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MODEL TO MACHINE IN 90 SECONDS: SMART, FAST TEMPLATING FOR FUSION 360 CAD-CAM WORKFLOWS

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LEARNING OBJECTIVES

- Learn how to design Fusion 360 manufacturing templates to expedite, standardize, and automate CAD-to-CAM workflows
- Learn about and use parametric design history and user-defined parameters to automate CAM setups
- Learn how to create material- and operation-specific tool libraries with adapted feeds and speeds suited to the material and setup
- Learn how to model and use generic reference geometry to automatically align multi-axis strategies to complex parts

DESCRIPTION

Discover what makes Fusion 360 software the fastest rapid-prototyping CAD/CAM software available. Users will learn how to use parametric design history, user-defined parameters, and the tools in the Manufacturing Workspace to create rapid-prototyping templates to bring models from CAD models to machines in minutes. When the tedious work of CAM setups, tool libraries, feeds and speeds, and fixturing / work holding can be baselined in a standard template, designers and operators can spend more time focusing on product development and part optimization. With a few simple rules, tips, and tricks coming straight from the Autodesk Technology Center Workshops, you can create standardized CAD/CAM templates to streamline design to make workflows at any level.

SPEAKER

Chris Chekan oversees the workshop at the Autodesk Technology Center - Toronto, where he helps internal and resident teams alike to push the boundaries of design-make workflows. Prior to Autodesk, Chris ran his own industrial design+manufacturing practice both producing consumer products for niche industries, as well as consulting with fellow designers on Design for Manufacturing DfM best practices and optimizing parts for manufacture. He looks forward to a day when the necessity of translating between “Designers” and “Manufacturers” is a relic of a dark past.

LEARN HOW TO DESIGN FUSION 360 MANUFACTURING TEMPLATES TO EXPEDITE, STANDARDIZE AND AUTOMATE CAD-TO-CAM WORKFLOWS

OVERVIEW

Fusion360 is the ultimate rapid prototyping CAD-CAM package due to the speed and flexibility it affords the designer and CAM programmer. The connection between the DESIGN and MANUFACTURE workspaces allows for novel workflows and combining the power of a fully parametric CAD package with a CAM programming environment. This connection, without having to leave the software, results in a deeper potential to automate otherwise repetitive and tedious tasks when creating new setups, template toolpaths, fixture and stock models among others. With sound parametric structure, these template files can be easily adapted and configured in order to bring a model to the machine in a matter of minutes.

CAD/CAM – ONE ENVIRONMENT

- LEVERAGE PARAMETRIC MODELLING TECHNIQUES
- QUICKLY BRING NATIVE OR IMPORTED FILES TO THE MANUFACTURING WORKSPACE
- LEVERAGE USER DEFINED PARAMETERS TO QUICKLY MODIFY AND ITERATE ON DESIGNS
- COLLABORATE WITH TEAMS AND CUSTOMERS ALL IN ONE ENVIRONMENT
- CLOUD LIBRARIES ALLOW FOR WORK FROM ANY DEVICE WITHOUT LOSING DATA

MANUFACTURING TEMPLATES – WHY MAKE THEM?

- ELIMINATE REPETITIVE TASKS IN CAM PROGRAMMING
- STANDARDIZE MACHINE CONFIGURATIONS TO PREVENT HUMAN ERROR
    - INCLUDE WORKHOLDING, FIXTURING AND MACHINE GEOMETRY
- PARAMETRICALLY SOUND STOCK MODELS TO QUICKLY UPDATE FOR NEW PARTS
- MORE **ACCURATE** TOOLPATH SIMULATIONS (COLLISION CHECK)
- STOCK SIZING, MODEL POSITIONING AND STRATEGIZING OPERATIONS
- LIBRARY OF EXISISTING WORKHOLDING WITHIN FUSION360
    - JOINT RELATIONSHIPS SIMULATE OPENING LIMITS

LEARN ABOUT AND USE PARAMETRIC DESIGN HISTORY AND USER-DEFINED PARAMETERS TO AUTOMATE CAM SETUPS

PARAMETRIC MODELLING

Like a step-by-step recipe for how your design was constructed – if organized correctly, steps of this "recipe" can be edited, re-ordered or deleted and the design re-calculated with these new changes taking effect in the resultant design. The structure of the design – specifically, the order and organization of each action along the way to creating it – is critically important. Without sound parametric logic, changes in design variables or parameters can result in a failure to compute the design.

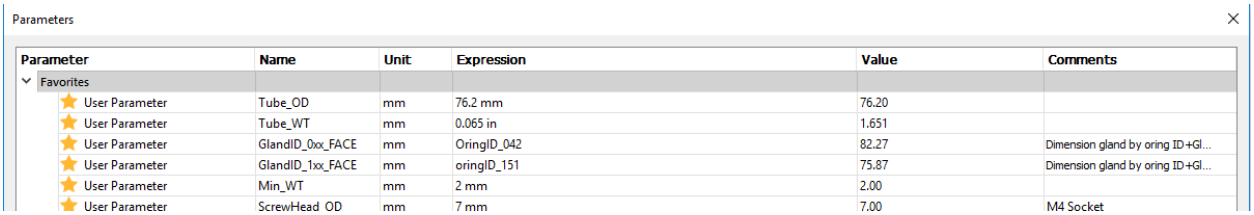
TIMELINE

The timeline is your graphical representation of the design history that has gone into your design. This is specific to each component/assembly in your design – so be sure to activate the component/assembly you are working on prior to doing anything.

Individual events/actions in your timeline can be edited directly through the modelling environment (look to bottom of your screen) or the values of the parameters therein can be edited directly under the "Change/Modify Parameters" command.

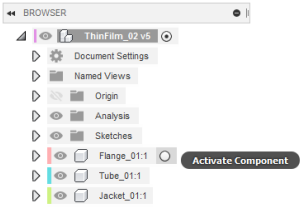
USER DEFINED PARAMETERS

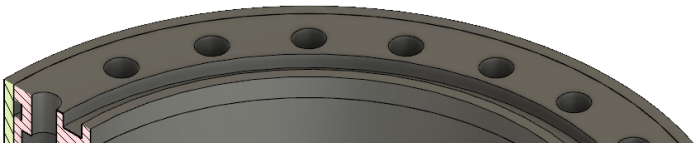
While any of the parameters used in your design can be updated directly through the timeline or "Change/Modify Parameters", it is also possible to create "user defined parameters". These can in turn be applied directly to dimensions/values in your design or be referenced in a function to have a dynamically configurable design. Updating the individual parameter would then update every other parameter that references it throughout the design. In this way, we can build configurable models that update based entirely on a few user-defined parameters.



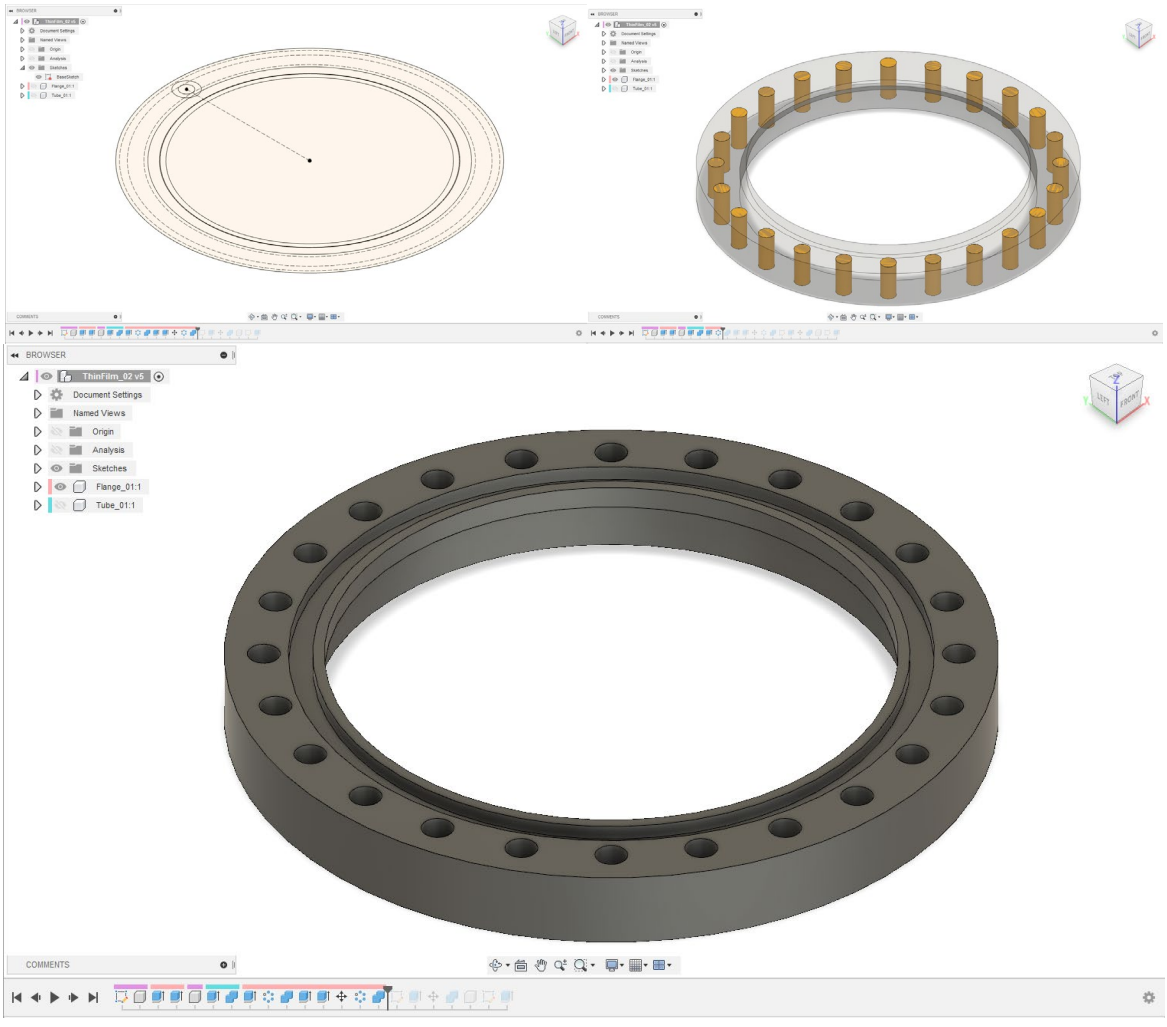
BEST PRACTISES

- NAME EVERYTHING
- ALWAYS ACTIVATE COMPONENT/ASSEMBLY





- PATTERN/MODIFY FEATURES, NOT SKETCHES
    - KEEP SKETCHES AS SIMPLE AS POSSIBLE, PER BODY



- REFERENCE GEOMETRY HEIRARCHY: WORK>BODY>FACE>EDGE>POINT
- EDIT SKETCH FEATURES – DO NOT DELETE!

LEARN HOW TO CREATE MATERIAL- AND OPERATION-SPECIFIC TOOL LIBRARIES WITH ADAPTED FEEDS AND SPEEDS SUITED TO THE MATERIAL AND SETUP

TOOL LIBRARIES

Tool libraries can be created with specific machines, materials, operations and even setups in mind. By duplicating a standard tool list and filtering for the specific parameters above, you can drastically reduce the time it takes to produce machine ready toolpaths for almost any part.

- **CREATE MATERIAL+OPERATION-SPECIFIC LIBRARIES**
    - CREATE MASTER TOOL LIBRARY OF ALL TOOLS FOR A GIVEN MACHINE
        - KEEP UNIQUE LIBRARIES FOR EACH MACHINE, EVEN IF OVERLAP EXISTS
        - MODEL HOLDERS INCLUDING SPINDLE COLUMN
    - DUPLICATE MASTER FOR EACH MATERIAL GROUP COMMONLY WORKED WITH
        - "**MASTER_TOOL LIBRARY**" > "**3XX SS_TOOL LIBRARY**"
        - FILTER TOOLS TO ONLY THOSE USED WITH GIVEN MATERIAL GROUP
    - MODIFY DEFAULT FEEDS AND SPEEDS TO MATCH MATERIAL AND OPERATION

TOOLPATH TEMPLATES

While the feeds and speeds are associated with the tool, the remaining toolpath variables are all associated with the operation. These variables can be saved as "Templates" and when combined with the material/operation specific libraries above, automate 95% of the "clicks". By using functions to define critical values referencing CAM Expression Variables (i.e. optimal load = 0.3***tool_diameter**) templates can be stored with parametric functionality that will update even when the tool is changed for that given operation.

- **SAVE OPERATION AS TEMPLATE**
    - RIGHT CLICK OPERATION
        - SELECT **"STORE AS TEMPLATE"**
        - RENAME USING ESTABLISHED NAMING CONVENTION
- EX: *"MACHINE ID_OPERATION_TOOLPATH ID_MATERIAL"*
    - "**ROBO_ROUGHING_2DA_6061**"

CAM EXPRESSION VARIABLES

The variables for the CAM workspace are listed below:

- **advancedMode**=false; // Advanced Mode TRANSIENT
- **allowRapidRetract**=true; // Allow Rapid Retract
- **alphaMode**=false; // Alpha Mode TRANSIENT
- **betaMode**=false; // Beta Mode TRANSIENT
- **bottom**=bottomOffset; // Bottom
- **bottomAbsolute**=false; // Absolute Bottom TRANSIENT
- **bottomMode**='from contour'; // Bottom Mode
- **bottomOffset**=0in; // Bottom Offset
- **bottomRef**=undefined; // Bottom Reference DISABLED
- **chainingTolerance**=0.0004in; // Chaining Tolerance
- **clearanceHeight**=retractHeight + clearanceHeightOffset; // Clearance Height
- **clearanceHeightAbsolute**=true; // Absolute Clearance Height TRANSIENT
- **clearanceHeightMode**='from retract height'; // Clearance Height Mode
- **clearanceHeightOffset**=0.4in; // Clearance Height Offset
- **clearanceHeightRef**=undefined; // Clearance Height Reference DISABLED
- **context**='operation'; // Context TRANSIENT
- **contourTolerance**=tolerance * 0.5; // Contour Linearization Tolerance
- **cuspHeight**=0mm; // Worst-Case Cusp Height TRANSIENT
- **direction**='climb'; // Direction
- **doMultipleDepths**=false; // Multiple Depths
- **explicitRampDiameter**=false; // Manual Ramp Diameter
- **fineStepdown**=maximumStepdown; // Fine Stepdown DISABLED
- **helicalRampDiameter**=Math.max((tool_diameter - 2 * tool_cornerRadius) * 0.95; tool_diameter * 0.25); // Helical Ramp Diameter
- **highFeedrate**=Math.max(tool_feedCutting; tool_feedEntry; tool_feedExit); // High Feedrate DISABLED
- **highFeedrateMode**='disabled'; // High Feedrate Mode
- **holder_attached**=false; // Attached Holder TRANSIENT
- **holder_comment**=''; // Holder Comment TRANSIENT
- **holder_description**=''; // Holder Description TRANSIENT
- **holder_libraryName**=''; // Holder Library TRANSIENT
- **holder_productId**=''; // Holder Product ID TRANSIENT
- **holder_vendor**=''; // Holder Vendor TRANSIENT
- **leadRadius**=tool_diameter * 0.1; // Horizontal Lead In/Out Radius
- **liftHeight**=.1in; // Lift Height

- **loadDeviation**=(optimalLoad<(tool_diameter-optimalLoad*0.20))?(optimalLoad*0.10):(tool_diameter-optimalLoad)/2; // Load Deviation
- **machineCavities**=true; // Machine Cavities
- **maximumStepdown**=Math.min(tool_fluteLength; 10mm); // Maximum Roughing Stepdown DISABLED
- **metric**=false; // Metric TRANSIENT
- **minimumRadius**=tool_diameter * 0.1; // Minimum Cutting Radius
- **minimumRampDiameter**=helicalRampDiameter; // Minimum Ramp Diameter
- **minimumStayDownClearance**=Math.max(Math.min(tool_diameter * 0.1; 15.0); 2.0); // Minimum Stay-Down Clearance
- **noEngagementFeedrate**=Math.max(tool_feedCutting; tool_feedEntry; tool_feedExit); // No-Engagement Feedrate
- **optimalLoad**=tool_diameter * 0.45; // Optimal Load
- **orderByDepth**=false; // Order by Depth
- **overrideToolView**=false; // Tool Orientation
- **rampAngle**=4deg; // Ramping Angle (deg)
- **rampClearanceHeight**=0.1in; // Ramp Clearance Height
- **rampDiameter**=(tool_diameter - 2 * tool_cornerRadius) * 0.95; // Minimum Ramp Diameter DISABLED
- **rampTaperAngle**=0.0deg; // Ramp Taper Angle (deg)
- **rampType**='helix'; // Ramp Type
- **reduceOnlyInnerCorners**=true; // Only Inner Corners DISABLED
- **reducedFeedChange**=25deg; // Maximum Directional Change DISABLED
- **reducedFeedDistance**=tool_diameter * 0.2; // Reduced Feed Distance DISABLED
- **reducedFeedRadius**=tool_diameter * 0.05; // Reduced Feed Radius DISABLED
- **reducedFeedrate**=tool_feedCutting * 0.25; // Reduced Feedrate DISABLED
- **retractHeight**=stockZHigh + retractHeightOffset; // Retract Height
- **retractHeightAbsolute**=true; // Absolute Retract Heigth TRANSIENT
- **retractHeightMode**='from stock top'; // Retract Height Mode
- **retractHeightOffset**=0.2in; // Retract Height Offset
- **retractHeightRef**=undefined; // Retract Height Reference DISABLED
- **roundWalls**=false; // Round Walls DISABLED
- **simpleStockToLeave**=false; // Simple Stock To Leave
- **slopeAngle**=tool_taperAngle; // Wall Taper Angle (deg) DISABLED
- **slotClearingWidth**=1.25 * tool_diameter; // Slot Clearing Width DISABLED
- **smoothingFilter**=false; // Smoothing
- **smoothingFilterTolerance**=tolerance * 0.1; // Smoothing Tolerance DISABLED
- **stayDownDistance**=5 * tool_diameter; // Maximum Stay-Down Distance

- **stayDownLevel**='level10'; // Stay-Down Level
- **stockBoundaryMode**='bounding-box'; // Stock Boundary
- **stockToLeave**=0.005in; // Radial Stock to Leave
- **stockZHigh**=0.0089535m; // Top of the Stock TRANSIENT
- **stockZLow**=-0.0089535m; // Bottom of the Stock TRANSIENT
- **strategy**='adaptive2d'; // Strategy TRANSIENT
- **surfaceTolerance**=tolerance * 0.5; // Surface Triangulation Tolerance
- **surfaceZHigh**=0.0079375m; // Top of the Geometry TRANSIENT
- **surfaceZLow**=-0.0079375m; // Bottom of the Geometry TRANSIENT
- **tolerance**=0.004in; // Tolerance
- **toolViewOriginSelectionMode**='setupWCS'; // Origin Selection Mode DISABLED
- **tool_bodyLength**=(tool_type == 'form mill') ? (tool_overallLength) : (tool_shoulderLength + tool_diameter * 2); // Body Length TRANSIENT
- **tool_breakControl**=false; // Break Control TRANSIENT
- **tool_clockwise**=tool_type != 'tap left hand'; // Spindle Rotation TRANSIENT
- **tool_comment**=''; // Comment TRANSIENT
- **tool_compensationOffset**=tool_number; // Compensation Offset TRANSIENT
- **tool_coolant**='flood'; // Coolant
- **tool_cornerRadius**=tool_isTurning ? 0.8mm : tool_diameter/4; // Corner Radius DISABLED TRANSIENT
- **tool_description**=''; // Description TRANSIENT
- **tool_diameter**=0.4in; // Diameter TRANSIENT
- **tool_diameterOffset**=tool_number; // Diameter Offset TRANSIENT
- **tool_feedCutting**=40inpm; // Cutting Feedrate
- **tool_feedEntry**=tool_feedCutting; // Lead-In Feedrate
- **tool_feedExit**=tool_feedCutting; // Lead-Out Feedrate
- **tool_feedPerRevolution**=tool_feedPlunge/tool_spindleSpeed; // Feed per Revolution
- **tool_feedPerTooth**=tool_feedCutting/(tool_spindleSpeed * tool_numberOfFlutes); // Feed per Tooth
- **tool_feedPlunge**=(tool_type=='drill')?(40inpm):(tool_feedCutting/3); // Plunge Feedrate
- **tool_feedRamp**=tool_feedPlunge; // Ramp Feedrate
- **tool_feedRetract**=tool_feedPlunge; // Retract Feedrate DISABLED
- **tool_fluteLength**=(tool_type=='drill')?(tool_diameter * 10):(tool_diameter * 2); // Flute Length TRANSIENT
- **tool_isDrill**=false; // Tool is for drilling TRANSIENT
- **tool_isMill**=true; // Tool is for milling TRANSIENT
- **tool_isTurning**=false; // Tool is for turning TRANSIENT

- **tool_lengthOffset**=tool_number; // Length Offset TRANSIENT
- **tool_manualToolChange**=false; // Manual Tool Change TRANSIENT
- **tool_material**='hss'; // Material TRANSIENT
- **tool_number**=1; // Number TRANSIENT
- **tool_numberOfFlutes**=3; // Number of Flutes TRANSIENT
- **tool_overallLength**=(tool_isTurning || tool_type == 'form mill') ? 30.0mm : tool_bodyLength + tool_diameter * 2; // Overall Length TRANSIENT
- **tool_productId**=''; // Product ID TRANSIENT
- **tool_rampFeedPerTooth**=tool_feedRamp/(tool_rampSpindleSpeed * tool_numberOfFlutes); // Ramp Feed per Tooth
- **tool_rampSpindleSpeed**=tool_spindleSpeed; // Ramp Spindle Speed
- **tool_rampSurfaceSpeed**=tool_isTurning ? (200m/min) : (tool_stockDiameter * Math.PI * tool_rampSpindleSpeed); // Ramp Surface Speed
- **tool_shaftDiameter**=tool_diameter; // Shaft Diameter TRANSIENT
- **tool_shoulderLength**=tool_fluteLength + tool_diameter; // Shoulder Length TRANSIENT
- **tool_spindleSpeed**=tool_isTurning ? 500rpm : 5000rpm; // Spindle Speed
- **tool_stockDiameter**=tool_isTurning ? (tool_unit == 'millimeters' ? 25 : 25.4) : tool_diameter; // Stock Diameter DISABLED
- **tool_surfaceSpeed**=tool_isTurning ? (200m/min) : (tool_stockDiameter * Math.PI * tool_spindleSpeed); // Surface Speed
- **tool_taperAngle**=(tool_type == 'chamfer mill') ? 45.0deg : 5.0deg; // Taper Angle DISABLED TRANSIENT
- **tool_threadPitch**=0.04in; // Thread Pitch DISABLED TRANSIENT
- **tool_tipAngle**=(tool_type == 'counter sink') ? 90.0deg : 118.0deg; // Tip Angle DISABLED TRANSIENT
- **tool_tipDiameter**=tool_type == 'spot drill' ? 0.0 : tool_diameter*0.5; // Tip Diameter DISABLED TRANSIENT
- **tool_tipLength**=(tool_type == 'center drill')?(tool_tipDiameter * 2):(0); // Tip Length DISABLED TRANSIENT
- **tool_tipOffset**=0; // Tip Offset DISABLED TRANSIENT
- **tool_turret**=0; // Turret TRANSIENT
- **tool_type**='flat end mill'; // Type TRANSIENT
- **tool_unit**='inches'; // Unit TRANSIENT
- **tool_vendor**=''; // Vendor TRANSIENT
- **top**=stockZHigh + topOffset; // Top
- **topAbsolute**=true; // Absolute Top TRANSIENT
- **topMode**='from stock top'; // Top Mode
- **topOffset**=0in; // Top Offset

- **topRef**=undefined; // Top Reference DISABLED
- **useEvenStepdowns**=false; // Use Even Stepdowns DISABLED
- **useFeedOptimization**=false; // Feed Optimization
- **useSlotClearing**=false; // Use Slot Clearing
- **useStockToLeave**=true; // Stock to Leave
- **verticalLeadRadius**=leadRadius; // Vertical Lead In/Out Radius
- **verticalStockToLeave**=stockToLeave; // Axial Stock to Leave
- **viewOrigin**=''; // Tool Orientation Origin DISABLED
- **viewPlane**=''; // Tool Orientation Plane DISABLED
- **viewReverseX**=false; // Reverse X Axis DISABLED
- **viewReverseY**=false; // Reverse Y Axis DISABLED
- **viewReverseZ**=false; // Reverse Z Axis DISABLED
- **viewSelection**='originAndOrientation'; // Tool Orientation Selection DISABLED
- **wcsOriginSelection**='top center'; // WCS Origin DISABLED

LEARN HOW TO MODEL AND USE GENERIC REFERENCE GEOMETRY TO AUTOMATICALLY ALIGN MULTI-AXIS STRATEGIES TO COMPLEX PARTS

CAD GEOMETRY VS. MACHINED RESULT

CAM simulation result has no requirement to match the as-modeled CAD geometry. There are times when a result other than the part as-modeled is desirable as simplified drive geometry can produce better tool paths.

- CHAMFERS LIKE EDGES, NOT FACES
- THREAD-MILLING OPERATIONS LIKE SMOOTH MINOR OR MAJOR DIAMETER BORES

"WORKING MODELS" (DERIVE COMMAND)

When attempting to get the cleanest toolpaths possible, it can often be effective to simplify the model and thus the geometry driving the toolpath calculation. This can mean removing holes, edge treatments etc. in order to use clean surfaces/contours to produce the toolpaths.

To do this, without modifying the original design:

- CREATE NEW BODY INSTANCE USING **"DERIVE"** COMMAND
  - ALLOWS FOR MODIFICATIONS TO THE "WORKING MODEL" IN ORDER TO OPTIMIZE TOOL PATHING WITHOUT MODIFYING THE ORIGINAL
- SIMPLIFY DRIVE GEOMETRY ON NEWLY SIMPLIFIED BODY

TOLERANCE, SMOOTHING AND .STL CONVERSION

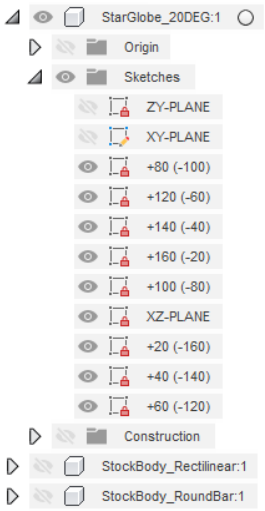
Most 3D toolpaths in Fusion/HSM first convert B.Rep geometry to a mesh (.STL) in order to then calculate the toolpaths. The degree of refinement of this resultant mesh is described as the parameter "Tolerance". This can result in strange toolpaths that might otherwise not make sense and produce an undesirable finish on your part.

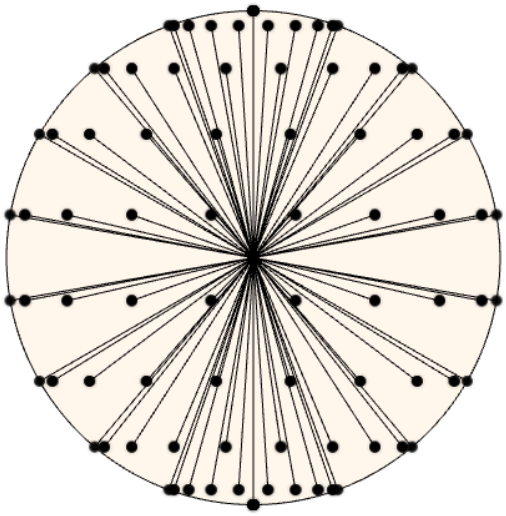
Here are some workarounds:

- BOUNDARY PROJECTIONS CAN MAKE FOR MESSY TOOLPATHS
  - USE TOLERANCE VALUES TO CREATE MACHINING BOUNDARY OFFSET TO AVOID SPLITTING ANY MESH GEOMETRY AT CONTOUR BOUNDARY
    - i.e. **"MACHINING BOUNDARY OFFSET= -1.1*Tolerance**
- OFFSET COPLANAR CURVES TO 2D GEOMETRY AND USE AS DRIVE GEOMETRY
  - SKETCH CONTOURS CAN WORK BETTER WITH TOOLPATHS LIKE MORPH/FLOW
- PERFECT CURVES/SURFACES (MATCHING TOOL DIAMETERS/CUT RADIUS) CREATE PROBLEMS DUE TO .STL CREATION
  - EVEN TINY OFFSETS CAN HELP REMOVE ERRATIC TOOLPATHS
    - i.e. OFFSET SKETCH CURVES BY **0.5*ToolOD+0.55*Tolerance**

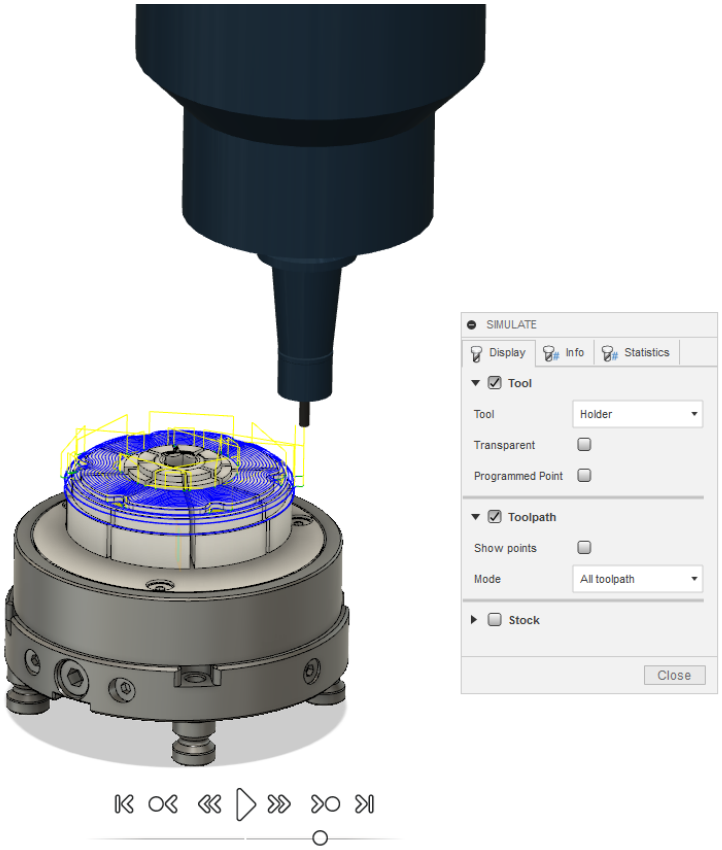
TOOL ORIENTATION, COLLISION AVOIDANCE

- CREATE STARGLOBE SKETCH FOR TOOL ORIENTATION QUICK REFERENCE



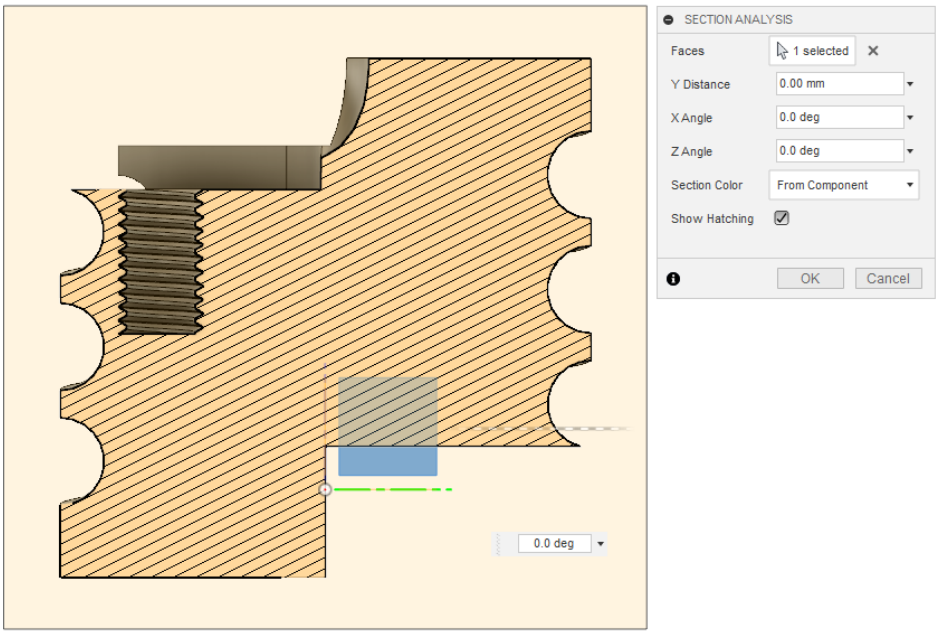


- MODEL SPINDLE COLUMN AS TOOL HOLDER FOR MORE ACCURATE COLLISION AVOIDANCE

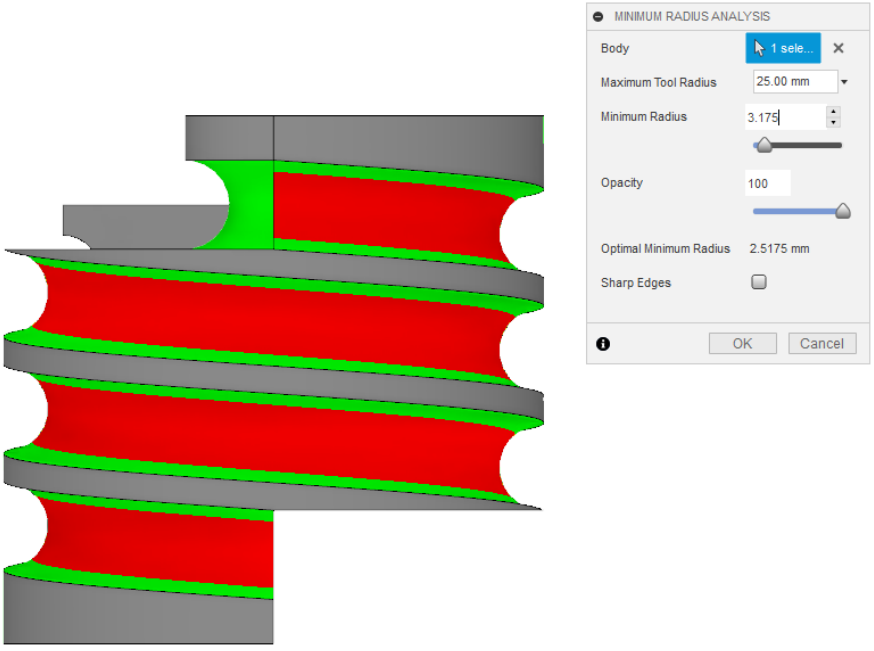


ANALYSIS TOOLS

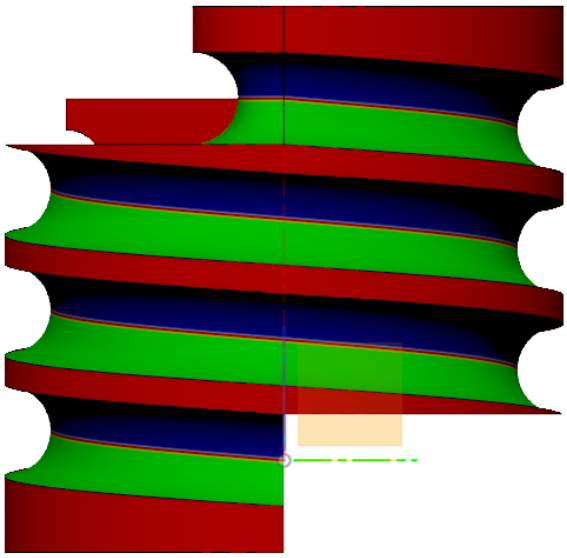
- **SECTION ANALYSIS**

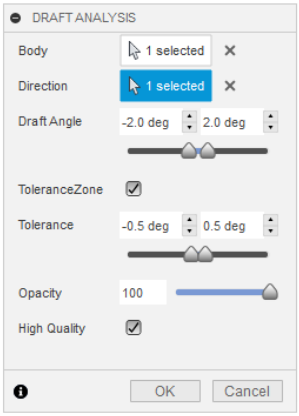


- **MINIMUM RADIUS ANALYSIS**

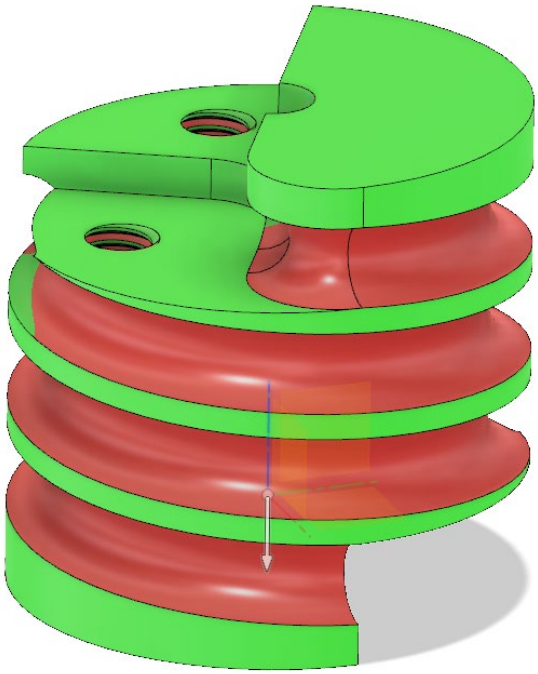


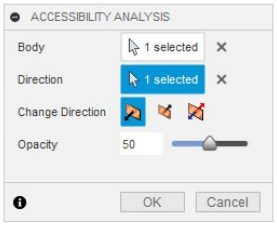
- **DRAFT ANALYSIS**





- **ACCESSIBILITY ANALYSIS**





IMPORTANT WORKFLOWS

ACCESS FUSION CAM SAMPLE FILES

1. From main data panel:
    a. **SAMPLES > CAM SAMPLES**
    b. **WORKHOLDING**
        i. Check regularly, updates from time to time
    c. **SAVE AS**

OPACITY CONTROL

ACTIVATE COMPONENT

1. Right click component to be edited
    a. **OPACITY CONTROL**
        i. Select preset value
        ii. Customize with exact value

CREATING JOINT RELATIONSHIPS WITHIN VISE ASSEMBLY

Ensure Design History is captured
ACTIVATE COMPONENT

1. **GROUND** Base of Vise
    - Right-click Component in Browser
    - **GROUND**
2. Create **RIGID GROUP** if necessary (with multiple Component Assemblies)
    - **ASSEMBLE > RIGID GROUP**
    - Can be used to lock down fixed jaws, for example
3. Create **JOINT (J)**
    - **ASSEMBLE > JOINT**
4. If prompted, **CAPTURE POSITION** of any moved Components
5. **SELECT** moving Component
    - choose position-location using hover-over
    - *if no hover-over location matches perfectly, create* **JOINT ORIGIN** *to locate*
6. **SELECT** fixed Component
    - Choose position-location using hover-over
    - *If no hover over location matches perfectly, create* **JOINT ORIGIN** *to locate*
7. Define **Joint Alignment** and **Motion Type**
8. Confirm joint definitions with **Animate**, click **OK**
9. Locate Joint in Browser, right-click to **EDIT JOINT LIMITS**

BONUS: Create **MOTION LINK** to impress your friends/simulate full vise operation

CREATE USER DEFINED PARAMETERS

Ensure Design History is captured
ACTIVATE COMPONENT

2. Create User Defined Parameters for stock dimensions
    a. **MODIFY > CHANGE PARAMETERS**
    b. Create **USER PARAMETER**
        i. Can be with specified units (dimensions)
        ii. Or without units (pattern qty etc.)

MODEL STOCK BODY

Ensure Design History is captured

1. Create User Defined Parameters for stock dimensions
    a. **MODIFY > CHANGE PARAMETERS**
    b. Create **USER PARAMETER (LxWxH**, or **LxØ)**
2. Create **SKETCH (S)** on bottom plane of vise jaws
3. Model stock with parametric design principles in mind
    a. In self-centering vise/chuck:
        i. create **CENTER RECTANGLE** or **CIRCLE (C)**
    b. In fixed jaw vise:
        i. Set corner using dimensioned **LINE (L)** from center of fixed jaw
            1. **D = 0.5*StockW**
        ii. Create **RECTANGLE (R)** from above defined corner point
    c. **DIMENSION (D)** using parameters defined above
    d. **EXTRUDE (E)** using parameters defined above
4. Modify **USER PARAMETER** to confirm parametric logics holds
5. Adjust **OPACITY** to view parts located within Stock
    a. Right-Click Component in Browser Tree
    b. Select **OPACITY CONTROL**

DEFINE STOCK BODY/VISE JAW JOINTS

Ensure Design History is captured

1. Create **RIGID GROUP** with Stock Body and Vise Base
    a. **ASSEMBLE > RIGID GROUP**
    b. This prevents stock body from moving from as-modeled position
2. Create **JOINT (J)**

   a. **ASSEMBLE > JOINT**
3. If prompted, **CAPTURE POSITION** of any moved Components
4. **SELECT** moving Component (Vise Jaw)
   a. choose position-location using hover-over
   b. *if no hover-over location matches perfectly, create* **JOINT ORIGIN** *to locate*
5. **SELECT** fixed Component (Stock Body)
   a. Choose position-location using hover-over
   b. *If no hover over location matches perfectly, create* **JOINT ORIGIN** *to locate*
6. Define **Joint Alignment** and **Motion Type**
7. Confirm joint definitions with **Animate**, click **OK**

CLEAN TOOLPATHS WITH CONTACT POINT BOUNDARY WITH TOLERANCE PARAMETER

Within tool path dialogue:

1. Under Geometry tab, locate **Geometry**
2. Select **MACHINING BOUNDARY** type from dropdown
   a. **SILHOUETTE** / **BOUNDING BOX** / **SELECTION**
3. Select **TOOL CONTAINMENT** type from dropdown
   a. **CENTER-ON** / **INSIDE** / **OUTSIDE**
4. Select **CONTACT POINT BOUNDARY** to prevent roll-over
5. Input additional offset:
   a. -1.1*tolerance

BONUS: hold SHIFT and hover over any input/variable in Fusion CAM environment to display parameter name for use in function-based inputs