SolidCAM
A Product Review

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Prepared by
CIMdata

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CIMdata, Inc. prepared this product review as an independent and unbiased assessment of the functional capabilities of SolidCAM, a CAM software product developed by SolidCAM Ltd. SolidCAM is a registered trademark of SolidCAM Ltd. This evaluation is one in a series of software product reviews produced by CIMdata, a worldwide consulting and marketing research firm. CIMdata has authorized SolidCAM to reproduce and distribute this document, without constraints from CIMdata.

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CIMdata is an industry-leading consultant on CAM software systems. It produces the NC Software Market Assessment Reports and the Compendium of NC Product Reviews. Market research has been conducted by CIMdata on a variety of CAM related topics. CIMdata provides consulting services to CAM software users and vendors and to the investment community.
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SolidCAM Ltd is rapidly becoming a significant player in the worldwide CAM marketplace. Their revenue growth rate is exceptional, they are implementing a distinctive market and product strategy, and they have an easy to use, highly competitive CAM product offering. CIMdata is favorably impressed by the core SolidCAM strategy to be closely aligned with and embedded within SolidWorks, the SolidCAM decision to only develop CAM products, and the breadth and depth of their CAM product offerings that meet the needs of a broad range of industries and users.

SolidCAM has established a distinctive position in the market as one of only two CAM software vendors that are certified Gold partners of SolidWorks. Certified Gold partners are those vendors that have embedded their NC software within a single SolidWorks window to create a single integrated CAD/CAM product. As such, in combination with SolidWorks, SolidCAM is able to provide a fully associative, integrated offering for design and NC. SolidWorks is the SolidCAM modeler. In 2002, SolidCAM customized their NC software to meet the SolidWorks Gold standard. This was a key decision of SolidCAM and thus far it appears to be a good one. CIMdata is supportive of this strategy.

SolidWorks has attained industry acceptance as the de facto standard product in the mid-range solid modeling market. They now have an installed base of approximately 200,000 industrial seats and this continues to grow at a fast pace. SolidCAM is doing an excellent job in leveraging this market acceptance. They have been very effective in promoting the SolidWorks relationship and building on the SolidWorks brand name.

SolidCAM has a clear strategic vision. They are totally focused on CAM and all modeling capability is provided by SolidWorks. SolidCAM is leveraging SolidWorks for design and design related functions such as part design, mold design, other design functionality, interfaces with third-party products, access to engineering analysis products and other CAD related products, information management, process planning, and PDM. Support of the SolidWorks certified Gold partnership is a key element of the SolidCAM program. As a Gold partner, SolidCAM is inextricably linked to SolidWorks in conducting their business, and in their marketing and product development programs.

Within NC, a strength of SolidCAM is that they offer the user an easy to use and modestly priced product that includes an exceptionally broad range of industry competitive machining capabilities. It is a general purpose CAM product. It supports all aspects of hole making, 2-axis milling, 3-axis milling, 4-axis milling, 5-axis positioning, simultaneous 5-axis milling, high-speed milling, indexed “tombstone” machining, basic turning, mill-turning, and wire EDM. A few of the more advanced and distinctive features supported in SolidCAM include automatic setting of coordinate systems, a 3D stepover option, a trochoidal milling strategy, plunge roughing, consideration of the holder in collision computations, “tombstone” machining, 3 + 2 machining, support of mill-turn operations, and full use of rest material machining.

With the single-window integration of SolidCAM in SolidWorks, all machining operations are defined, calculated and verified without leaving the SolidWorks environment. All 2D and 3D geometries used for machining are fully associative to the SolidWorks design model. When the geometry used to define a machining operation is changed in a SolidWorks design, SolidCAM enables the user to automatically synchronize all machining operations with the updated geometry.
SolidCAM is a process oriented CAM system that supports knowledge-based machining. The primary SolidCAM approach to automation is one of creating and capturing process templates, and then permitting the user to re-use these templates in subsequent and similar situations. Machining templates are provided with the software for specific functions such as thread milling, face milling, floor and wall machining, and rest milling. Users can also create standard machining processes to be captured as templates and employed as appropriate.

Many of the SolidWorks users and prospects within the manufacturing sector are potential SolidCAM users. The SolidCAM market is increasingly becoming the SolidWorks market. Given the large SolidWorks installed base, SolidCAM has a more than adequate cadre of companies from which to draw. SolidCAM is sold either as an add-on CAM product into the SolidWorks base of customers, or it is promoted as a packaged CAD/CAM offering of SolidWorks and SolidCAM to companies that have not yet implemented CAD/CAM or those that have previously selected other vendors. SolidCAM emphasizes the market position of SolidWorks as the standard mid-range solid modeler and the complete integration of SolidCAM within SolidWorks. The benefits of this tight integration are stressed as the key differentiator for SolidCAM, as compared to most other CAM-centric vendors.

In addition to their tight integration with SolidWorks, SolidCAM also highlights the availability of multiple third-party products from other SolidWorks partners, the broad product offering of SolidCAM in CAM, ease of use, programming process automation, modest software price, and worldwide support in their marketing program. As such, users can obtain a productive, extensive, and fully integrated CAD/CAM capability at an attractive price / performance ratio.

SolidCAM has been on a rapid growth path since they implemented the SolidWorks integration strategy. CIMdata ranked SolidCAM as the worldwide fastest growing NC software vendor in 2003 and 2004 with revenue growth rates of 39 percent and 51 percent. CIMdata is also forecasting that SolidCAM again will be the fastest growing vendor in 2005 with a growth rate of 41 percent. Although these growth rates are from a relatively smaller revenue base than some other suppliers, they are clearly substantial. SolidCAM is being well received in the marketplace.
modeler, and as such, it is used by companies in virtually every industry. Since SolidCAM promotes its use to the SolidWorks base and offers a packaged CAD/CAM solution with SolidWorks, it is also being used in the breadth of industries served by SolidWorks.

SolidCAM is used heavily in shop floor programming by machinists, as well as by professional dedicated programmers. Since it is easy to use, automated, and modestly priced it is well suited for this application. A demonstration version of SolidCAM, in which G-code is not generated, supports viewing by shop floor machinists. This helps them visualize the part to be produced and the machining operations to be performed.

SolidCAM currently does not provide support for parameter associated graphics within dialogue boxes, 4-axis lathes, or sub-spindles in mill-turn.

SolidCAM utilizes direct sales people in Germany and Israel, as they have an extensive installed base of customers in both of these countries. They have also rapidly built a very impressive reseller network in over 50 countries around the world. In the past year, the number of resellers has essentially doubled to 80 or so resellers, which is among the 10 largest CAM software reseller networks. Most of the new SolidCAM resellers are also SolidWorks resellers. As new resellers join the SolidCAM family, SolidCAM typically displaces other CAM software vendors, as essentially all of the new resellers previously supported other NC software products.

Since the SolidCAM market focus is moving in the SolidWorks direction, they have a focused marketing program. SolidCAM participates in SolidWorks user conferences, advertises on the SolidWorks Web site, and works closely with SolidWorks resellers. In the past, SolidCAM has only conducted a full marketing program in their major markets such as Germany. They have done relatively little direct marketing to the general CAM market. However, this is beginning to change as SolidCAM grows and expands its market presence.

Most of the new sales leads for SolidCAM are generated through the SolidWorks Web site and reseller network. These leads tend to be from users that have a serious interest in CAM. The high volume of these quality leads is such that SolidCAM has been able to achieve its rapid growth without implementing an extensive lead generation program of its own.

For product support, customers interact almost solely with resellers and the SolidCAM Web site. Their resellers appear to be well qualified in CAM. In fact, one of the major resellers in the U.S. operates a general purpose tool shop that employs a variety of machine tools, including a 5-axis machine. Customer access to SolidWorks is through SolidCAM.

SolidCAM 2006 Version 10, to be released in April 2005, was the version of software evaluated in this review. SolidCAM releases are done every six months. SolidCAM and SolidWorks product development and releases are done independently, but Alpha and Beta releases of SolidWorks are provided to SolidCAM. As SolidWorks releases new functionality it is quickly incorporated into SolidCAM.
1. Operating Environment

SolidCAM operates only within a single SolidWorks window. The user interface is the SolidWorks interface. When SolidCAM is installed a SolidCAM icon appears on the top level (File level) tool bar between Tools and Window. The line of SolidWorks icons across the top of the interface, including the SolidCAM icon, are always present when operating in SolidCAM. SolidCAM adds icons to the SolidWorks menus to provide CAM related functions. To maintain a consistent look and feel between the SolidWorks and SolidCAM code, SolidCAM must adapt to the methodologies and formats established by SolidWorks. SolidCAM does not provide a stand-alone CAM product.

When SolidCAM is launched within SolidWorks, the CAM Manager and CAM functions are listed along the left side of the screen in a tree structure format. For each operation shown, reference is made to the machining strategy, tool and geometry. As an option, the sequence of tools used to machine a part can be listed in the tree structure and could stay on the screen at all times. The order in which tools are employed can be optimized in SolidCAM. A holder can be added to the tool. By dragging and dropping, operations can be manually moved or re-ordered. To select a machining strategy or enter machining parameters, clicking on the operation brings up additional dialogue boxes. Appropriate selections are made within these dialogue boxes.

As an integrated Gold partner, there is no need for any data transfer to or from SolidWorks since SolidCAM works totally inside SolidWorks and it has access to all the SolidWorks data. This includes assembly and/or geometry data, features, and all other non-geometric aspects of product definition such as tolerances. As one manager in a U.S. machine shop observed, “SolidCAM fits nicely into SolidWorks. Being able to work within a single database is excellent.”

All SolidWorks certified CAM partners have the capability to read native SolidWorks geometry into their system and geometry associativity is also provided. However, a certified Gold partner, such as SolidCAM, provides single window integration within SolidWorks. The look and feel of the SolidWorks software is maintained. There are also two levels of associativity between SolidWorks and SolidCAM. There is geometry associativity, such that if there is a change in the geometry of the part to be produced, the toolpath is automatically updated to reflect the new geometry. In addition, and as a Gold partner, associativity is also maintained with related components such as fixtures and mold cores and cavities, so that if a geometry change occurs within a part, these related components are also automatically updated. Updates only occur in areas of a part in which a change is made.

SolidCAM is written in C++. Although users can customize certain aspects of the SolidCAM system, such as machining processes, technological database for hole recognition and machining and post-processing output, SolidCAM does not provide API-based customization using tools such as Visual Basic.

File management for SolidCAM users is accomplished in the SolidWorks environment. This includes support for all types of data such as parts, fixtures, and molds. PDMWorks is a full client-server PDM (product data management) capability that is provided by SolidWorks. It supports both individuals and workgroups. SolidCAM users can license PDMWorks to store and access files, maintain security on the vaulted files, organize and track design and NC data, control file revisions, manage project data, manage workflow, and enhance collaboration within or between workgroups as well as across a supply chain. Over time, a PDM offering will become increasingly important to CAM users. Unlike the major PDM systems, PDMWorks is designed for use in small to mid-sized firms. It is relatively easy to setup, learn and use.

A model compare function is available in both SolidWorks and SolidCAM. When comparing two
models, the software will indicate the areas that do not match. When a change to a model occurs in SolidWorks, a notification of this change appears in SolidCAM. At that point, the SolidCAM user can use the compare function to determine the nature of the change. A user could employ PDMWorks to obtain a historical record of changes, who made them, when, and why.

As a Gold partner, SolidCAM maintains a close relationship with SolidWorks product development. Alpha and Beta versions of new SolidWorks releases are provided to SolidCAM so that necessary modifications or additional features can be added to SolidCAM to take advantage of new SolidWorks functionality. As such, the SolidWorks and SolidCAM products remain closely coupled and SolidCAM releases closely follow new releases by SolidWorks.

2. Manufacturing Modeling

All manufacturing modeling is done in SolidWorks. SolidWorks has been a commercial product for approximately 10 years. It was introduced as a mid-range solid modeler with considerable functionality, but at a substantially lower price than the high end modelers from firms such as Dassault, UGS, and PTC. SolidWorks is currently owned by Dassault, but it, in effect, operates as an independent entity. Dassault positions CATIA primarily as a process-centric, broad-based PLM (Product Lifecycle Management) solution for large scale corporate enterprises. In contrast, SolidWorks is offered as a CAD-centric product for the design market. SolidWorks has been extremely successful as a company and as a product and it has become the worldwide de facto standard mid-range modeler.

SolidWorks is built on the Parasolid geometry kernel. It employs a feature-based part modeling capability to allow part designs to be created with extrudes, revolves, thin features, shelling, lofts, feature patterns and holes. Changes are made by dragging and dropping.

SolidWorks can accept wireframe sketches, surface, or solid models and NC programming can be performed on any of these types of models. The user has the option of converting wireframe or surface models to a solid or leaving them in their native state. A solid model can be generated from a surface model by adding a depth component. If a face is removed from a solid, it becomes a skin or surface. A user can work in either a solid or surface mode and solid and surface operations can be intermixed within the same model. The same modeling tools are used independent of whether the model is defined in surfaces or solids or a combination of both. Solid operations, such as Boolean operations, can be applied to both solids and surfaces, and to assemblies and parts. Surface operations can be applied to solids. Surfaces and solids can be blended together and the blended area can be either a surface or a solid. Surfaces are treated as a solid of zero thickness. Surfaces can be manipulated and curvature continuity can be maintained.

The strength of SolidWorks is, of course, in solid modeling. It is less capable in surface modeling, which is typically employed with complex shapes such as molds and dies. SolidWorks has some software limitations in handling files that contains thousands of surfaces, as is often encountered in a model of an automotive die or complex mold. Mold design tools are provided, but the mold tool market is not a major area of focus for SolidWorks. As such, other modelers, such as those provided by the PLM suppliers and some CAM-centric vendors, are probably more appropriate for the high-end mold and die market.

![Figure 4—Mold Design in SolidWorks](image)
Machining in SolidCAM is done on a tessellated solid and/or surface model. This is a commonly employed technique to minimize gouges and increase machining performance. Associativity is provided between the SolidWorks model and SolidCAM machining in all machining operations. As such, if a model is changed, the toolpath regeneration function automatically recalculates a toolpath in the area affected by a design change.

Stock models for machining can be defined using any 2D contour, 3D model, or the stock model can be automatically derived from the target model. A German user observed that, “A big advantage for SolidCAM relative to other systems is the combination of 2D, 2.5D, and 3D working together.”

In SolidCAM, a user can enter the material on either a linear or helical path. If an obstacle is encountered when entering on a helical path, the helix will automatically continuously reduce in diameter until the obstacle is no longer encountered. Or in the extreme, the helix will revert to a linear material entry to avoid an obstacle. With SolidCAM, one only requires a single model to machine on different sides of a part. In some software systems, multiple models are required to machine on multiple sides of a part.

The SolidCAM tool library contains cutting tools, holders, and tool assemblies. Graphical representations of the tool and tool holder are available in the tool library. The software accepts customer-specific cutting data for automatic calculation of recommended speeds, feeds, and depth of cut. Tools can be loaded from the tool library or they can be interactively defined.

3. Basic Machining

A strength of SolidCAM machining is that it is relatively easy to learn and use, although considerable product breadth, depth, and flexibility is provided. SolidCAM 2.5-axis milling supports drilling, profiling and pocketing. Canned drill cycles are provided.
SolidCAM efficiently determines the coordinate system for a part. The software generates optional home positions and the user can select the most appropriate one for the job. One can edit the parameters associated with the home position and move the home position. Both a part and assembly environment are supported. In assembly mode, jigs and fixtures are shown on the model as well as the part to be machined. Several SolidWorks parts can be machined as a single CAM part.

A key capability of SolidCAM is that it supports knowledge-based machining. Standard machining processes can be defined to perform various functions. SolidCAM includes a customizable machining process technology database to store and re-use these processes. Once a process is created and stored it can be employed as appropriate in machining a part. By so doing, programming is automated, time is saved, and a consistency of programming is achieved. Some standard templates are delivered with the software and others can be created by the user. Templates can be established for almost any process including pocketing with a drill entry, thread milling, corner finishing, and rest milling. Some rules are also built into the technology database. For example, one could have a rule as to when to spot drill that would be related to the size of the hole, material being used, etc.

SolidCAM processes are based on parametric definitions. Process parameters such as downsteps, stepovers, surface offsets, etc., are considered as well as machining strategies. The parameters and processes can be modified to meet user needs, such as changing the amount of downstep to be utilized. Once a process has been established, the template can be saved in the In-Process Table.

SolidCAM provides a strong one button capability for pocketing. For prismatic parts, SolidCAM analyzes the model and automatically recognizes pockets and profiles to be machined using constant Z machining strategies. Pockets can be cut by individual pocket or if thin walls are present the cutting can be accomplished level-by-level. Circular, contour, zigzag, or one direction only cuts are employed. Pocketing in any order, an unlimited number of islands, an island cleanup option, high-speed pocketing, contoured walls pocketing, and open or closed pockets are supported.

Feature-based machining is employed within SolidCAM to automate the hole making process. Using automatic feature recognition developed internally by SolidCAM, the software is able to analyze a SolidWorks model and automatically recognizes the hole features in the solid model. Feature recognition can be an important component of feature-based machining and programming automation. It detects and identifies all types of holes including through holes, threaded holes, counter-bored holes, etc. SolidCAM generates the toolpath for the machining of the features using knowledge-based machining processes stored in the technology database. The process is automatic, but user control of the machining is also available.

When machining a mold with holes such as those for ejector pins, SolidCAM has the capability to turn off the hole features or cover the holes in the model and lay down a surface over the holes. In this way, one can machine the part surface and cross over the holes without having the tool drop into a hole. Drill cycles in SolidCAM are sorted by levels; in this way all the operations needed to create a threaded hole can use the same subroutine and thus save G-code lines. The subroutine does not include the Z levels as every operation using this subroutine may have to drill to a different level.

In volume milling or roughing, automatic selection of the machining strategy is provided. SolidCAM users typically do roughing level-by-level and then employing a zigzag or one-way only cutting pattern for finishing. The software knows the flat areas of a part and these could be finished to the final depth while material is left on other areas. When there is an outside opening in the model, the tool will automatically enter from the outside and avoid a plunge. However, the user always has the option to plunge into the middle.
and then move to the outside. Roughing and re-roughing of material left behind can be accomplished in a single command. By generating an in-process model the software knows where excess material remains.

Rest machining is employed in roughing and cutting only occurs if material remains in a given area. In 2D operations within SolidCAM, the amount and location of rest material remaining is computed by having knowledge of the original stock, final part model, toolpaths generated, and cutting tools that have been employed. After each successive machining step, the rest material will be automatically updated. Rest material functions are available for 2.5D, 3D and 3 + 2 multi-sided machining. The use of rest material machining is also available in 5-axis machining.

A trochoidal cut can be employed in combination with other strategies when deep material is encountered in roughing. This is a relatively new and advanced machining strategy. It employs a circular cutting motion that is partly in and partly out of the material.

SolidCAM supports plunge roughing. This is a recently introduced roughing operation that is not heavily employed, but can be appropriate for roughing large parts made with soft material. With SolidCAM one can rough by column or in steps. A regular roughing strategy such as a spiral cut can be changed to a plunge and the operation can be completed with a plunge roughing strategy.

For new users it is often desirable to have graphics displayed to illustrate a machining strategy or operation that is listed in a dialogue box. SolidCAM includes the graphics within the help function, but they are not available as part of the strategy or parameter dialogue boxes. When computing is being done in SolidCAM, other functions cannot be performed.

SolidCAM is exceptionally strong in “tombstone” machining and CIMdata believes that they could be an industry leader in this type of machining. This can be a very important function in production machining. Parts can be placed anywhere on the “tombstone.” A home position is automatically determined. One can machine multiple copies of the same part on a single face of the “tombstone” or different machining setups for a given part can be placed on a “tombstone.” One can perform both 2D and 3D milling on the same or multiple parts. Indexing to turn the “tombstone” is performed automatically.

Support of 2-axis to 4-axis wire EDM is provided in SolidCAM. SolidCAM Wire-EDM handles profiles and tapers with constant and variable angles, as well as 4-axis contours. Intelligent algorithms prevent the falling of material pieces by automatic pocket processing. SolidCAM provides full user control of stop points and of wire cutting conditions at any point of the profile or taper.
4. **3- to 5-Axis Milling**

SolidCAM provides an industry competitive 3- to 5-axis milling capability. The user selects faces on the SolidWorks model to identify areas to be machined. In SolidCAM one can define check surfaces to avoid. This is an APT like function that provides a containment area for work to be done or not done. A variety of finishing strategies are available in 3-axis machining. A British user observed that “he particularly liked the variety of machining strategies that are available in SolidCAM.” They include:

- Parallel-plane
- Constant-Z
- Zigzag
- Spiral inside-out or outside-in and linear spiral
- Radial
- Circular
- Parallel or perpendicular to any curve including a flow line curve
- Boundary collapse
- Pencil milling
- 3D stepover
- Combination processes for steep and flat areas

SolidCAM automatically detects flat and vertical areas of the design model. As such, a parallel-plane machining strategy could be employed in flat areas and a Z-level strategy could be used in vertical areas.

As in 2.5D operations, SolidCAM makes extensive use of rest milling in 3-axis operations. Rest material machining is accomplished on either block stock or a 3D cast model. Machining only occurs where rest material is detected. Automatic rest machining has become common practice in all aspects of machining, but it is extremely important in machining of complex parts. This permits removing material left behind as a result of tools being too large to reach into corners, valleys, depressions, etc. In rest machining, a smaller cutter is selected, but the toolpath is re-computed and machining only occurs in those areas in which material remains.

In 3D operations within SolidCAM, the rest material is determined from an in-process model that is generated with each cutting pass. The amount of stock remaining is automatically updated after each machining sequence. From the in-process model, the software can establish the depth of material at any point on the surface by comparing the in-process model to the final model of the part. The 3D in-process model also includes the 2D areas of a part. SolidCAM uses the difference between the stock and target model to optimize subsequent toolpaths on the 3D model. Within a dialogue box a user can select whether machining should be done across the entire part or only where material remains from a previous cut.

One can view the stock within the NC operations, but the depth of stock remaining is not displayed to the user in machining. Since the computations are performed in MachineWorks, these are only presented at the time of toolpath verification. Within MachineWorks, the depth of material can be displayed in four different colors. Each color can be associated with a range of material depth. As such, by viewing the color model, a user can quickly ascertain the depth of material at any point or area on the part. By changing the range of material depth associated with a color, the color on the model will change.

For control of toolpath stepover, SolidCAM offers a wide variety of options. They include both 2D and 3D stepover, control by the maximum scallop height to be left on a surface, and by an angle stepover for radial machining. One can morph the stepover between two distances or between two surfaces. Some techniques can also be used in combination, such as control by maximum scallop height in combination with a 2D stepover. Use of a 3D stepover and the capability to morph the stepover are advanced technology options that are particularly important for obtaining a smooth surface finish. The stepover options available in SolidCAM are competitive with other products available in the industry.
In SolidCAM, gouge checking is performed on all moves and gouge avoidance is provided. If the toolpath is truncated to avoid gouging, the software will record the location and mark the toolpath file as having been truncated. Also, the cutting tool, shank, and tool holder are all considered in collision checking in both 3-axis and 5-axis milling. Some software products only consider the cutting tool. Both the part and fixtures are considered in collision detection. If a collision is detected the user is notified. Testing is done against the in-process model, as compared to the part model. This capability is not common. If a collision is detected, the user can stop the process and modify the gouge avoidance strategy.

High-speed machining continues to grow in importance in the cutting of molds and dies. SolidCAM includes a capability to support this type of machining operation. It can be employed in either roughing or finishing operations. Some of the machining features included in SolidCAM to specifically support high-speed milling are:

- All corners are rounded
- Loops are added to the toolpath to make smooth transitions
- Rounded connections are made between adjacent toolpaths
- A multi-part capability is provided to sequentially machine multiple parts in high speed
- A linear finish with a rounded toolpath strategy is provided
- An offset finish toolpath along one or two directional offset profiles is available

SolidCAM provides an advanced capability for support of 3+2 indexed multi-sided machining. In this operation, a 2-axis tilting rotary table is added to a 3-axis machining center so that parts can be positioned at different angles by tilting the table and rotating the parts. This type of machining is particularly important for cutting multi-sided parts on 4- and 5-axis machining centers. SolidCAM rotates the SolidWorks model to the user defined machining planes and automatically calculates all necessary shifts and tilts for 3D machining. It enables flexible set-ups and reduces the need for special clamping jigs. One can define machining operations on any face and check them using SolidCAM’s toolpath verification. In SolidCAM, multiple home positions can be defined anywhere on the model.

Simultaneous 5-axis machining is becoming more common as the price of these machine tools continues to decrease and the benefits become more accepted. To meet this market need, SolidCAM has licensed a simultaneous 5-axis machining module from ModuleWorks. They are a German software development firm that only provides component software. They do not sell product to end users. ModuleWorks is gaining recognition in the market, as SolidCAM and several other CAM software vendors are now offering it as their 5-axis product. The continuous 5-axis machining strategies available to SolidCAM users include:

- Parallel-plane
- Following a curve and cutting parallel or normal to a curve or surface
- Cutting along a projected curve
- Morphing between curves or surfaces
- Cutting at a constant lead, lag, or tilt
- Swarf cutting by tilting the tool 90 degrees
- Trimming

As in 3-axis milling, check faces or surfaces can be established and these faces or surfaces will be avoided. Rest material machining and full associativity with SolidWorks are also provided in the 5-axis module.

The visualization provided in machine simulation is excellent. The full machine tool can be seen as well as the part and cutting tool. For collision detection one has the option of considering the tool holder as well as the tool. The software also displays if and where a gouge occurs in a part. If this condition occurs, the user has a number of options that can be tried in se-
quence to avoid the gouge. By so doing, the software provides the user with control and allows the user to correct a mistake. The options are:

- Moving the tool away from the gouge location
- Tilting the tool to avoid a gouge
- Leave out the points where a gouge is occurring
- Stop the toolpath calculation

The use of ModuleWorks has leveraged the SolidCAM product development resources and has provided SolidCAM with a competitive near term 5-axis product.

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5. Turning and Mill-Turn

SolidCAM has a strong capability in turning, grooving, and mill-turn. As in milling, a rest machining capability is built into all turning operations. As such, the user has the option to machine only in areas where rest material is available or to perform turning over the entire part. Also, as in milling, the software is fully associative so that changes in the SolidWorks model will automatically update the toolpath in turning. When a change in geometry is made the software tells the user the jobs that are affected by the change.

The user has total control of the tool in SolidCAM turning and grooving. SolidCAM supports all machine turning cycles. The user can select either long G-code or short G-code with machine turning cycles. The turning features provided include the ability to set the feed rate to obtain a constant surface speed, a custom feed rate that can be applied to any segment of the boundary, a user option to change feeds and speeds in the middle of a toolpath, tool control so that the tool will back off at the end of a profile to avoid a dwell mark, and automatic estimation of the cycle time including tool changes. For grooving, SolidCAM supports a large number of tool shapes including special support for the advanced machining technologies of ISCAR’s Turn-Groove technology. The ISCAR Turn-Groove tool library is provided with the SolidCAM software.

Mill-turning is becoming an increasingly important machining function as most lathes now include a milling attachment. This capability to perform milling and turning on the same tool is particularly important in production machining operations, and it is also required in most general purpose machine shops. SolidCAM is one of the limited number of CAM software vendors to effectively support this type of machine tool with an integrated mill-turn product.

An integrated mill-turn capability is available as a separate module in SolidCAM. The turning and milling operations are programmed in the same environment. The output is brought together as a single program in the post-processor. Access to the complete SolidCAM 2.5- to 5-axis milling capability is available. The software selects the home position for the coordinate system. Machining operations are defined directly on a solid model. Milling and turning can be accomplished on the same spindle. There are three modes of operation in mill-turn. They are:

- Mill-Turn with XZC
- Mill-Turn with XYZC
- Mill-Turn with XYZCB

Figure 12—Simultaneous 5-Axis Machining of impeller

Figure 13—Turning with the ISCAR CUT-GRIP Tools
As in 3-axis milling, each programming operation can be captured and processes or templates can be established. These templates can then be saved for subsequent re-use.

Sub-spindles or back spindles can not currently be programmed within the same SolidCAM mill-turn environment. If they are to be employed, they must be programmed in a separate program and then combined in the post-processor and synced with other mill-turn operations.

Also, SolidCAM does not yet support programming of balanced or pinch turning on 4-axis lathes, such that two turrets operate simultaneously on a single spindle. This necessitates a high degree of program synchronization.

6. Toolpath Simulation and Machine Tool Control

Three levels of simulation are provided by SolidCAM. A basic toolpath simulation and a 2D simulation are available as internally developed software. In addition, SolidCAM has licensed MachineWorks for 3D simulation. It performs solid toolpath verification and simulation and is the primary simulation capability employed by SolidCAM users. MachineWorks has become recognized as the de facto industry standard product for toolpath verification. Many CAM software vendors have licensed MachineWorks and provide it as a component of their NC offering.

In MachineWorks, simulation occurs before posting and before the G-codes are computed in the post-processor. Some users expressed concern in that they are not able to view the code after posting and as it will be seen by the machine tool. Parts can be rotated during verification. The entire machine tool including fixtures and the part are simulated in 5-axis operations. In 2- and 3-axis operations the entire machine tool is not simulated.

SolidCAM has developed its own post-processor generator. This is somewhat unusual as most CAM vendors license a post-processor from a third-party vendor that specializes in that type of development. However, by developing their own product, SolidCAM maintains greater control over the process.

The SolidCAM post generator is language based; the language being similar to Basic. There is neither a Wizard nor graphics to aid the user when developing posts. From a large library of post-processors, the specific posts required by a customer are provided with the system. Post-processors can be and are often customized by a SolidCAM reseller. Additional posts can be generated by the SolidCAM reseller and there is usually a charge for this service. Only a few users create their own post-processor. When the G-code is created in the post, there is no need for further editing before it is sent directly to a machine.

Unlike most CAM systems, a CL-file is not directly generated in SolidCAM. It can be generated from a post-processor. Instead, SolidCAM employs its own internal code that is unique to SolidCAM. It is referred to as parameter code or P code. SolidCAM believes that their P code is more efficient than use of a CL-file. Sub-routines are built into the P code. If an operation is to take place at multiple levels the commands are only created once, as compared to being generated for each level. The SolidCAM program output is efficient. If the same operation is performed several times the commands are only recorded once in the output, thereby minimizing the program length. In other systems the commands are often repeated.
7. **Product Plans**

The near term product development plans of SolidCAM are as follows:

- Strengthen 3D milling capabilities that support mold machining
- Provide more automation for 2.5D milling capabilities
- Continue enhancements of the simultaneous 5-axis milling module
- Expand mill-turn by adding support for 2 spindles and 2 turrets
- Add full machine tool simulation for all operations
- Expand the knowledge-based machining capabilities