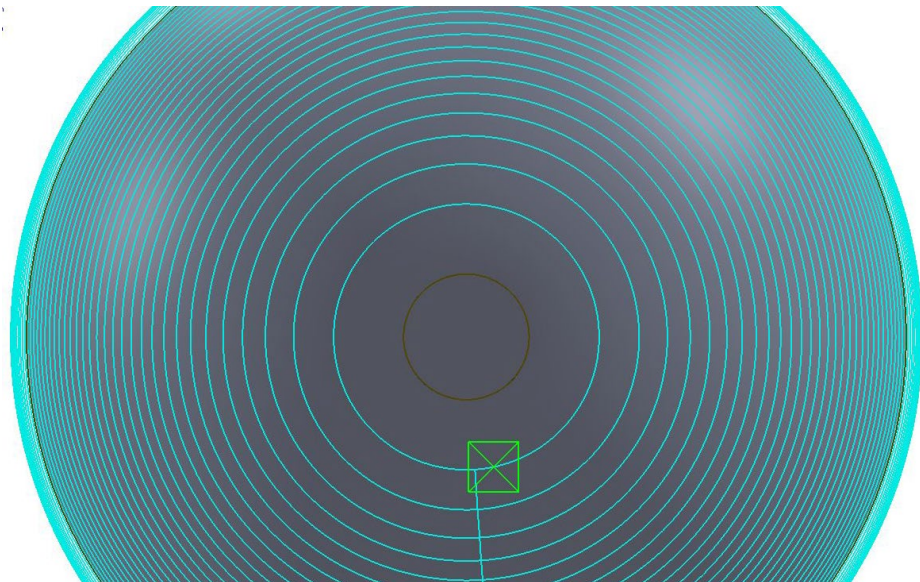
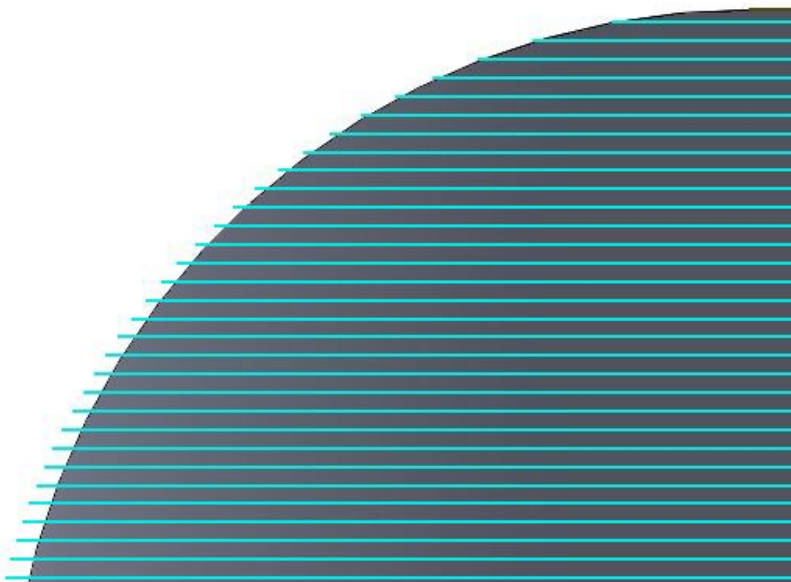


図9.7 深さ一定の工具軌跡



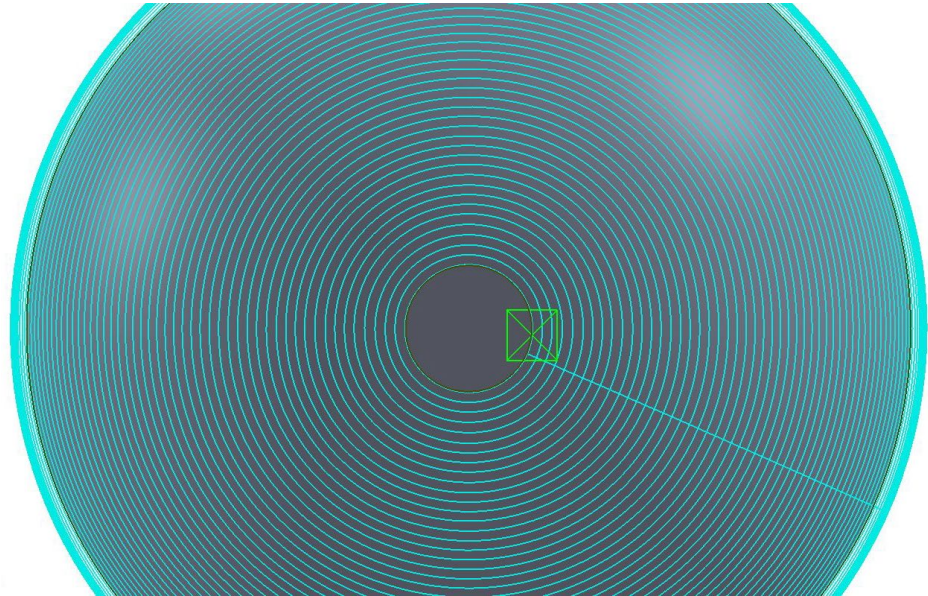
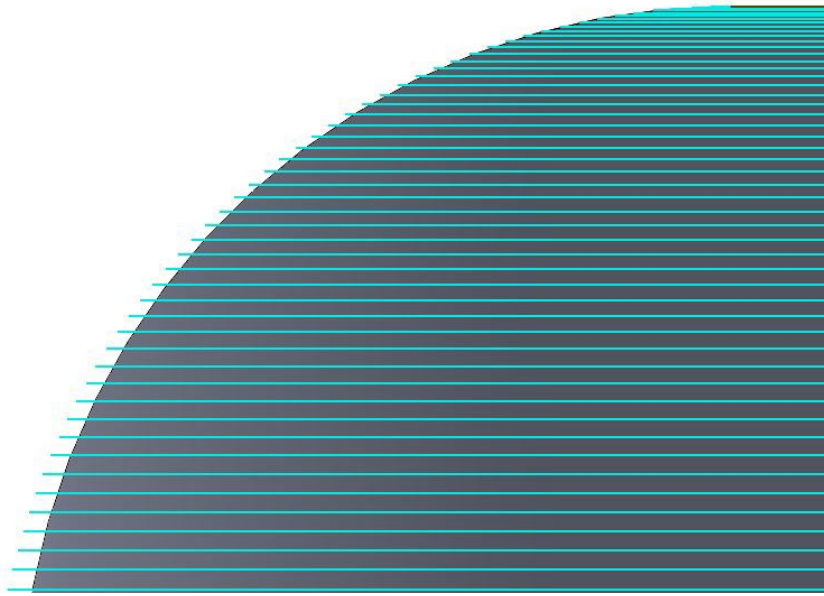


図9.8 カस्पハイトを指定した工具軌跡



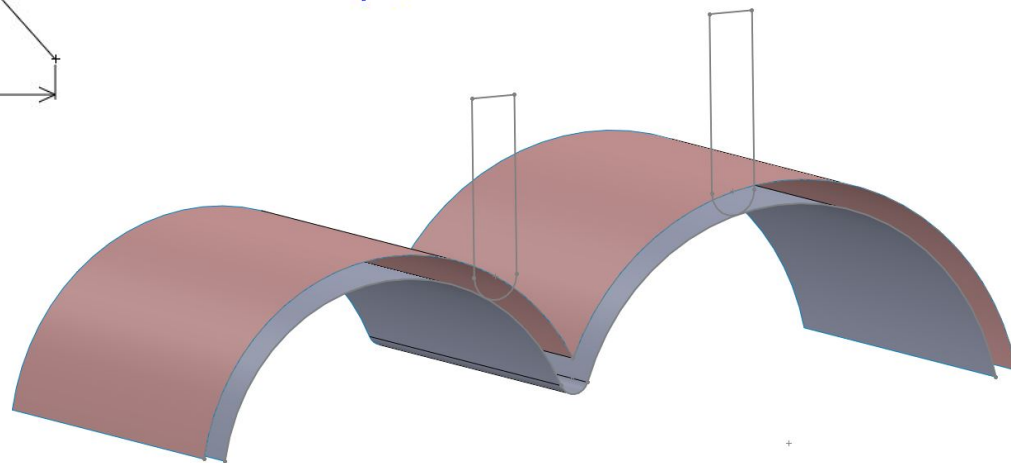
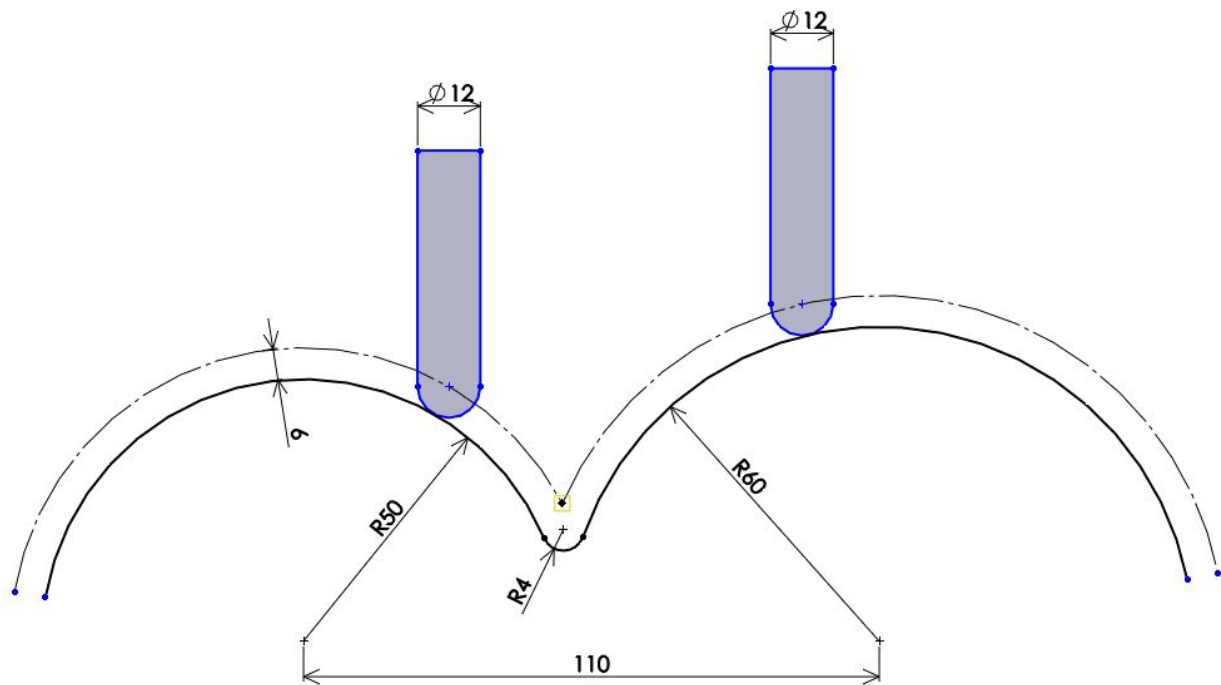


図9.9 半径50 mm, 4 mm, 60 mm の円弧が正接で接続



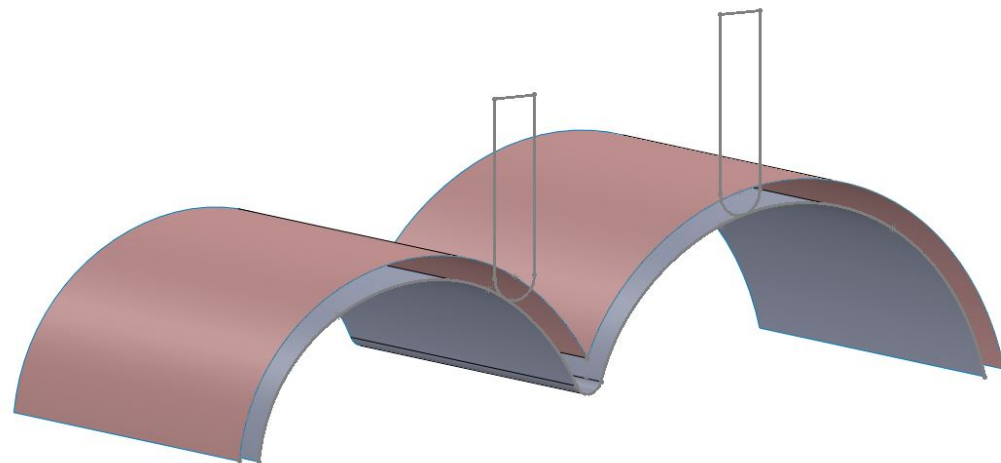
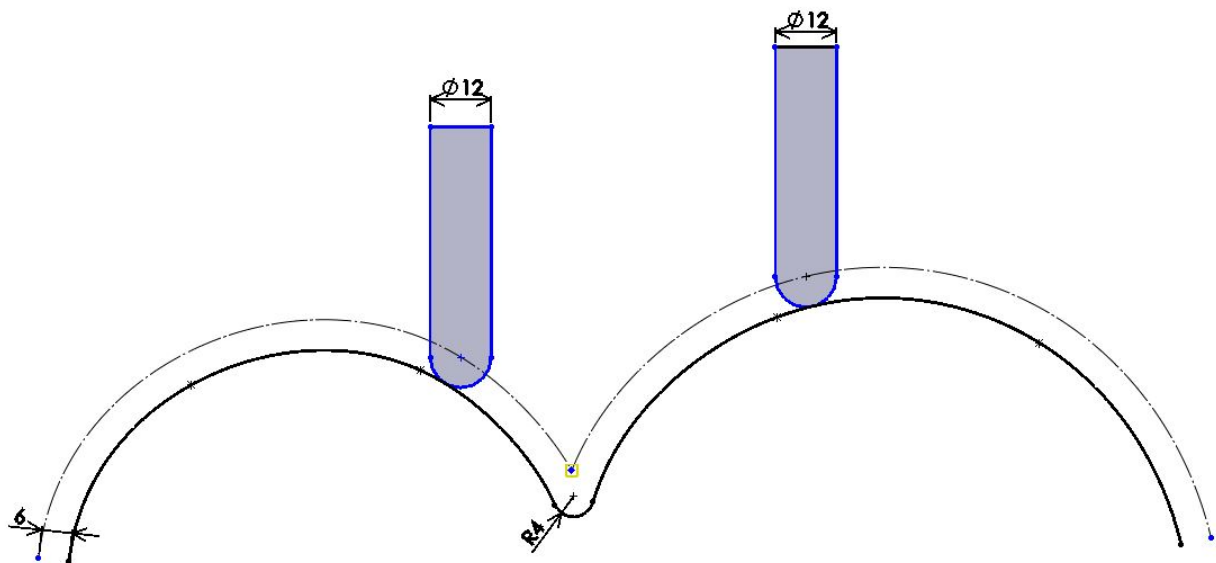


図9.10 半径50mmと半径60mmの円弧をスプライン曲線で近似



スプライン曲線の上側に6mmのオフセットはエラー

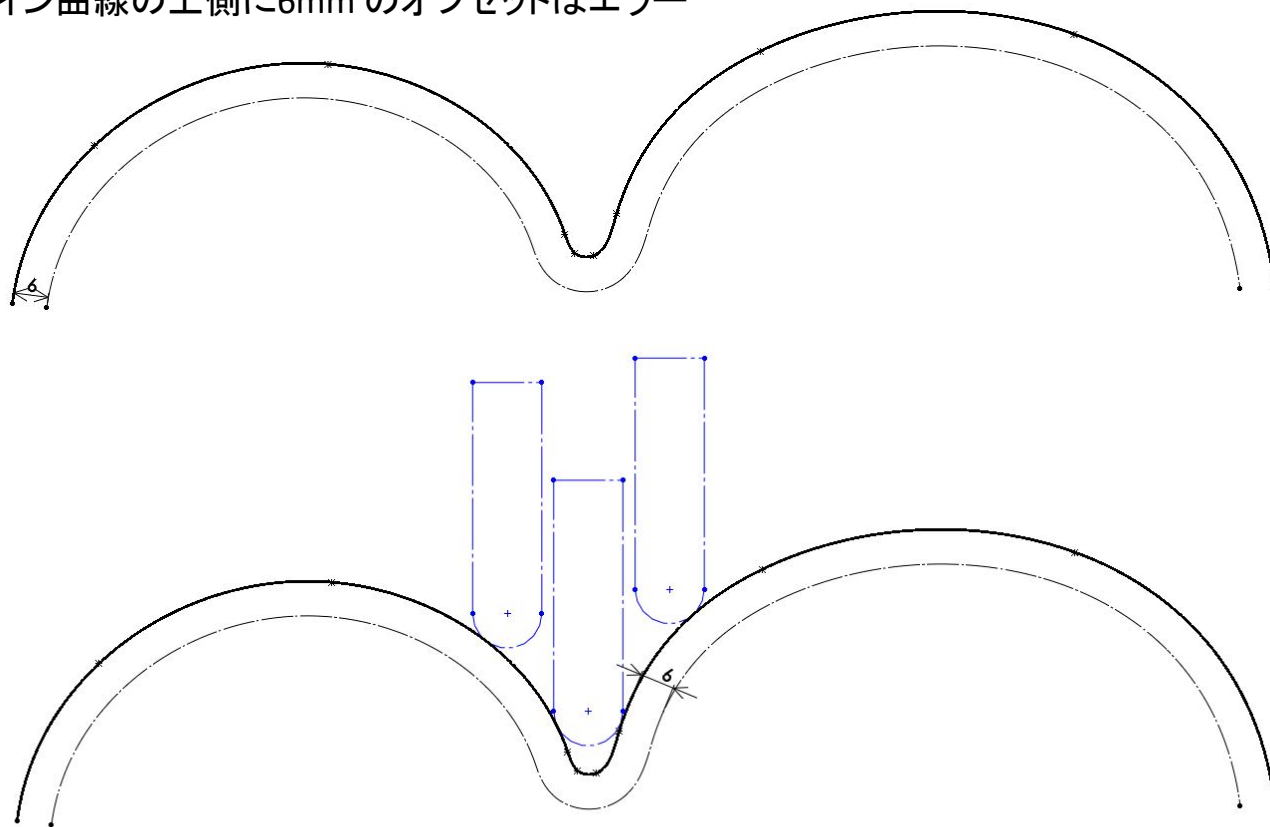


図9.11 図9.9の曲線を一つのスプラインで近似



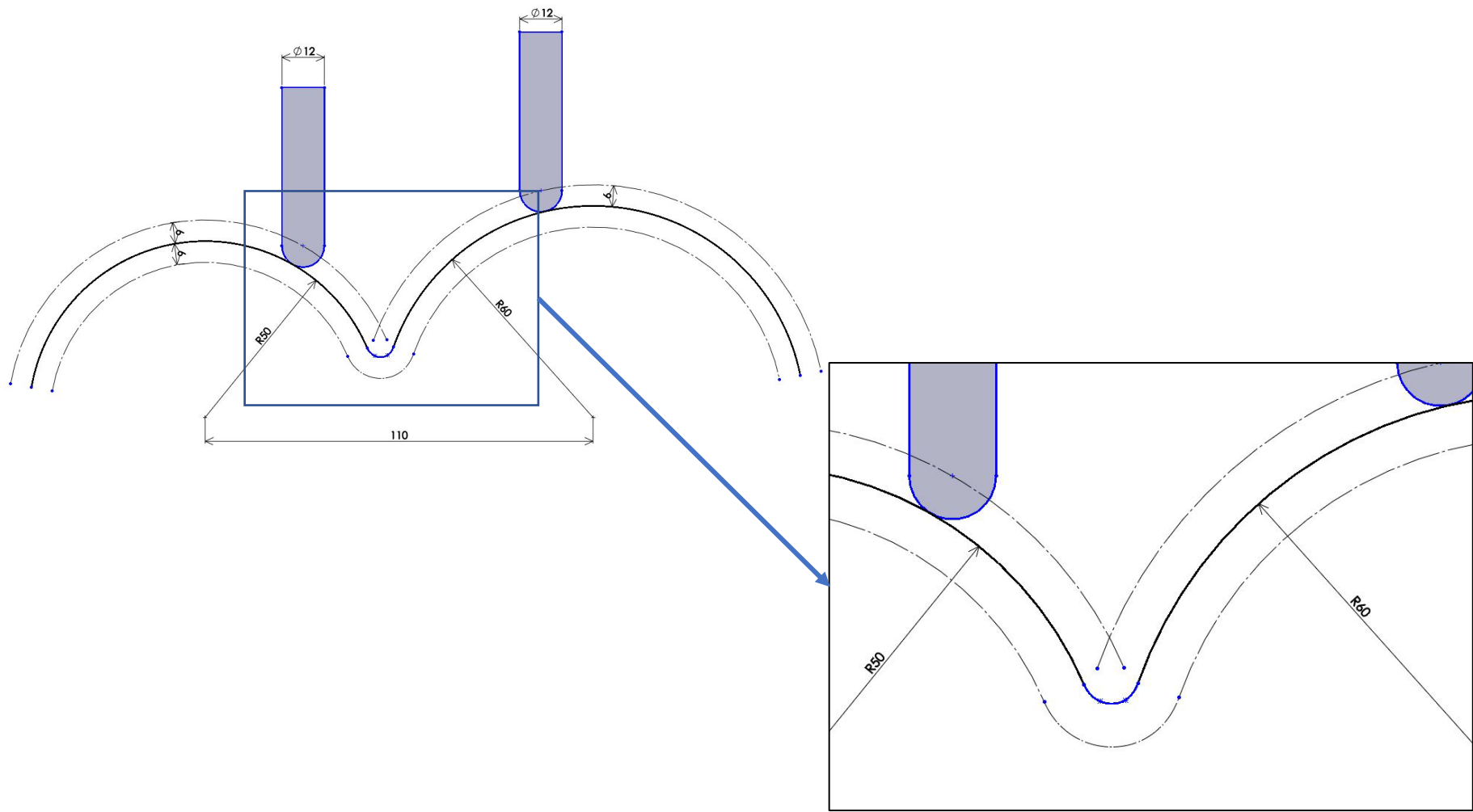


図9.12 半径50 mm と半径60 mm の円弧がスプライン曲線で正接に接続している図



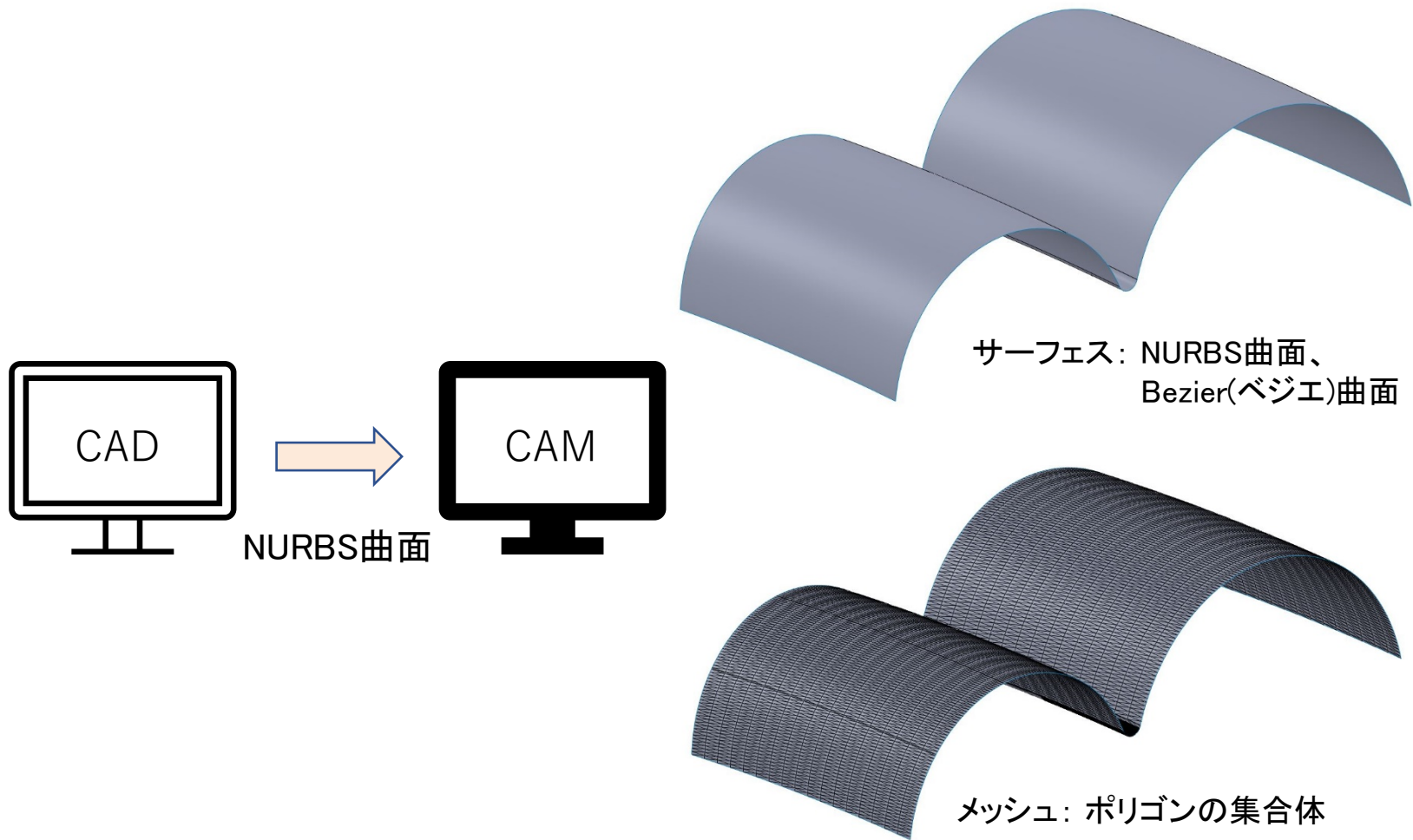
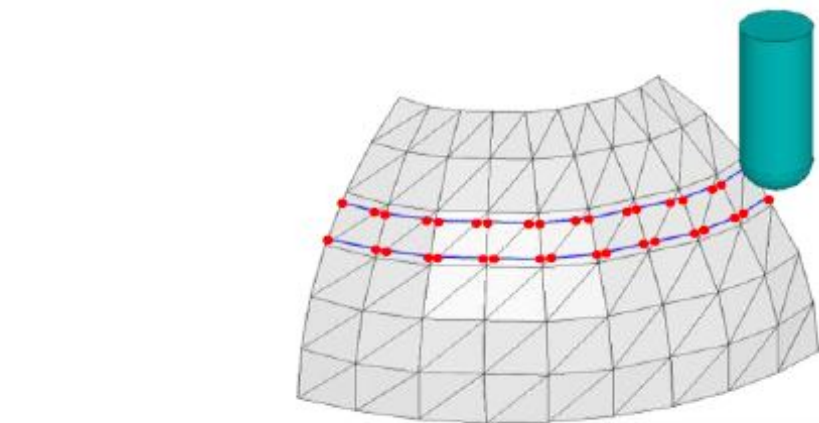
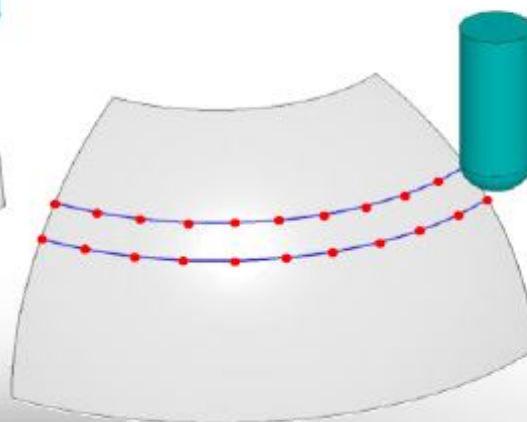


図9.13 CAMにおけるサーフェスの形状表現





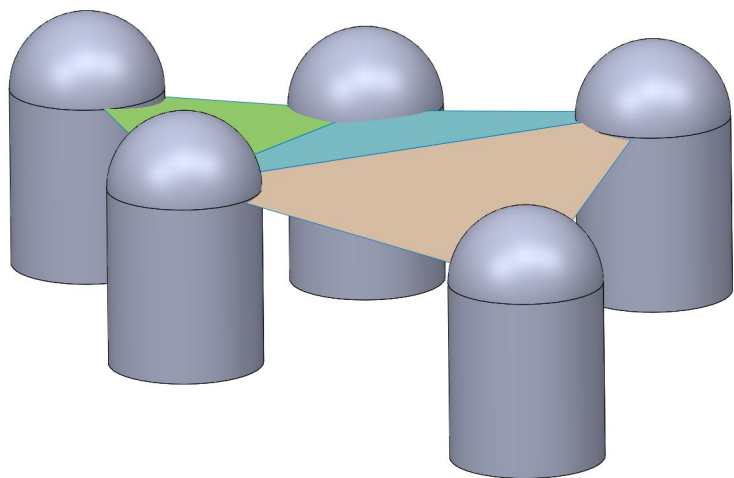
ポリゴン演算
面近似⇒切削点



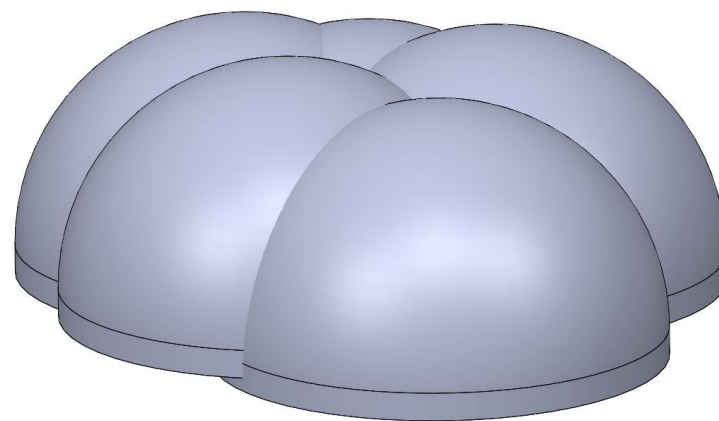
サーフェス演算
面接触⇒切削点

図9.14 切削点の演算





(a) 工具を反転してポリゴンの頂点に工具の中心を一致させる



(b) 工具の直径 > ポリゴン

図9.15 ポリゴンメッシュによる逆オフセット



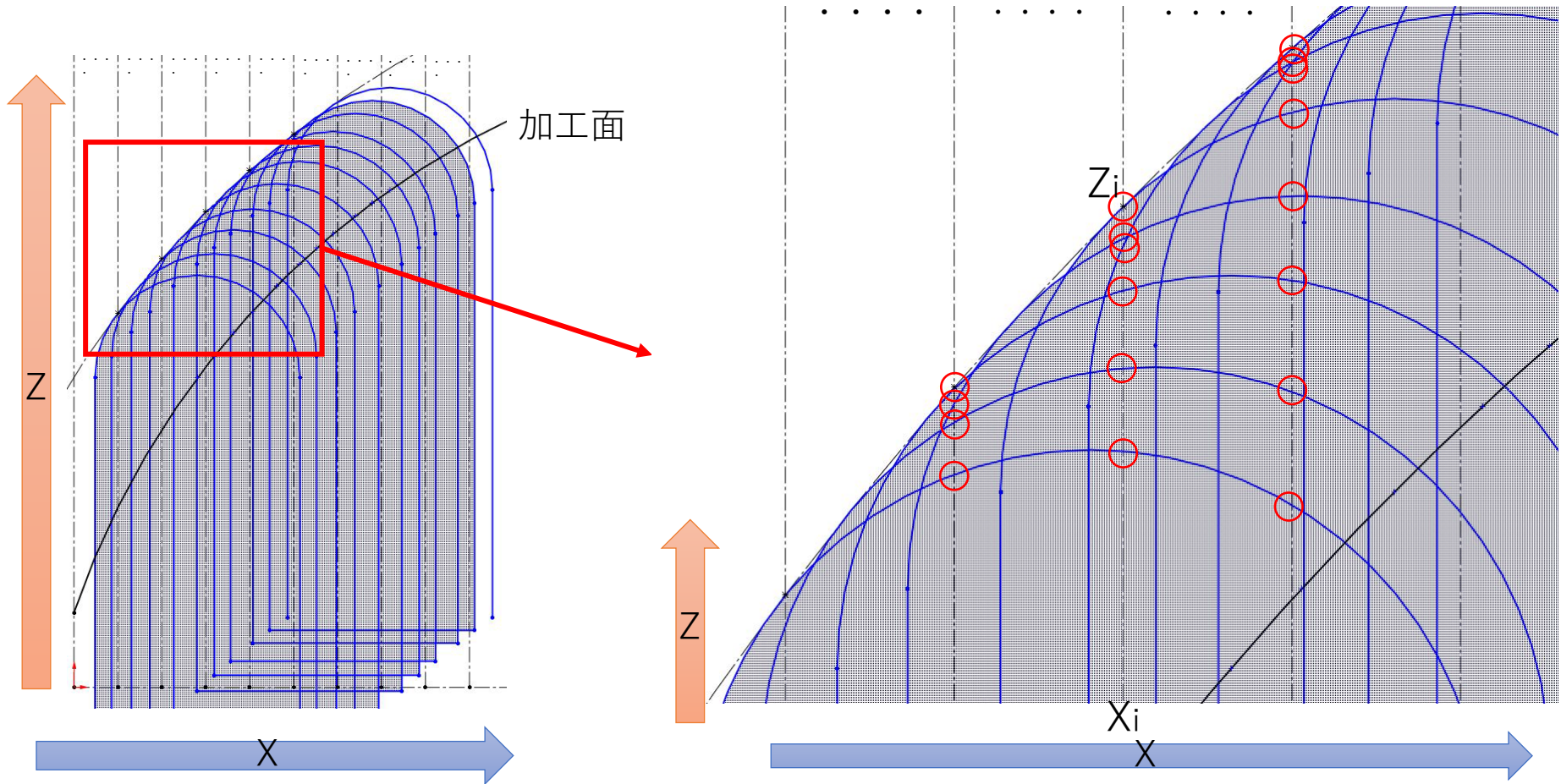


図9.16 Zマップを用いて包絡線を求める方法



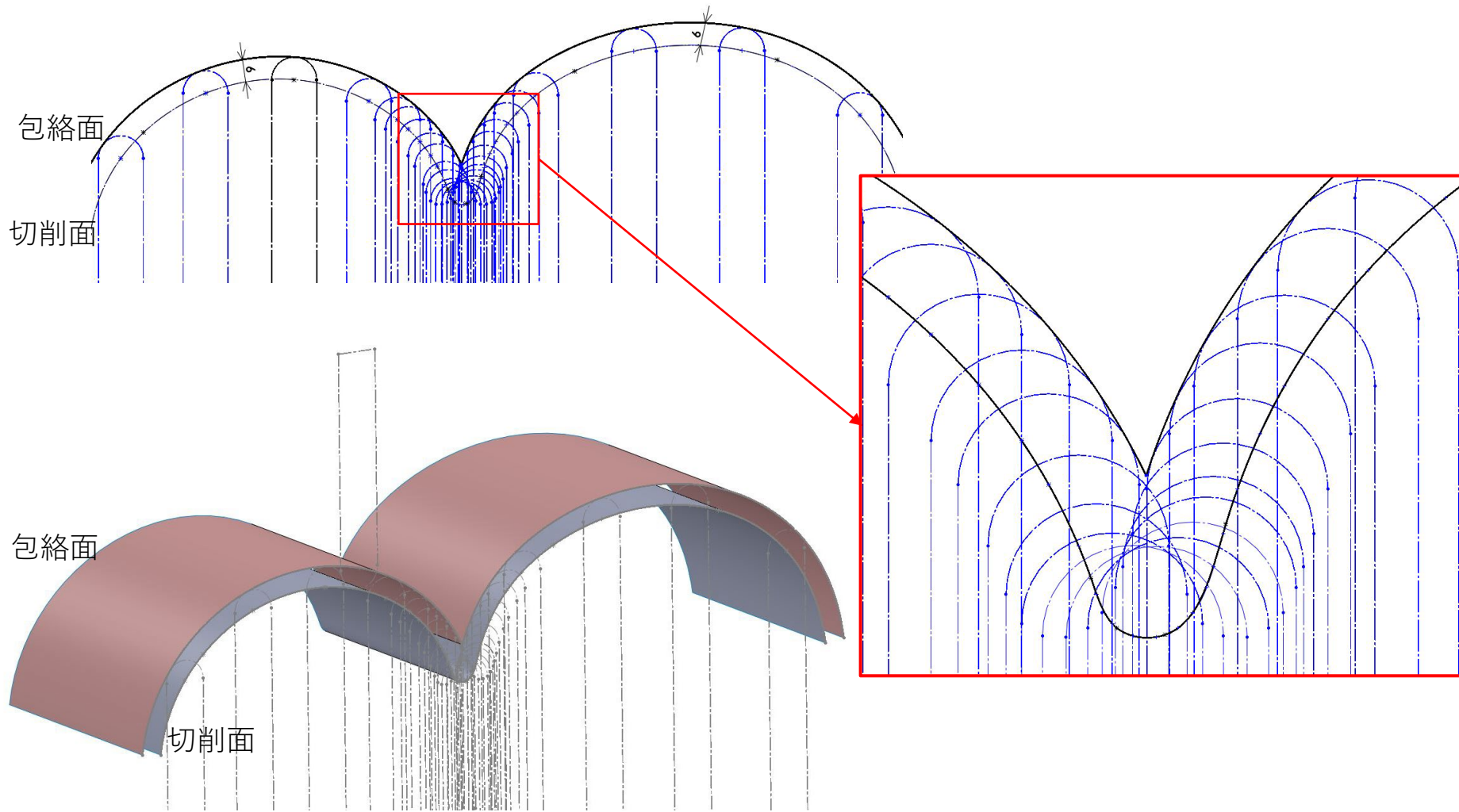


図9.17 ポリゴンメッシュによる方法で生成した包絡面



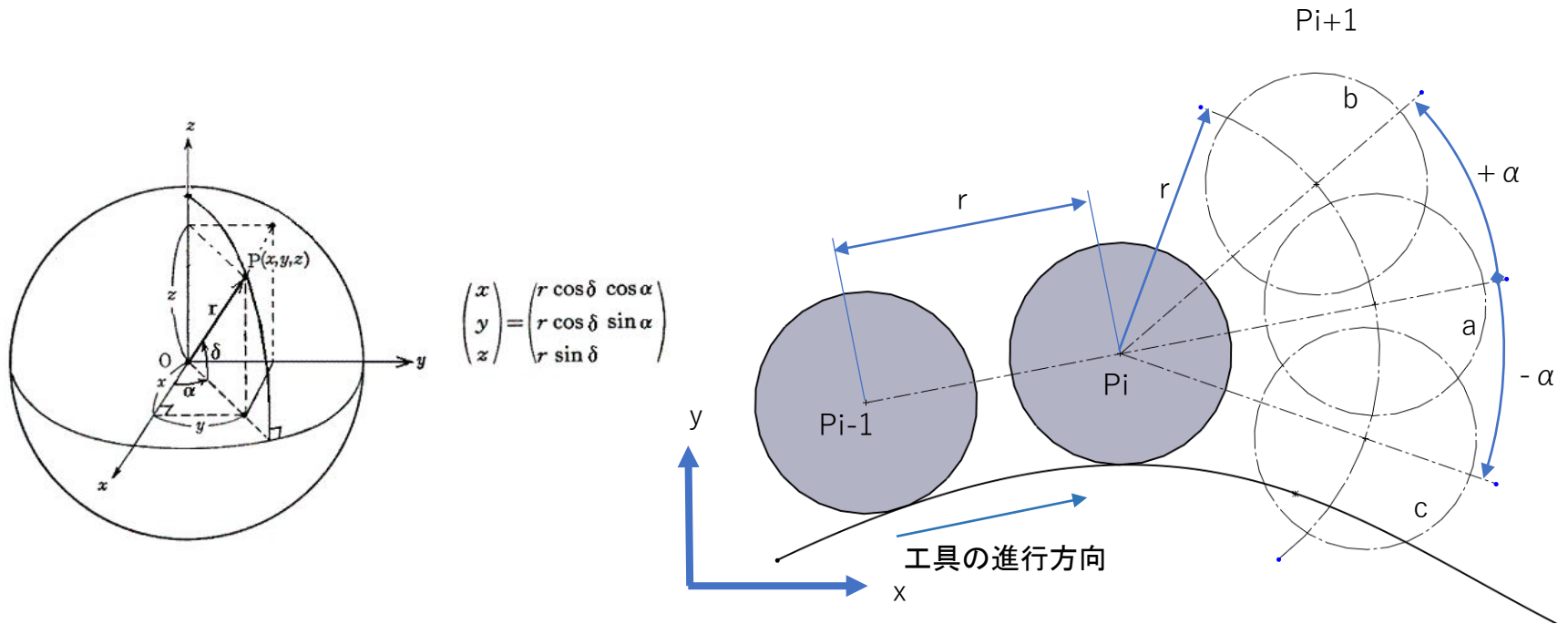
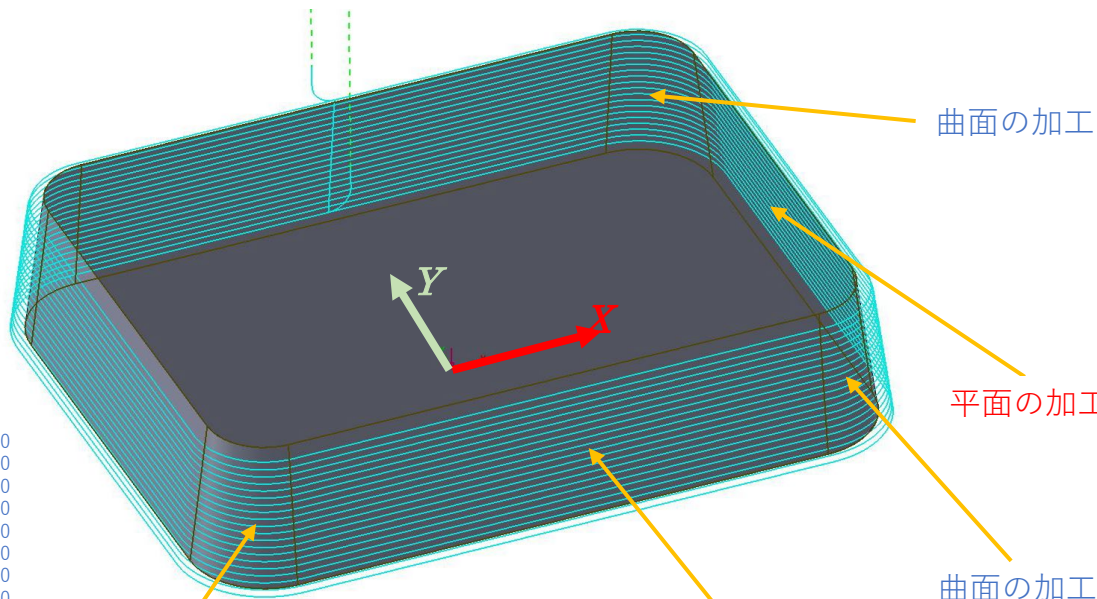


図9.18 サーフェスから切削点を演算する方法の一例



A
 ↓
 -35.736332,-35.514221,10.000000
 -36.271140,-35.463665,10.000000
 -36.998901,-35.349730,10.000000
 -37.716359,-35.183055,10.000000
 -38.232221,-35.033182,10.000000
 -38.924931,-34.782638,10.000000
 -39.417943,-34.569294,10.000000
 -40.076057,-34.238433,10.000000
 -40.708305,-33.860474,10.000000
 -41.152607,-33.558526,10.000000
 -41.735625,-33.108293,10.000000
 -42.284220,-32.616796,10.000000
 -42.664075,-32.236943,10.000000
 -43.150606,-31.683848,10.000000
 -43.479852,-31.259382,10.000000
 -43.897388,-30.652555,10.000000
 -44.269583,-30.016892,10.000000
 -44.513463,-29.538248,10.000000
 -44.807709,-28.862944,10.000000
 -45.051925,-28.168036,10.000000
 -45.201798,-27.652173,10.000000
 -45.361952,-26.933164,10.000000
 -45.445990,-26.402583,10.000000
 -45.519805,-25.669700,10.000000



曲面の加工

曲面の加工

平面の加工

曲面の加工

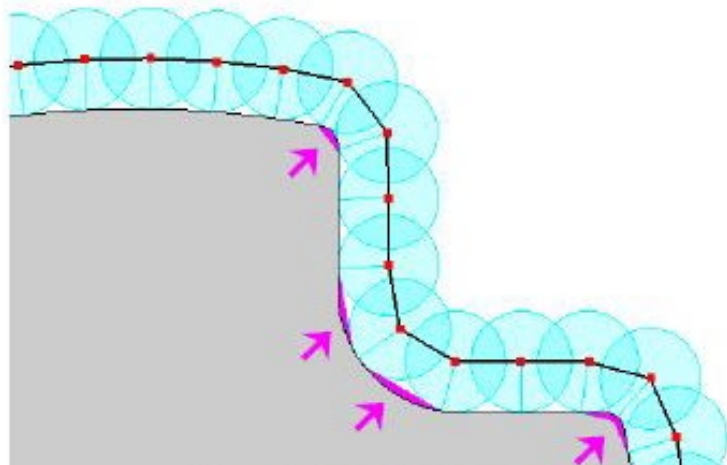
平面の加工

35.132986,35.536661,10.000000
 35.669916,35.519788,10.000000
 36.402798,35.445949,10.000000
 36.933376,35.361915,10.000000
 37.652381,35.201739,10.000000
 38.168244,35.051866,10.000000
 38.863147,34.807630,10.000000
 39.538441,34.513365,10.000000
 40.017084,34.269484,10.000000
 40.652736,33.897273,10.000000
 41.259551,33.479718,10.000000
 41.684019,33.150468,10.000000
 42.237095,32.663925,10.000000
 42.753179,32.138413,10.000000
 43.108435,31.735457,10.000000
 43.558647,31.152428,10.000000
 43.860594,30.708126,10.000000
 44.238536,30.075866,10.000000
 44.569375,29.417742,10.000000
 44.782721,28.924729,10.000000
 45.033247,28.232012,10.000000
 45.232589,27.522944,10.000000
 45.349772,26.998689,10.000000
 45.463690,26.270923,10.000000
 45.514244,25.736114,10.000000
45.541109,25.000000,10.000000
45.541109,-25.000000,10.000000
 45.519774,-25.670131,10.000000
 45.445916,-26.403010,10.000000
 45.361879,-26.933591,10.000000
 45.201684,-27.652589,10.000000
 45.051810,-28.168453,10.000000
 44.807552,-28.863348,10.000000
 44.513267,-29.538634,10.000000
 44.269386,-30.017278,10.000000
 43.897154,-30.652919,10.000000
 43.479582,-31.259722,10.000000
 43.150336,-31.684188,10.000000
 42.663773,-32.237254,10.000000
 42.138245,-32.753321,10.000000
 41.735294,-33.108572,10.000000
 41.152249,-33.558771,10.000000
 40.707947,-33.860720,10.000000
 40.075677,-34.238641,10.000000
 39.417545,-34.569462,10.000000
 38.924533,-34.782807,10.000000
 38.231807,-35.033310,10.000000
 37.522734,-35.232630,10.000000
 36.998477,-35.349816,10.000000
 36.270709,-35.463709,10.000000
 35.735901,-35.514265,10.000000
34.999784,-35.541110,10.000000
-35.000216,-35.541110,10.000000



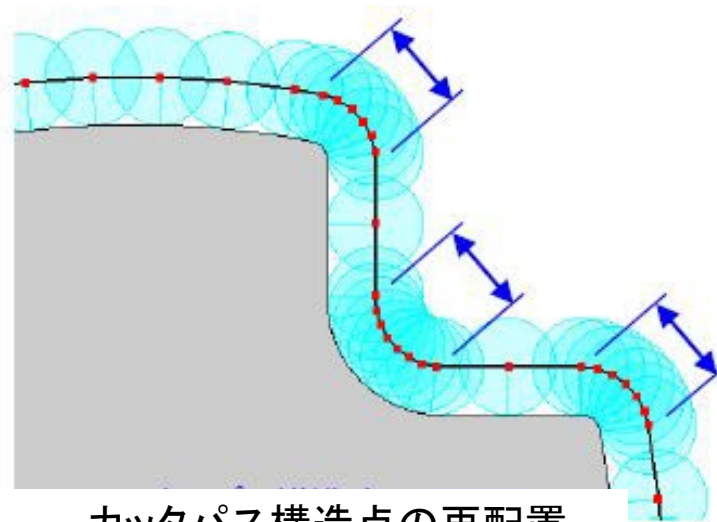
図9.19 サーフェスのCL(工具中心の座標値)





削り込み/ 削り残しが発生

(a) ポリゴン演算



カッターパス構造点の再配置

(b) サーフェス演算

図9.20 工具経路と加工精度



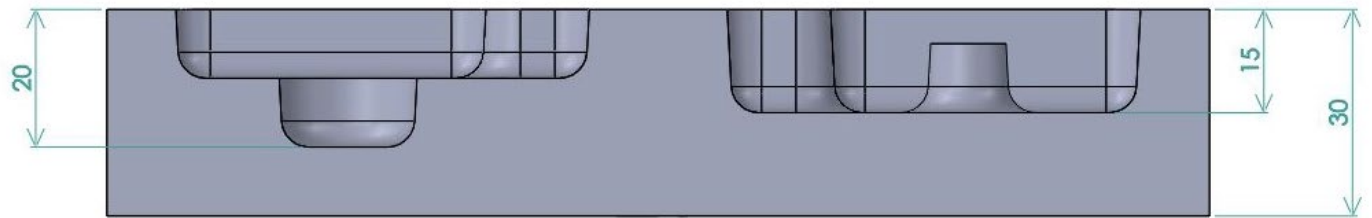
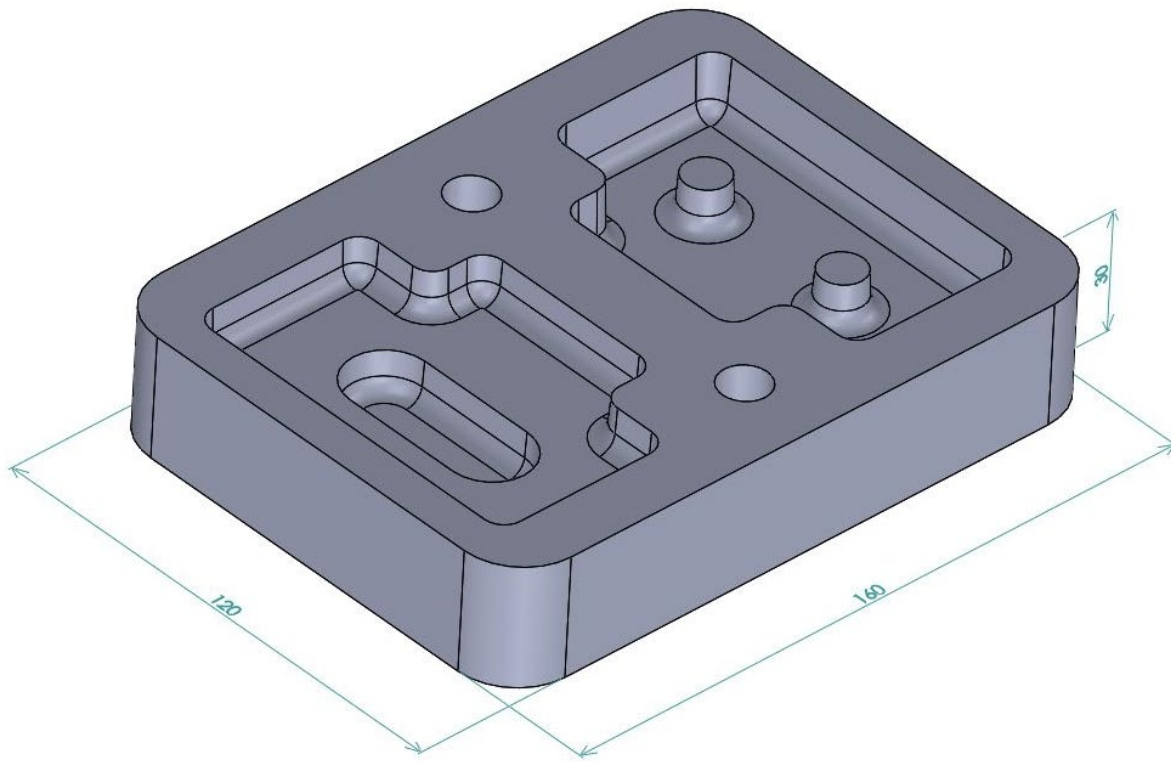


図9.21 加工形状



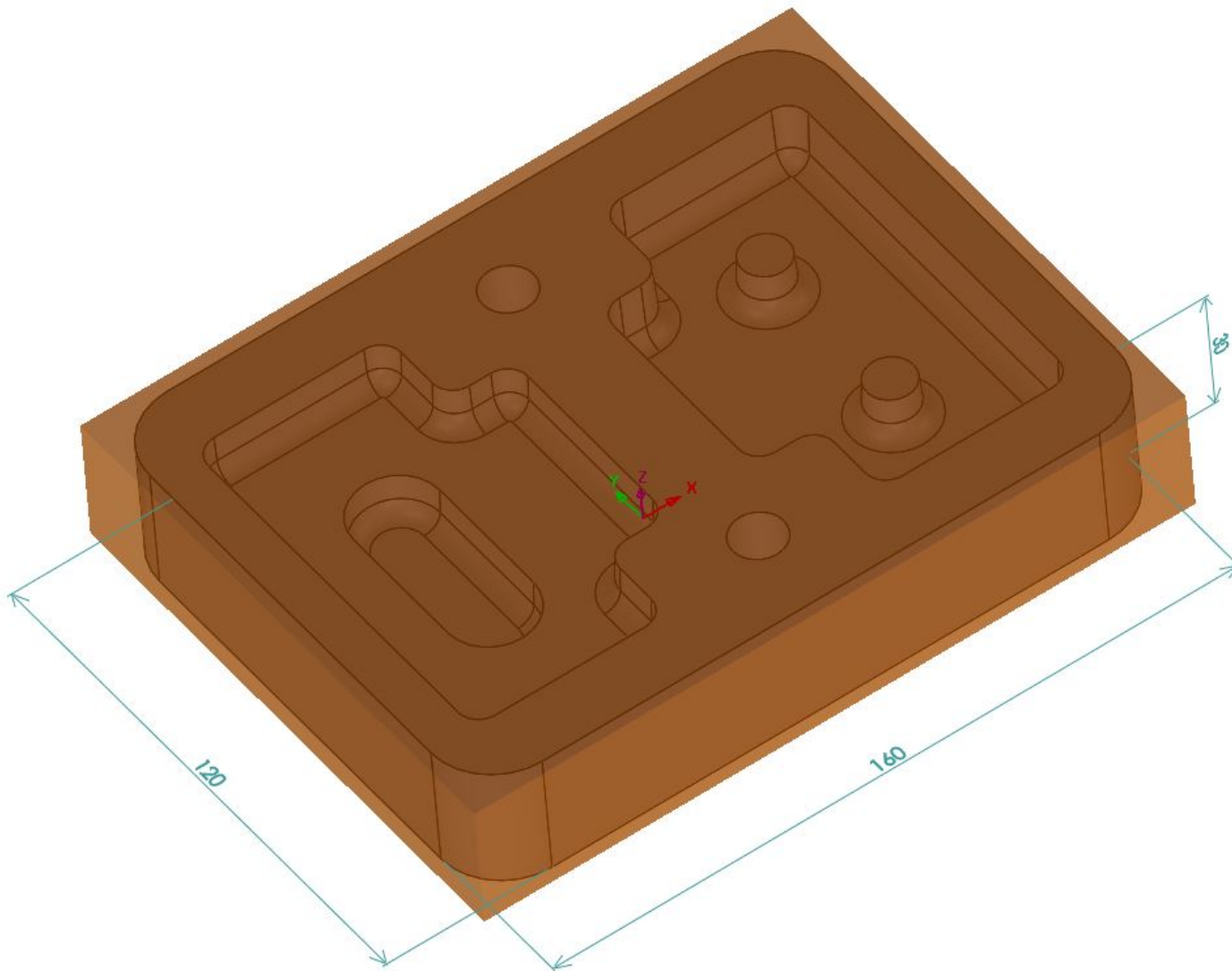


図9.22 ストックと加工形状



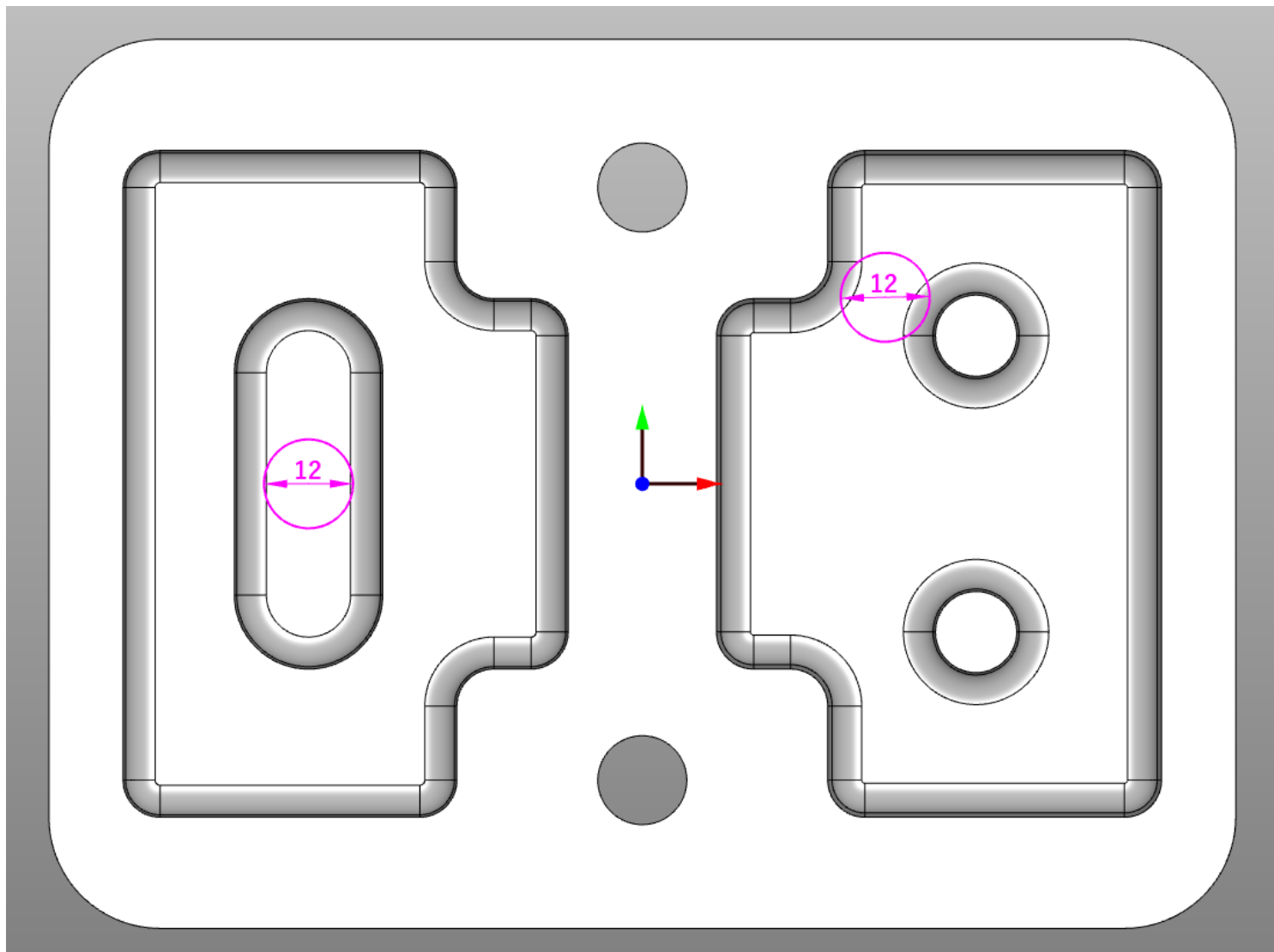
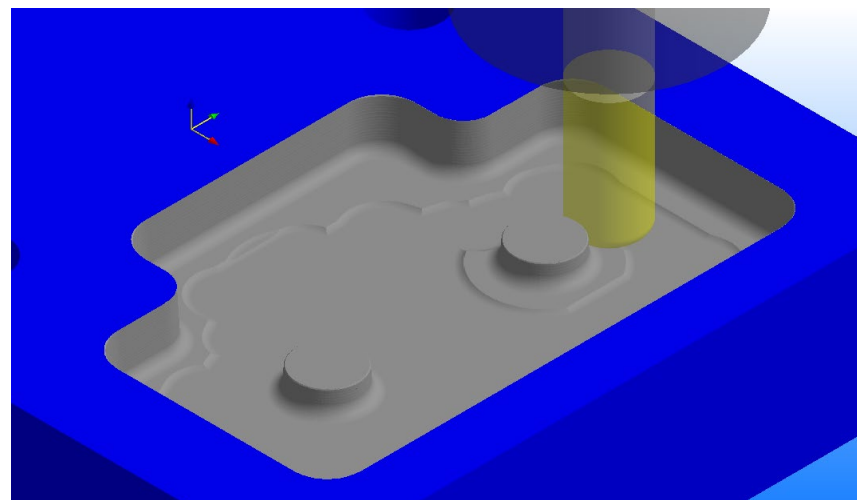
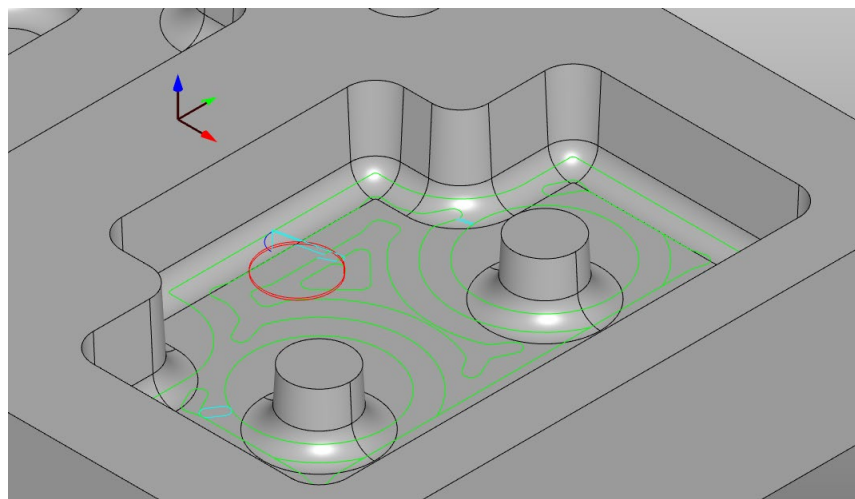
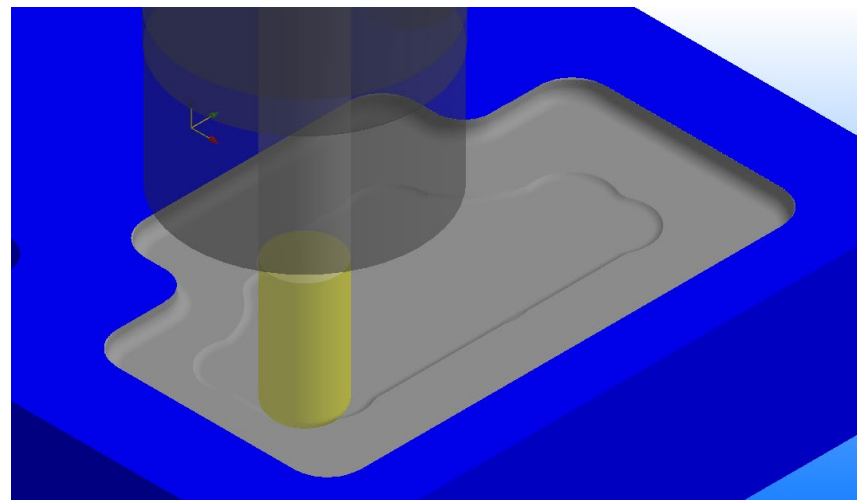
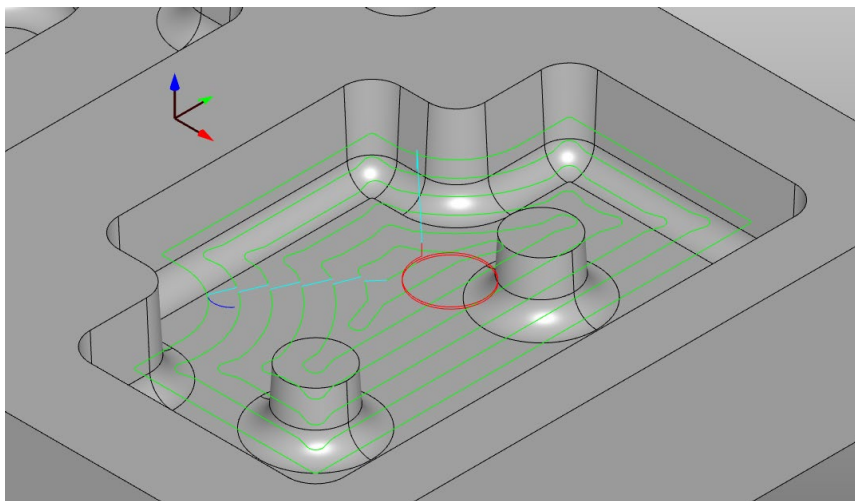


図9.23 荒取り加工の工具選定 (直径12 mm の工具による検証)

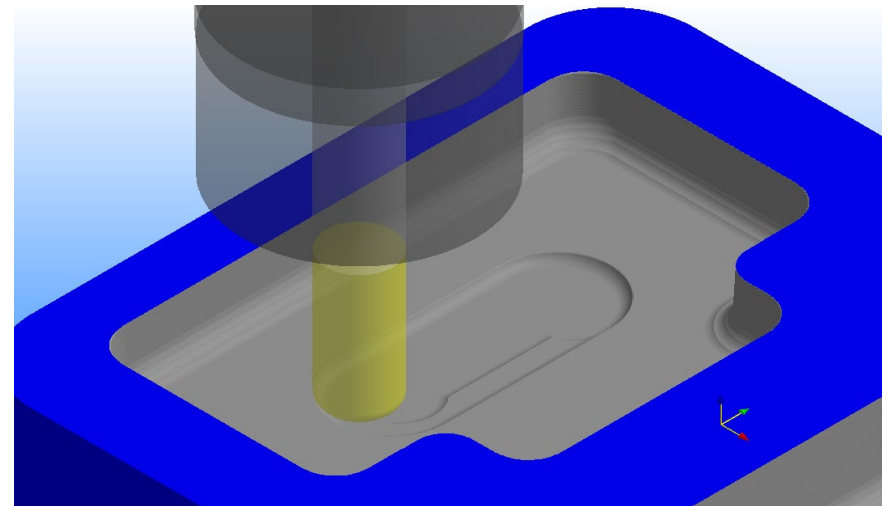
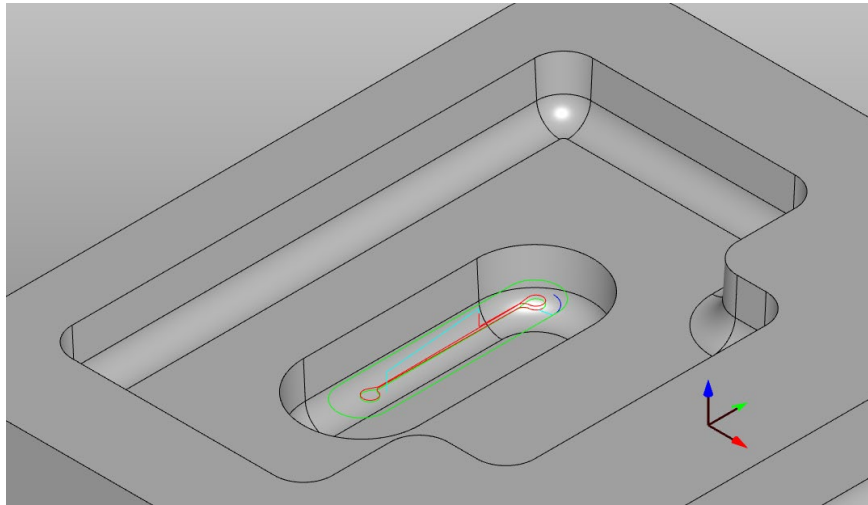
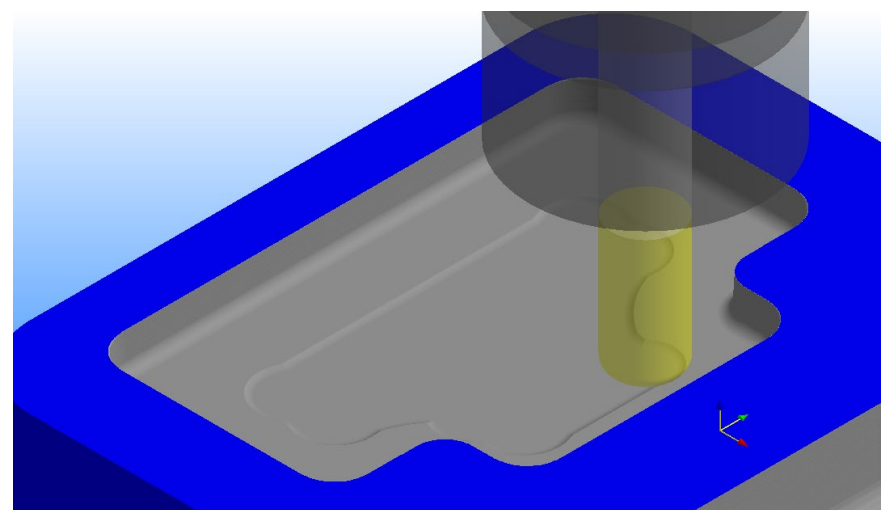
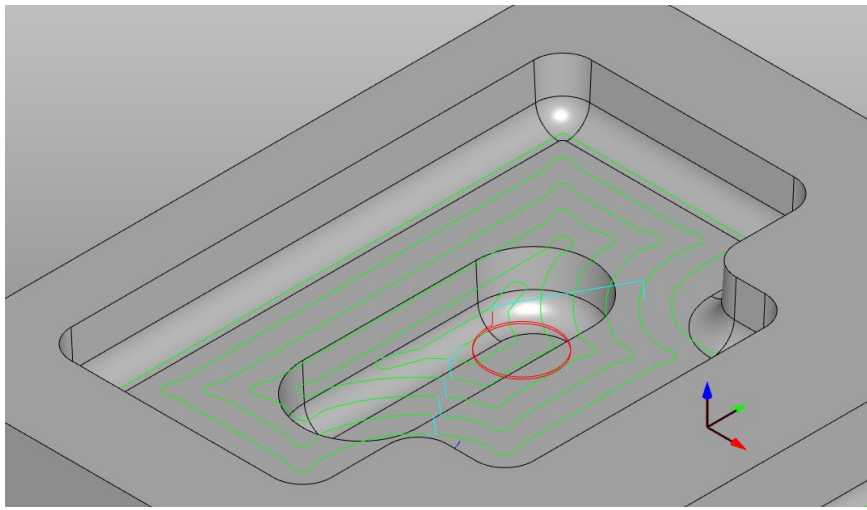




No.1: 直径12 mm のラジラスエンドミル, 仕上げ代0.2 mm

図9.24 等高線荒取り加工(続く)

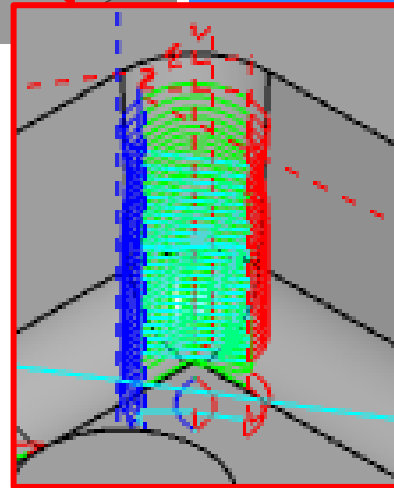
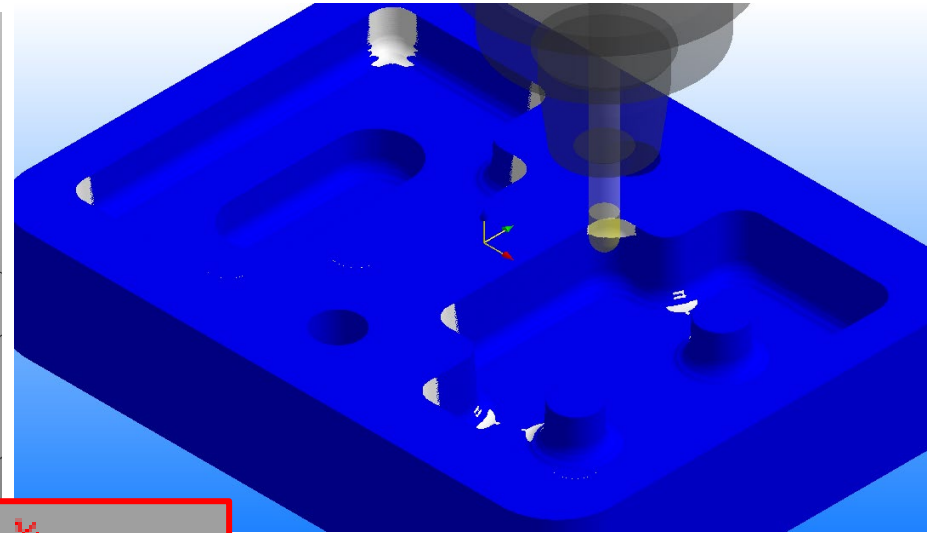
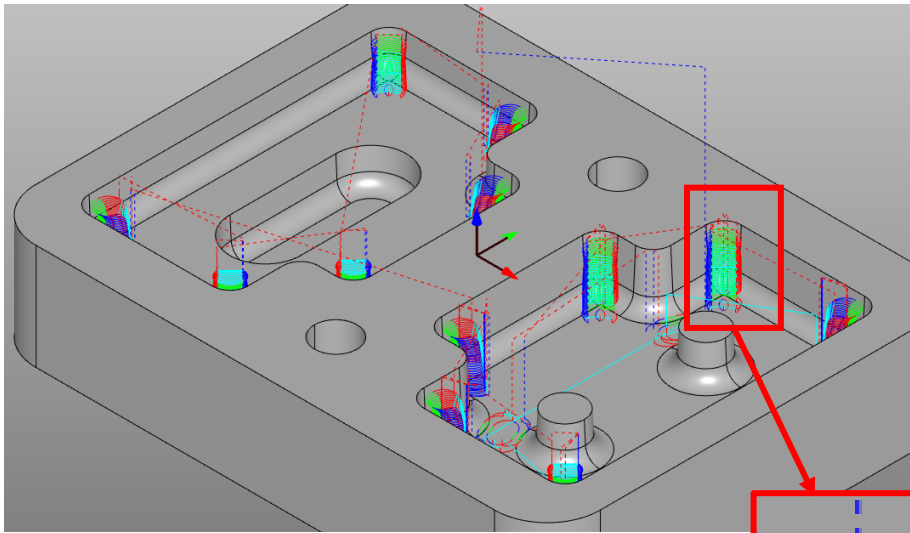




No.1: 直径12 mm のラジラスエンドミル, 仕上げ代0.2 mm

図9.24 等高線荒取り加工(続き)

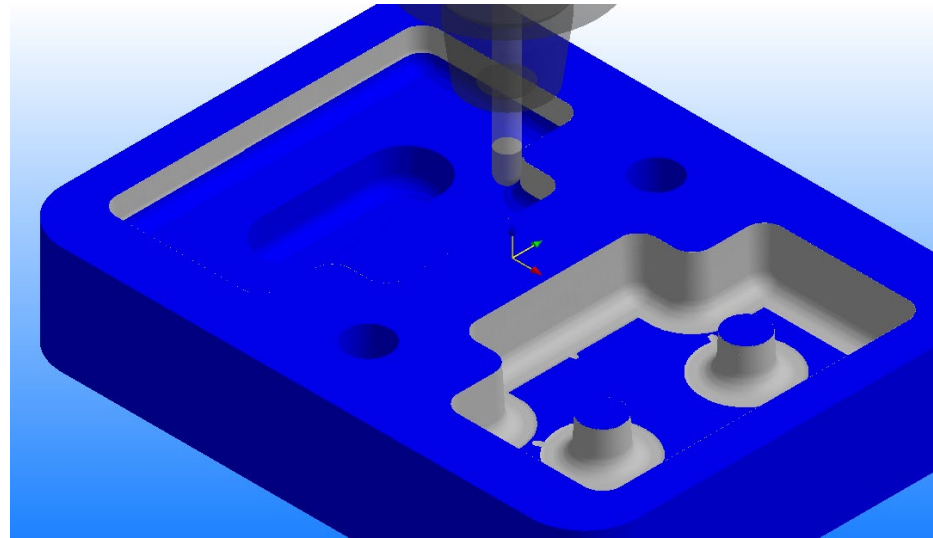
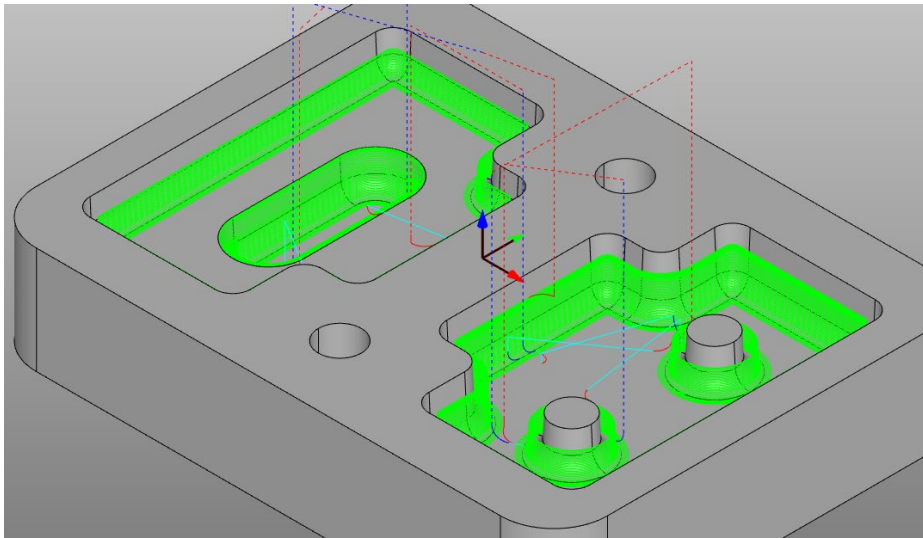




No.2: 直径6mm のボールエンドミル, 仕上げ代0.2mm

図9.25 隅部取り残し加工

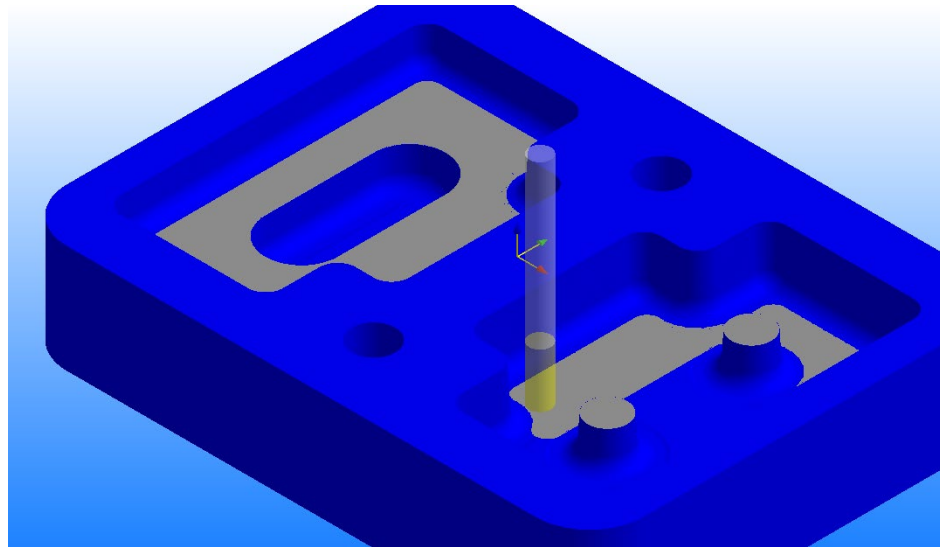
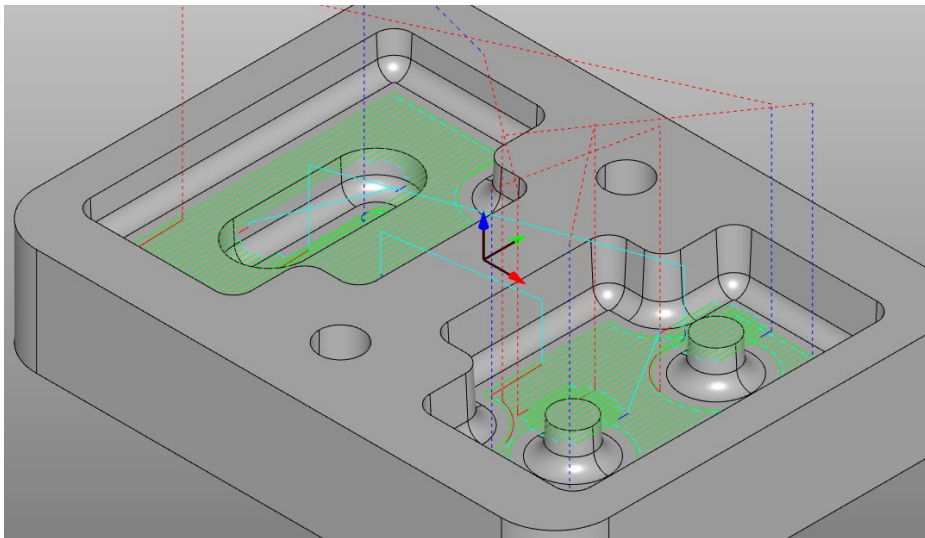




No.3: 直径6mm のボールエンドミル, 仕上げ代0.05mm

図9.26 中仕上げの等高線仕上げ加工と水平部仕上げ加工(続く)

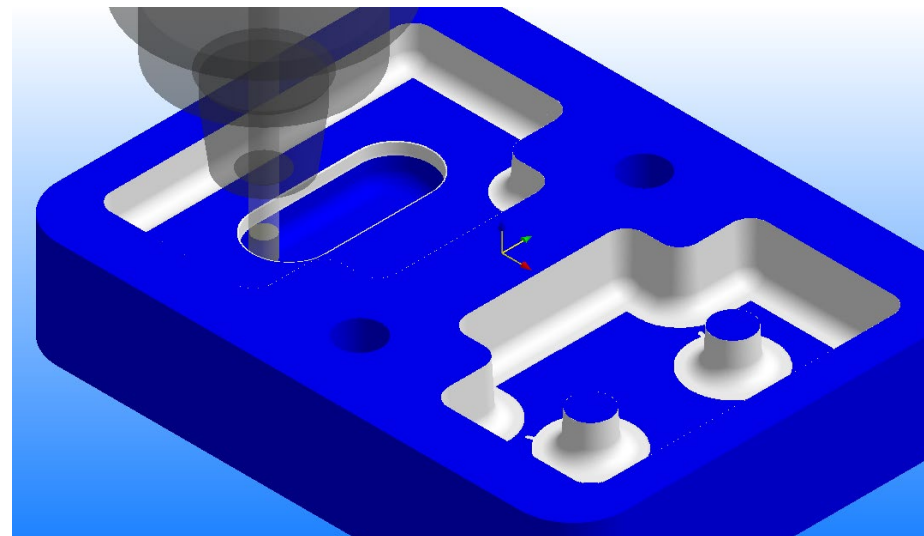
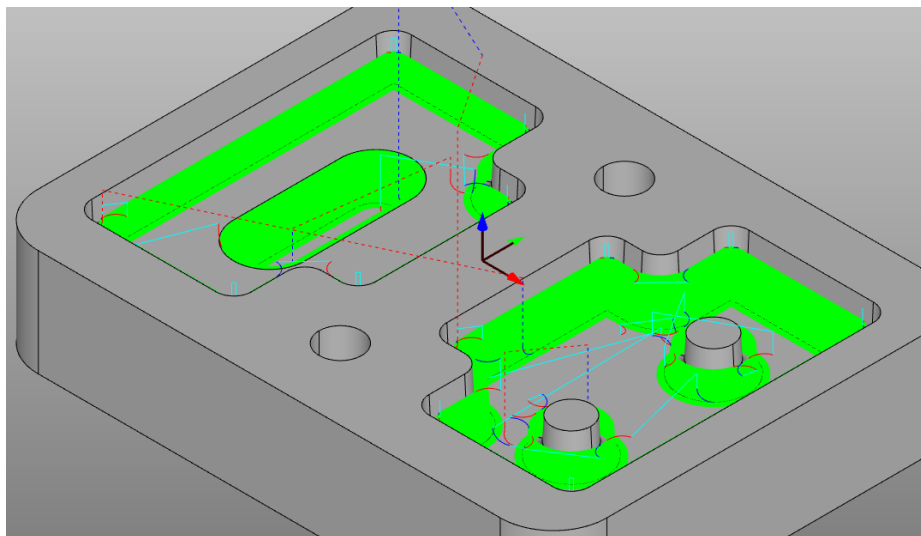




No.4: 直径6mm のスクエアエンドミル, 仕上げ代0.05mm

図9.26 中仕上げの等高線仕上げ加工と水平部仕上げ加工(続き)

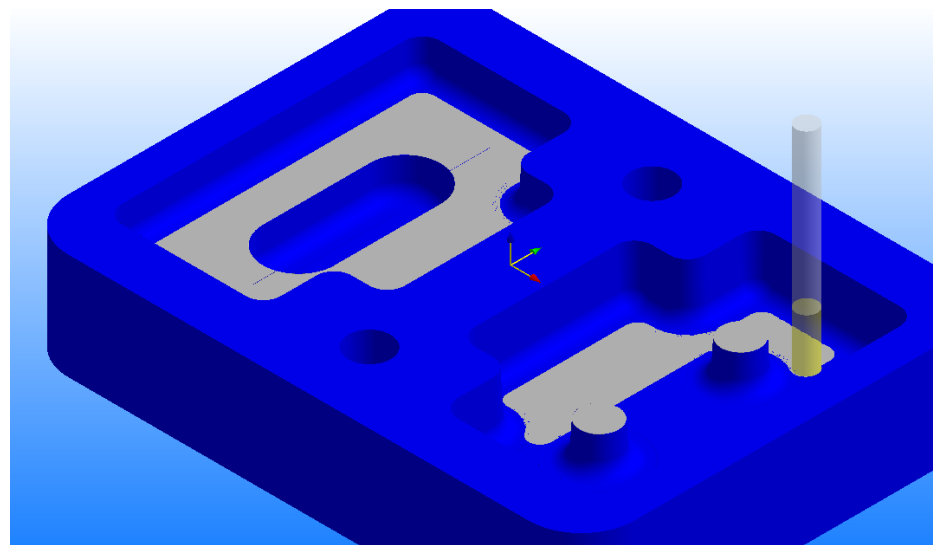
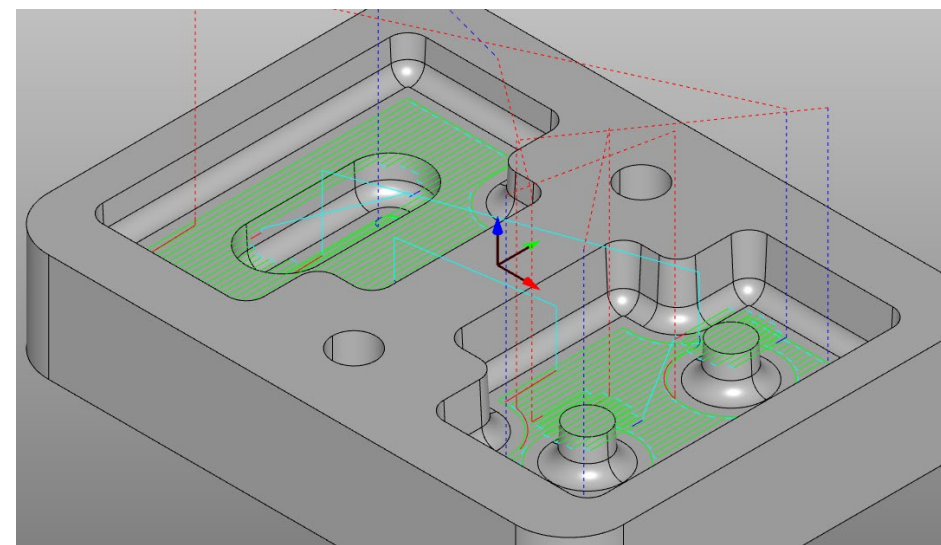




No.5: 直径 6mm のボールエンドミル, 仕上げ代 0.0mm

図9.27 仕上げの等高線仕上げ加工と水平部仕上げ加工(続く)

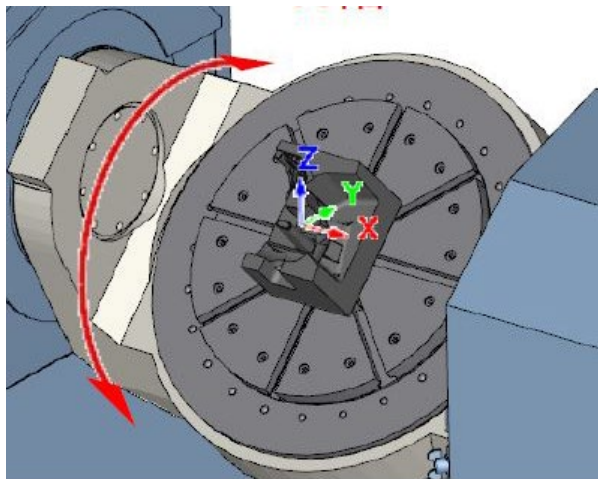




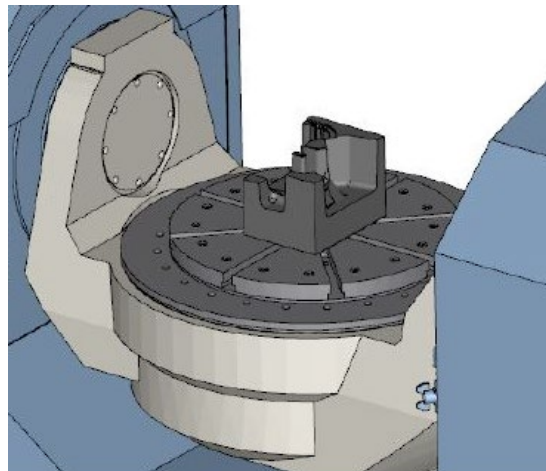
No.6: 直径 6mm のスクエアエンドミル, 仕上げ代 0.0mm

図9.27 仕上げの等高線仕上げ加工と水平部仕上げ加工(続き)

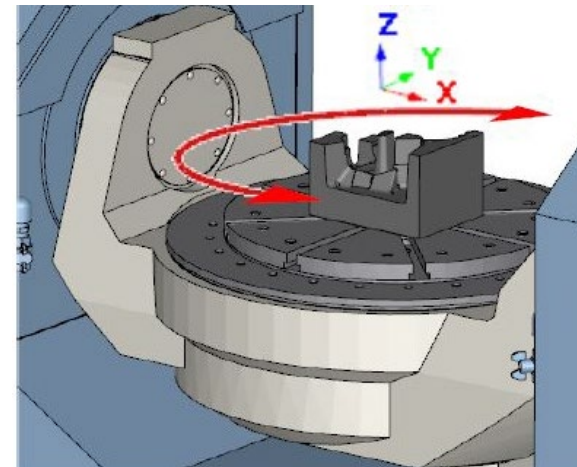




(a) 傾斜軸でワークを傾ける



(b) 初期位置



(c) 旋回軸でワークを回転する

図9.28 A軸が傾斜軸, C軸が旋回軸の例



G01X-7.788Y5.825Z134.867A-34.296C98.53
G01X-7.93Y6.742Z134.823A-34.193C98.913
G01X-8.077Y7.659Z134.773A-34.088C99.296
G01X-8.231Y8.575Z134.716A-33.987C99.68
G01X-8.391Y9.489Z134.652A-33.899C100.065
G01X-8.559Y10.406Z134.58A-33.799C100.453
G01X-8.733Y11.32Z134.501A-33.7C100.84
G01X-8.912Y12.232Z134.416A-33.601C101.228
G01X-9.098Y13.141Z134.324A-33.5C101.615
G01X-9.29Y14.047Z134.225A-33.401C102.003
G01X-9.489Y14.949Z134.119A-33.304C102.391
G01X-9.693Y15.849Z134.006A-33.206C102.78
G01X-9.904Y16.746Z133.887A-33.108C103.168
G01X-10.12Y17.639Z133.76A-33.01C103.557
G01X-10.343Y18.53Z133.627A-32.912C103.945
G01X-10.572Y19.417Z133.488A-32.815C104.334
G01X-10.807Y20.301Z133.341A-32.724C104.723
G01X-11.048Y21.182Z133.188A-32.629C105.112
G01X-11.295Y22.06Z133.028A-32.524C105.499
G01X-11.548Y22.934Z132.861A-32.428C105.888
G01X-11.808Y23.804Z132.688A-32.332C106.276
G01X-12.074Y24.676Z132.507A-32.235C106.667
G01X-12.348Y25.546Z132.319A-32.139C107.058
G01X-12.627Y26.412Z132.123A-32.053C107.452
G01X-12.913Y27.275Z131.922A-31.958C107.843
G01X-13.204Y28.133Z131.713A-31.862C108.235
G01X-13.501Y28.988Z131.498A-31.756C108.624

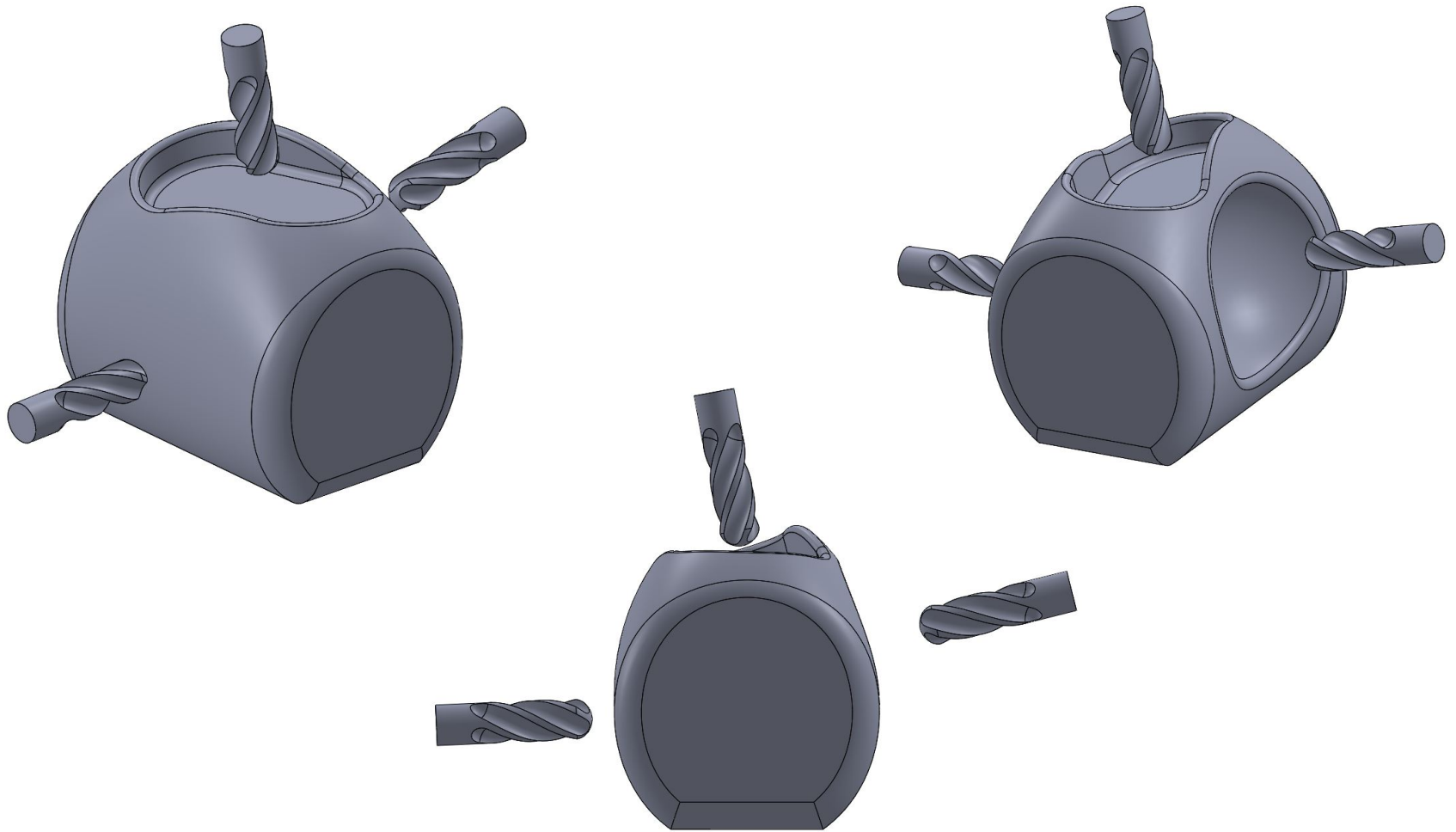
(a) 同時5 軸加工

G01X-7.788Y5.825Z134.867A-47.25C98.53
G01X-7.93Y6.742Z134.823A-47.25C98.913
G01X-8.077Y7.659Z134.773A-47.25C99.296
G01X-8.231Y8.575Z134.716A-47.25C99.68
G01X-8.391Y9.489Z134.652A-47.25C100.065
G01X-8.559Y10.406Z134.58A-47.25C100.453
G01X-8.733Y11.32Z134.501A-47.25C100.84
G01X-8.912Y12.232Z134.416A-47.25C101.228
G01X-9.098Y13.141Z134.324A-47.25C101.615
G01X-9.29Y14.047Z134.225A-47.25C102.003
G01X-9.489Y14.949Z134.119A-47.25C102.391
G01X-9.693Y15.849Z134.006A-47.25C102.78
G01X-9.904Y16.746Z133.887A-47.25C103.168
G01X-10.12Y17.639Z133.76A-47.25C103.557
G01X-10.343Y18.53Z133.627A-47.25C103.945
G01X-10.572Y19.417Z133.488A-47.25C104.334
G01X-10.807Y20.301Z133.341A-47.25C104.723
G01X-11.048Y21.182Z133.188A-47.25C105.112
G01X-11.295Y22.06Z133.028A-47.25C105.499
G01X-11.548Y22.934Z132.861A-47.25C105.888
G01X-11.808Y23.804Z132.688A-47.25C106.276
G01X-12.074Y24.676Z132.507A-47.25C106.667
G01X-12.348Y25.546Z132.319A-47.25C107.058
G01X-12.627Y26.412Z132.123A-47.25C107.452
G01X-12.913Y27.275Z131.922A-47.25C107.843
G01X-13.204Y28.133Z131.713A-47.25C108.235
G01X-13.501Y28.988Z131.498A-47.25C108.624

(b) 同時4 軸加工

図9.29 5軸加工のCL

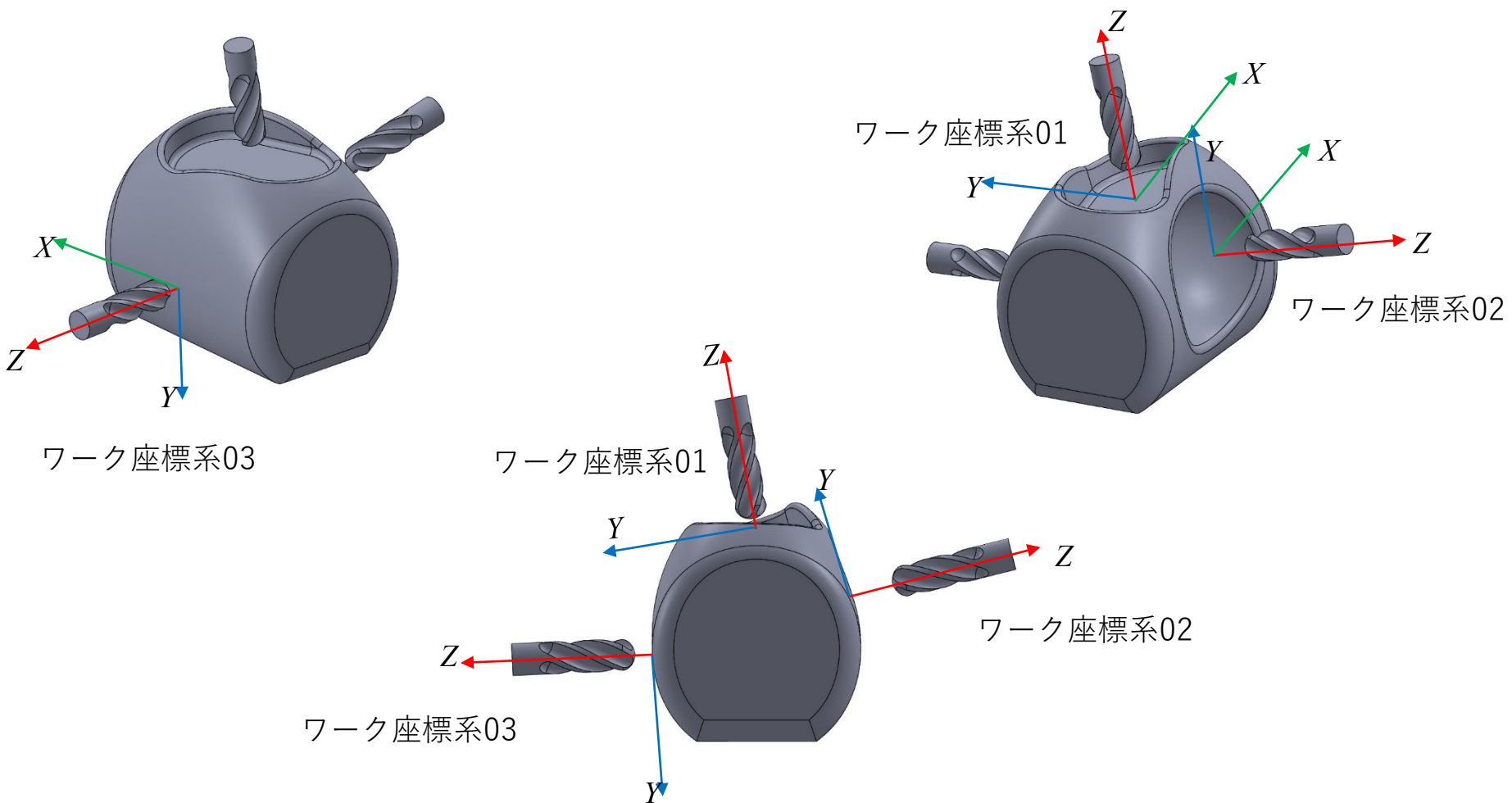




(a)ワーク形状と工具の姿勢

図9.30 位置決め5軸加工(続く:図(a)~(e))





(b)ワーク座標系

図9.30 位置決め5軸加工(続く)



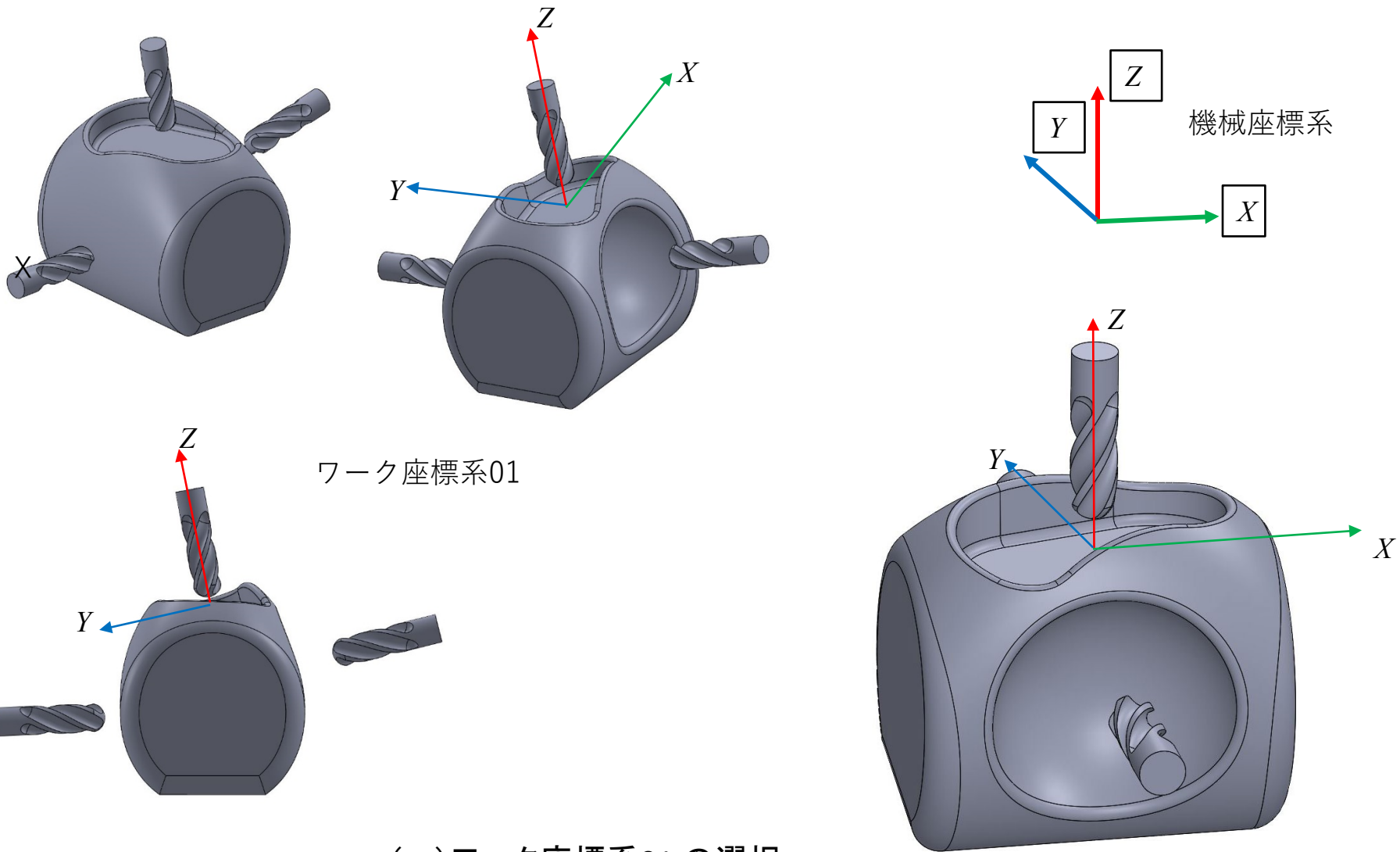
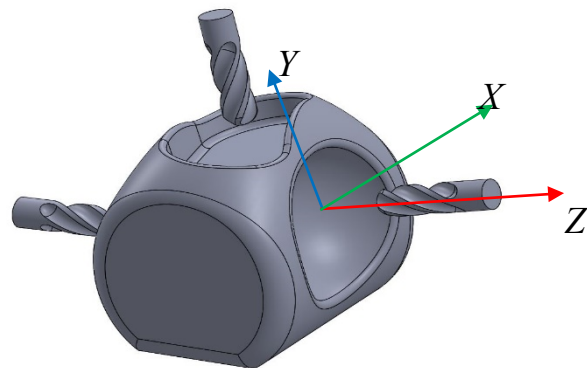
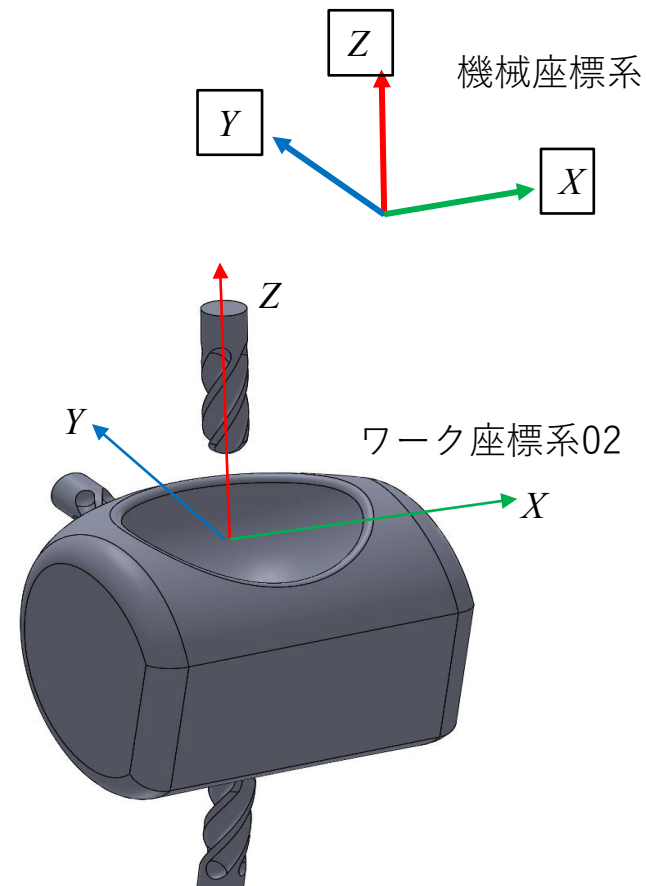
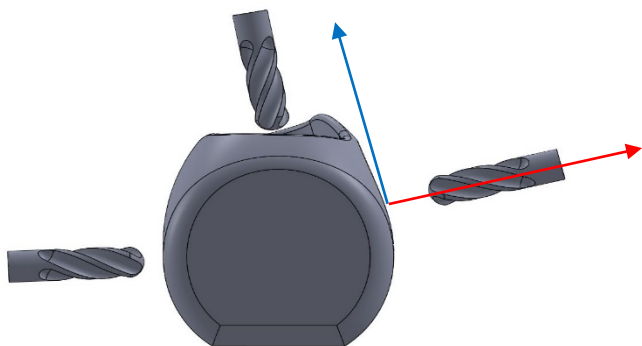


図9.30 位置決め5軸加工(続く)





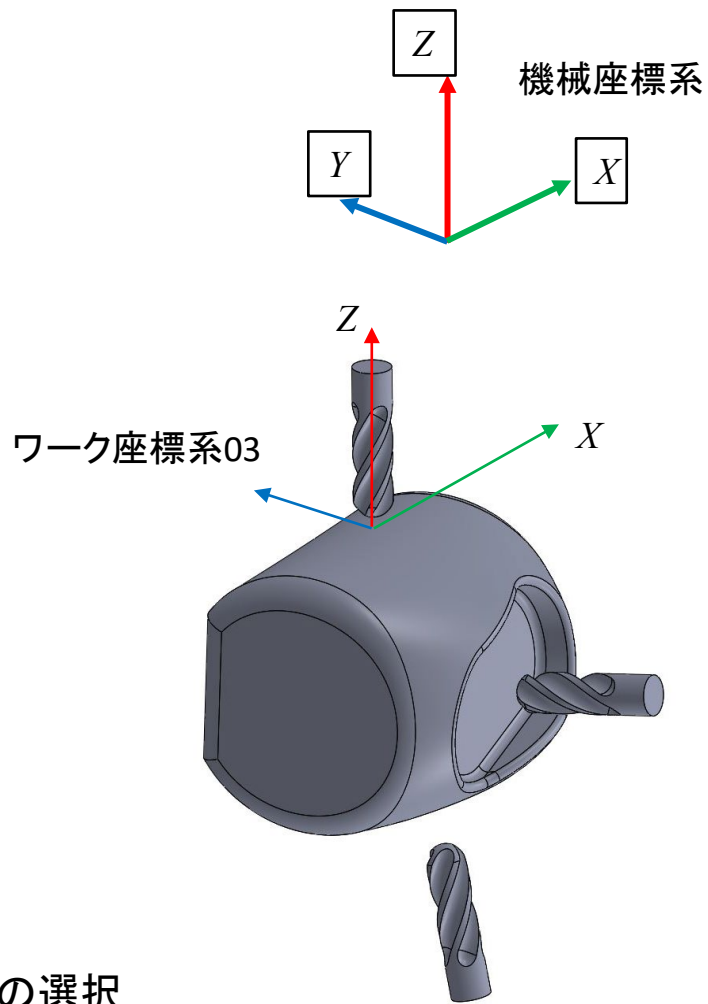
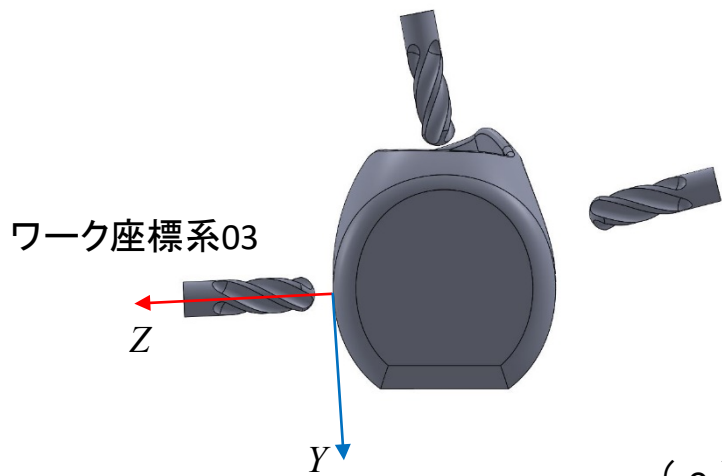
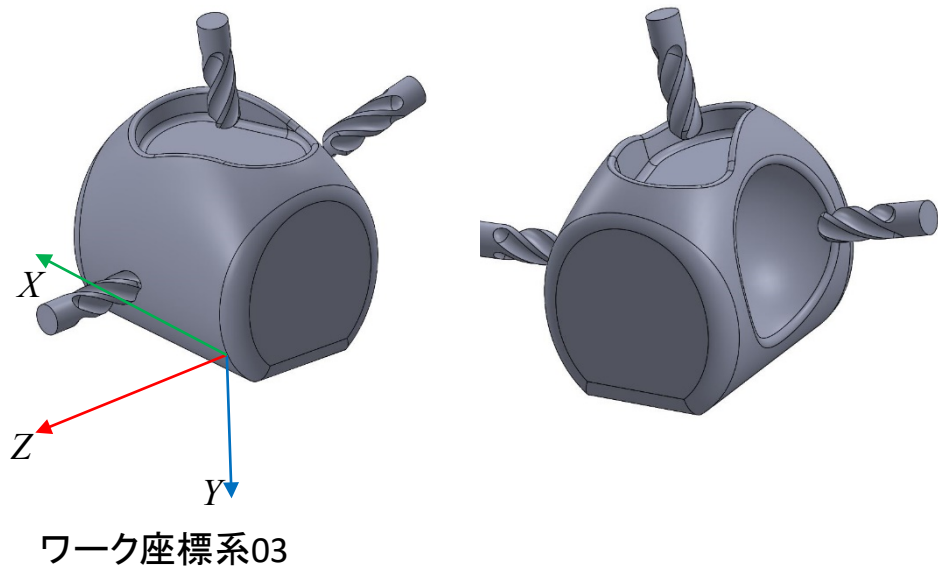
ワーク座標系02



(d) ワーク座標系02 の選択

図9.30 位置決め5軸加工(続く)





(e)ワーク座標系03 の選択

図9.30 位置決め5軸加工(続き)



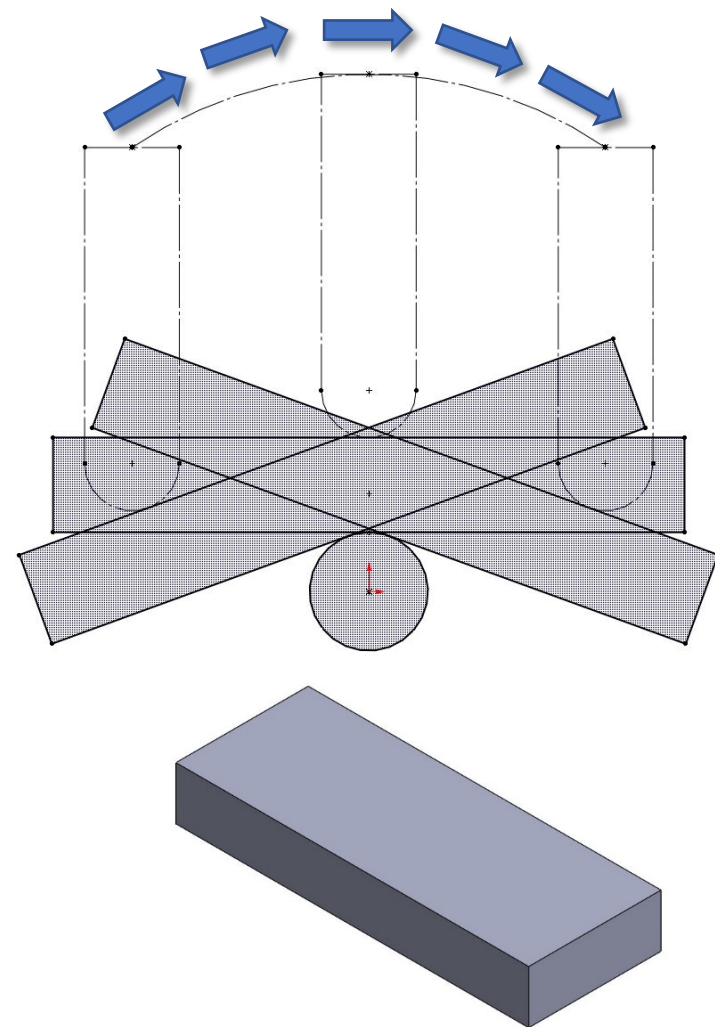
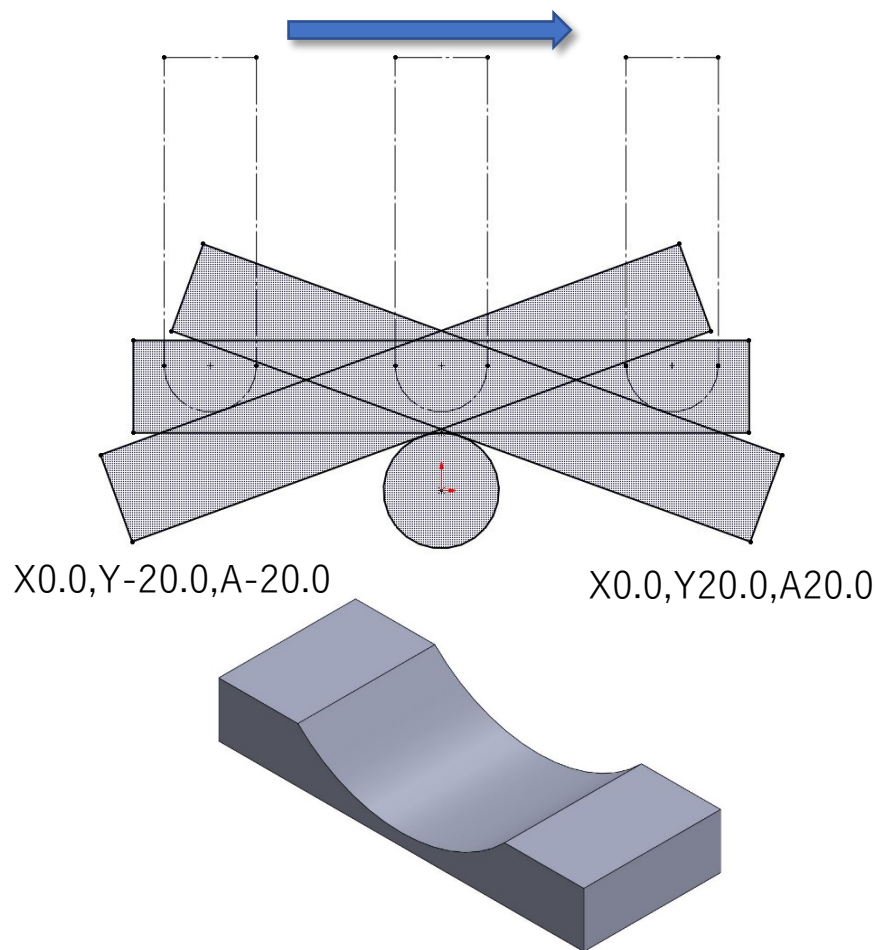
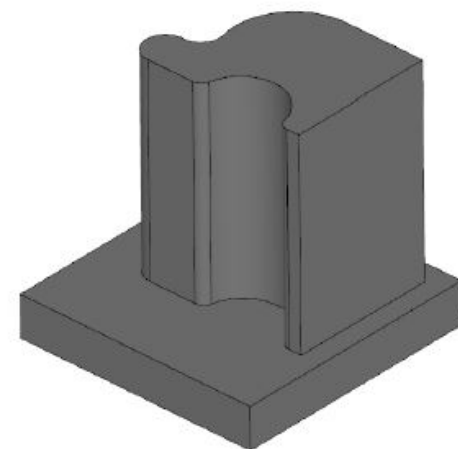
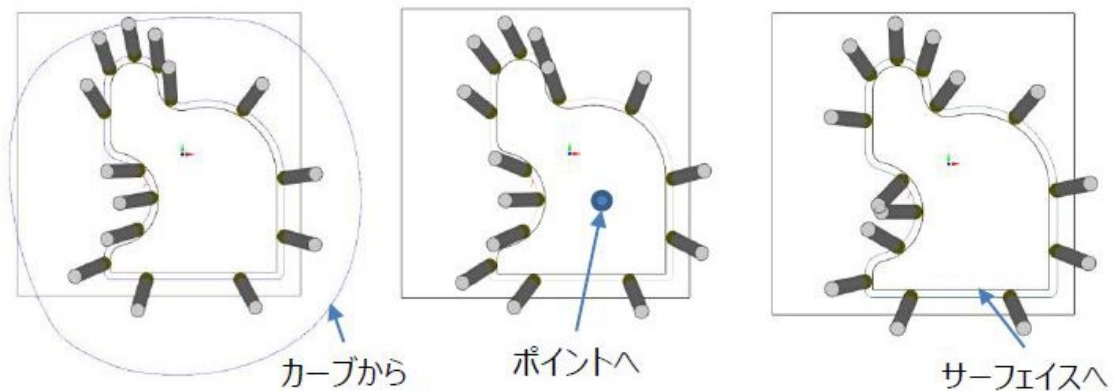


図9.31 工具先端点制御 (tool center point control, TCPC)



指示した図形との最短距離方向を工具軸にする手法



自動工具軸付加機能(干渉しない方向に自動で工具軸の方向を付加)

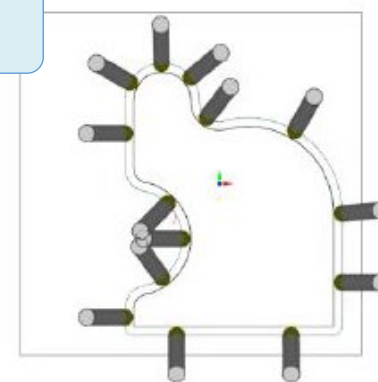
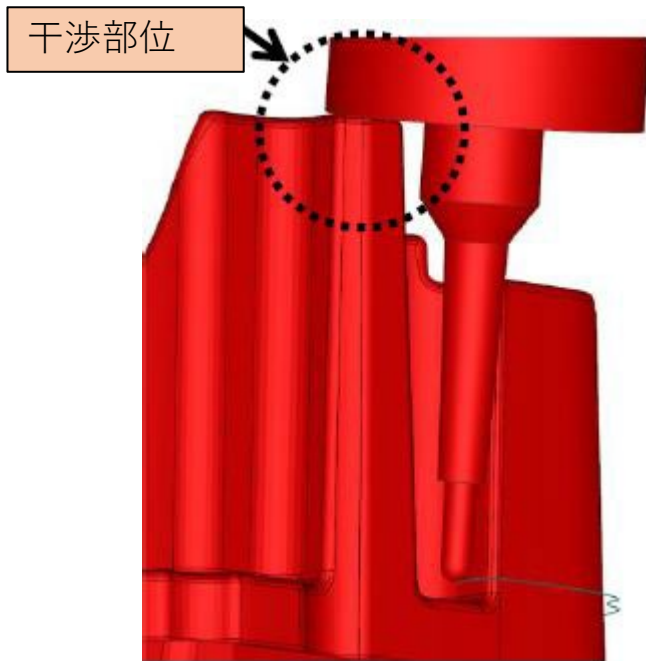
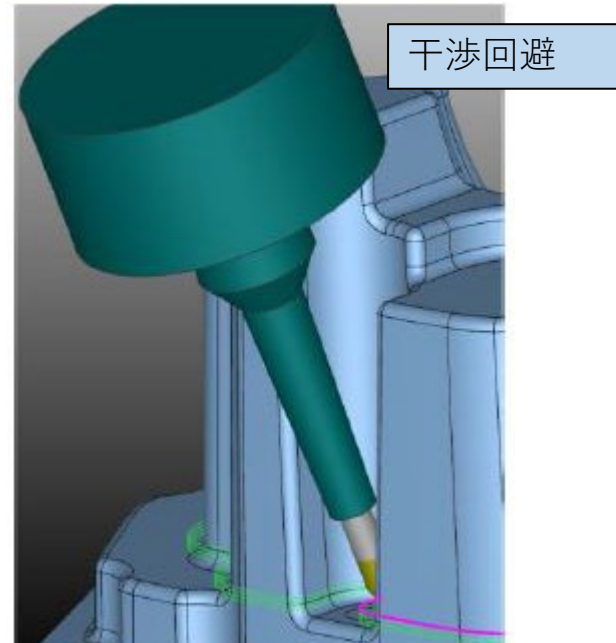


図9.32 工具軸の方向





(a) 傾斜軸角度 10°



(b) 傾斜軸角度 21°

図9.33 干渉の検出と回避機能(傾斜軸の変更)の例



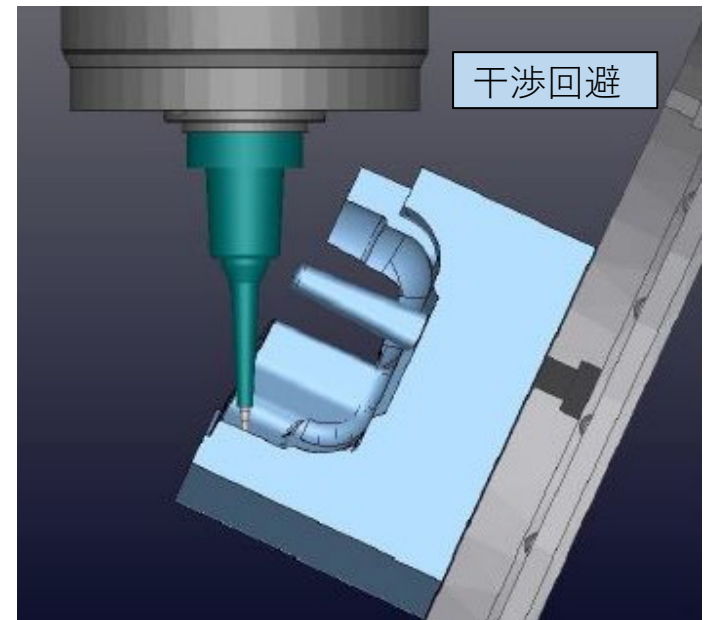
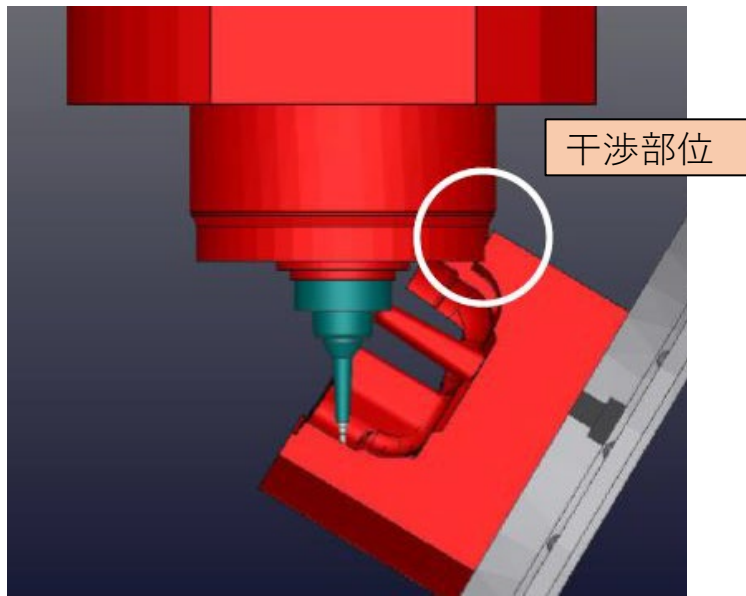


図9.34 干涉の検出と回避機能(工具ホルダの変更)の例



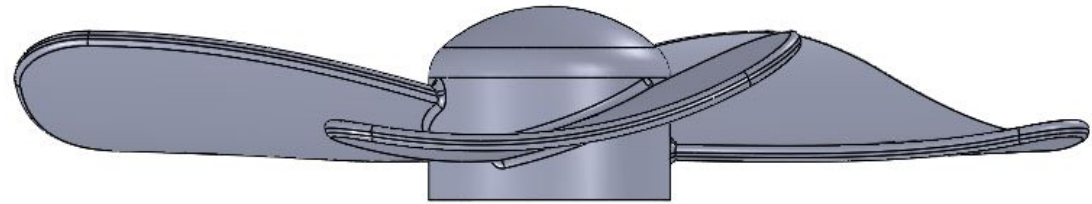
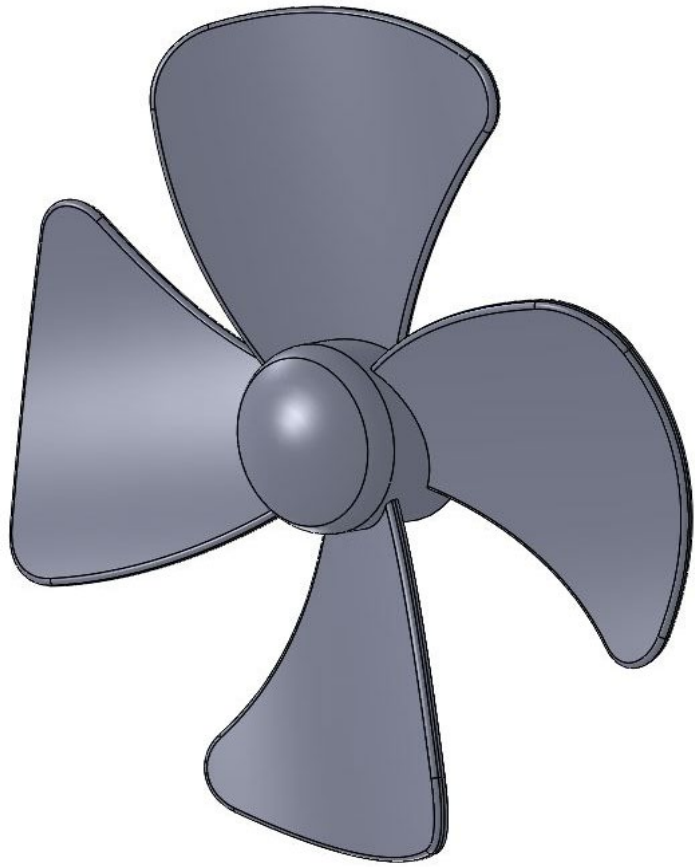


図9.35 4枚羽プロペラの形状



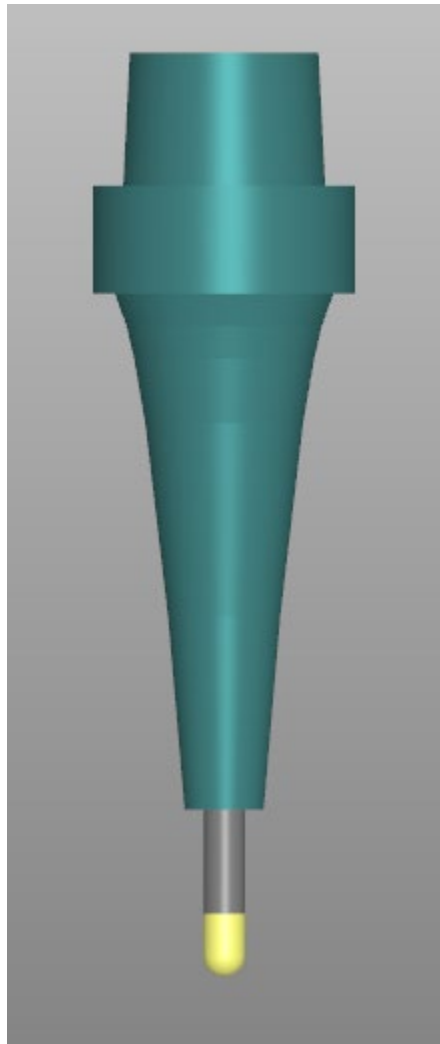


図9.36 工具(直径10mmのボールエンドミル)とホルダ



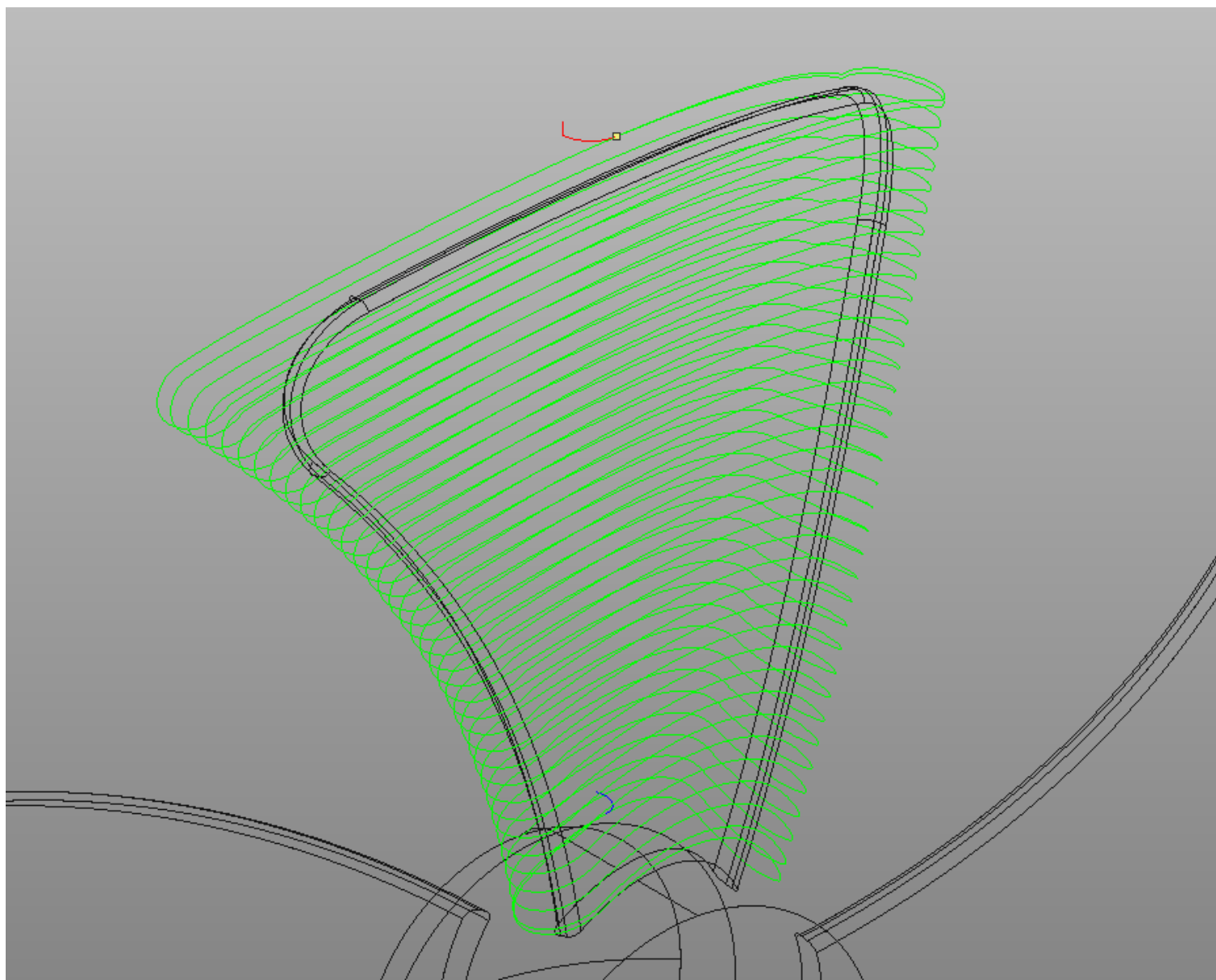


図9.37 同時5軸加工のCL



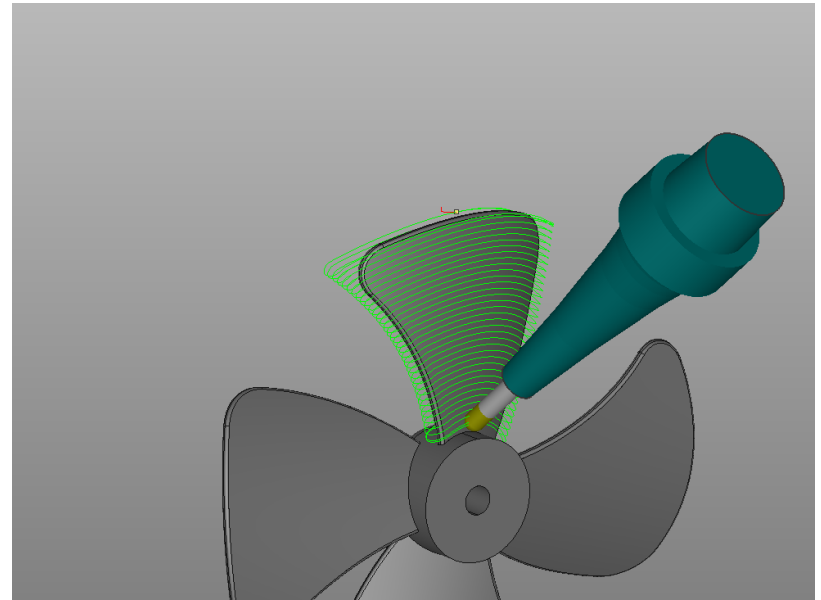
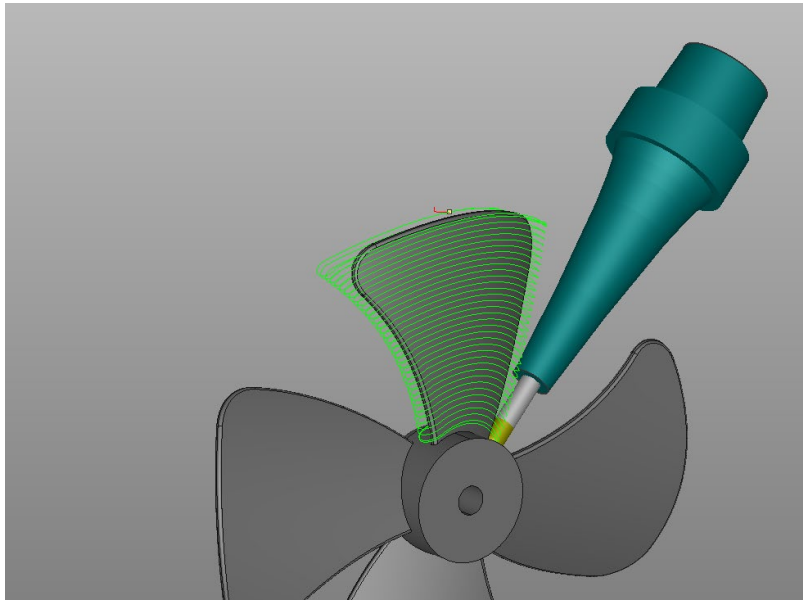
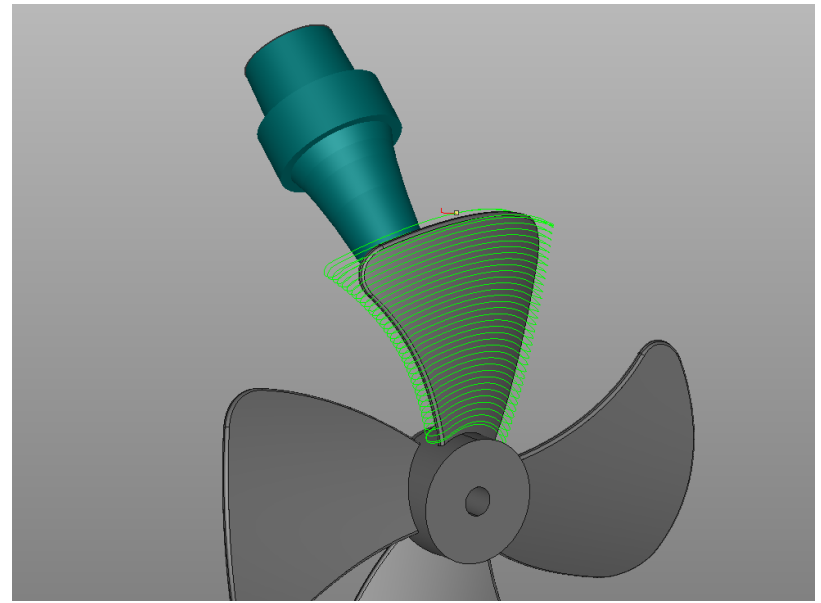
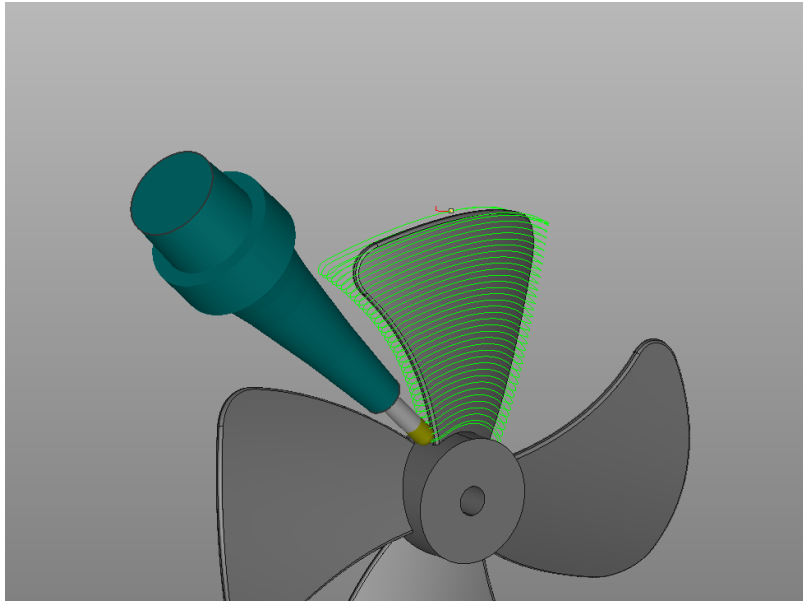
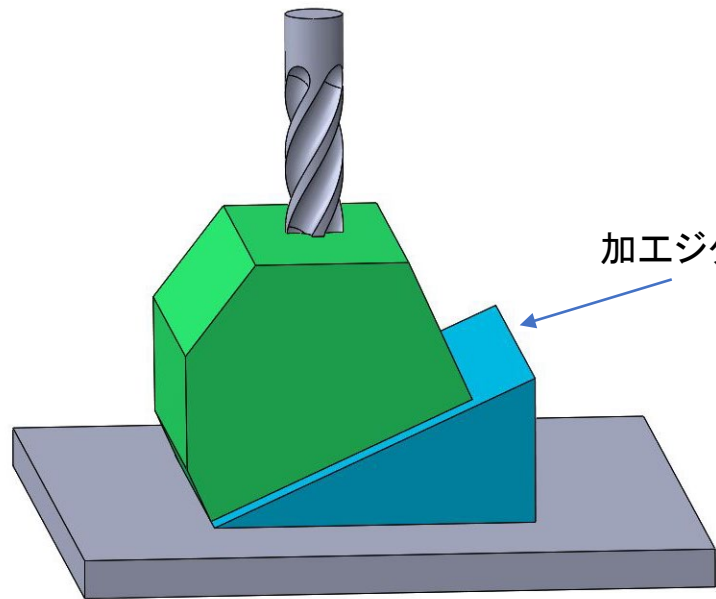
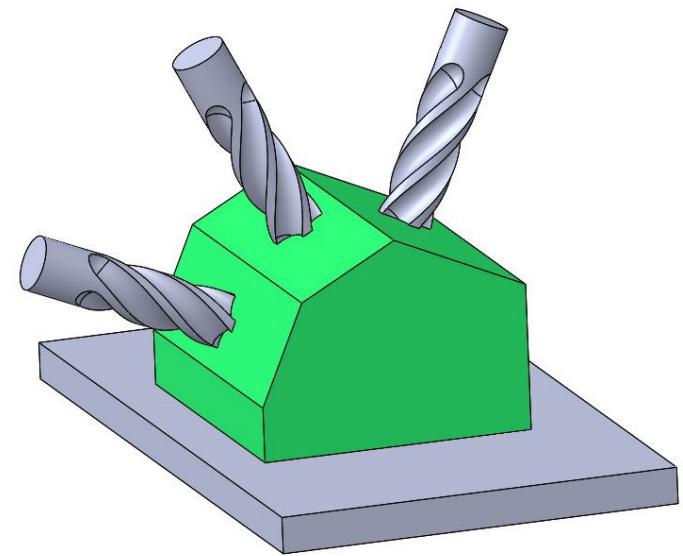


図9.38 同時5軸加工の工具姿勢





3軸

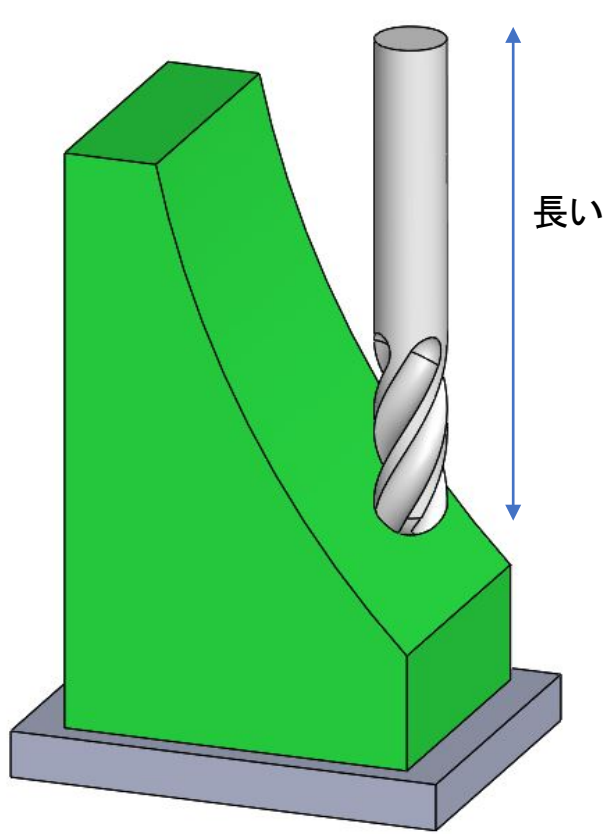


5軸

段取り替えの削除

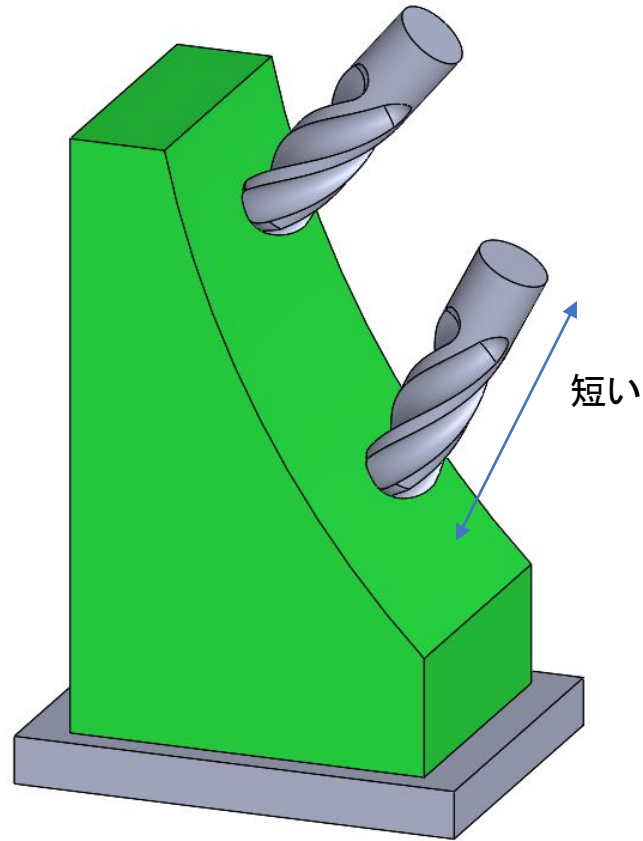
図 9.39 同時 5 軸加工の長所(続く)





3軸

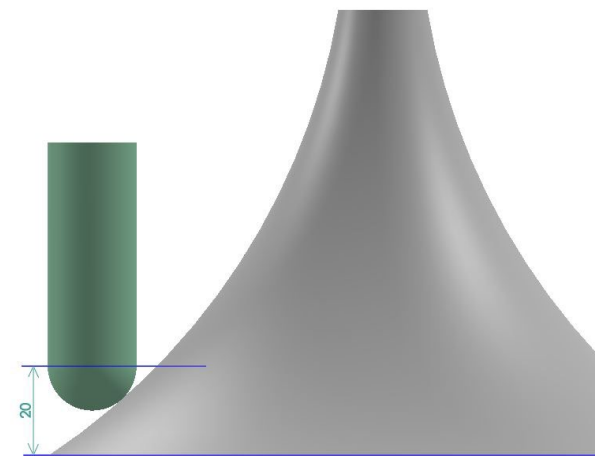
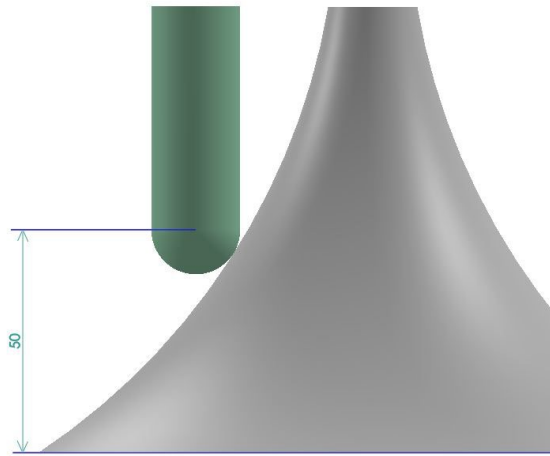
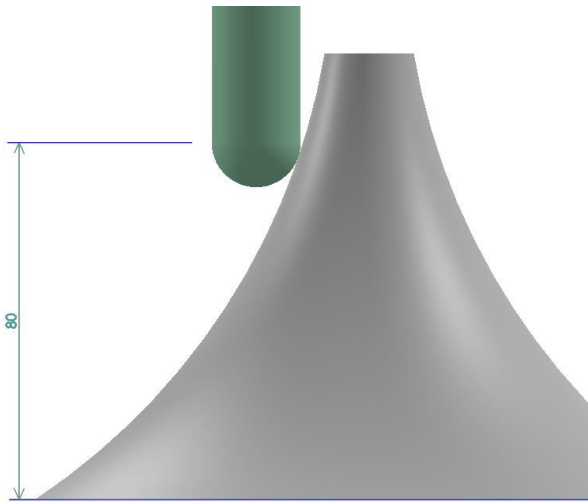
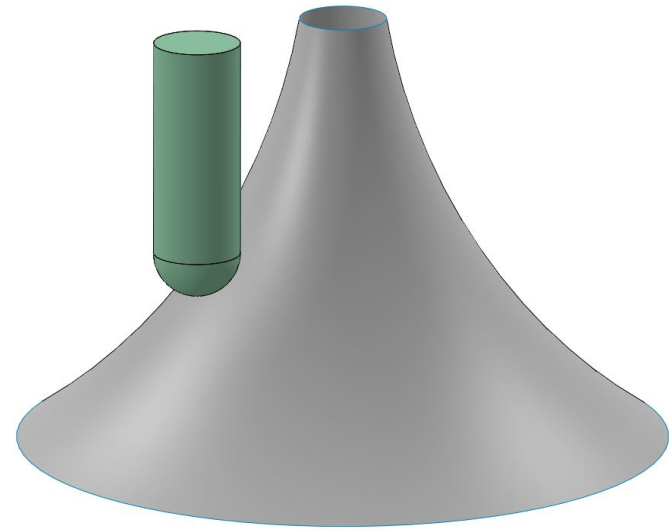
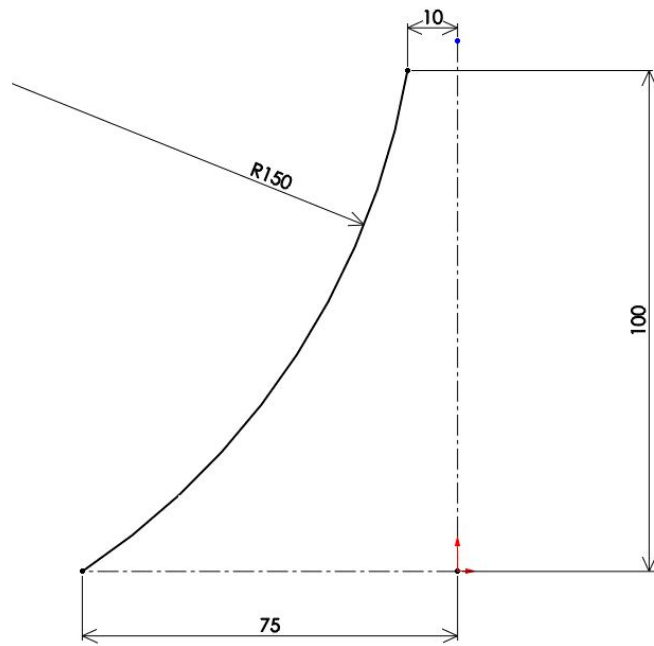
工具の突き出し長さ



5軸

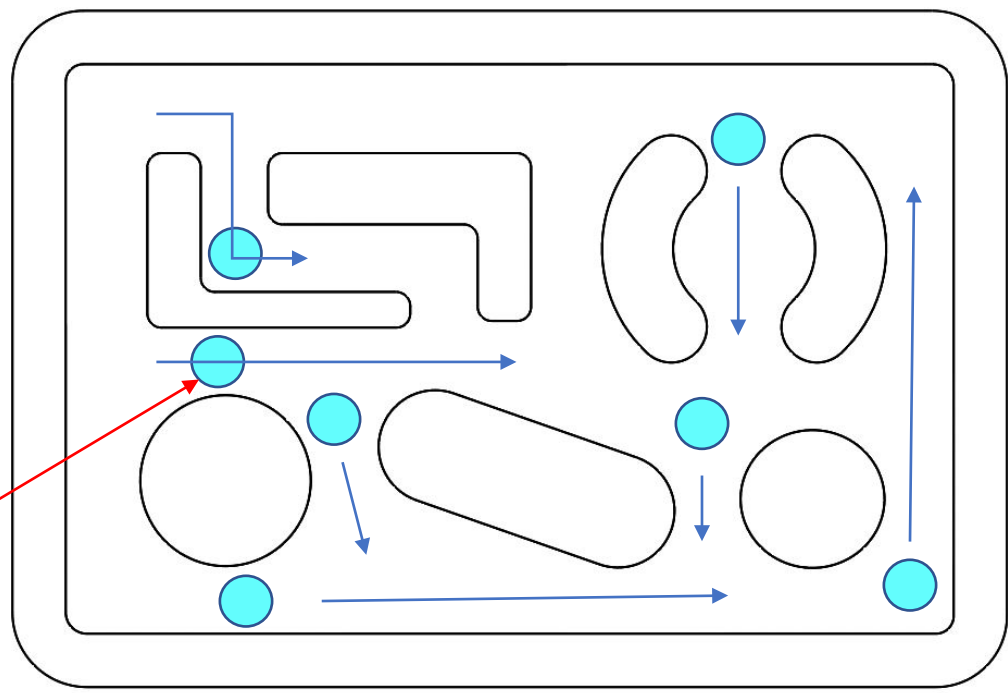
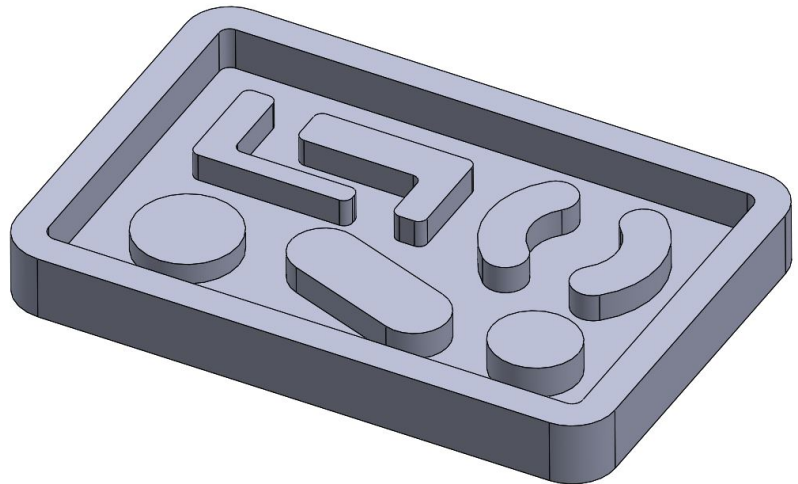
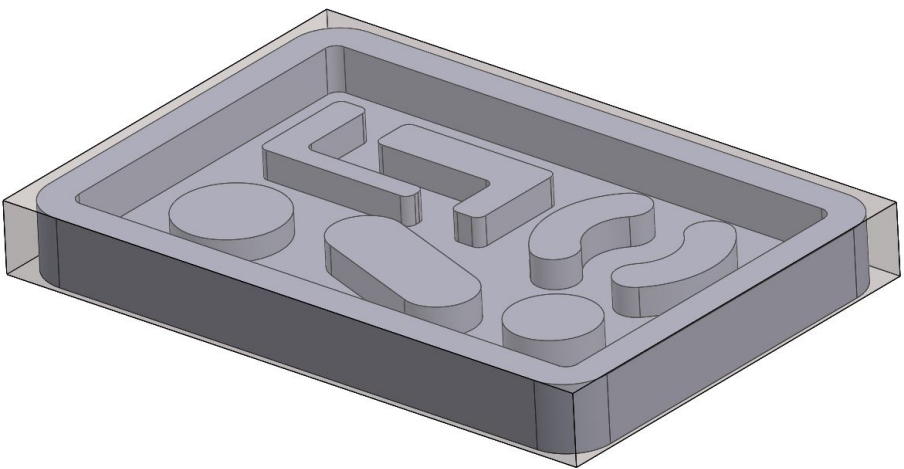
図 9.39 同時 5 軸加工の長所(続き)





問図9.1





エンドミル

問図9.2

