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CAD/CAM Interaction with High Speed Machinery

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Abstract:

Modern manufacturing enterprises are built from facilities spread around the globe, which contain equipment from hundreds of different manufa cturers. Immense volumes of product information must be transferred between the various facilities and machines. Most computer numerical control (CNC) machines are programmed in the ISO 6983. Programs are typically generated by computer aided manufacturing (CAM) systems that use computer aided design (CAD) information. The purpose of this paper is to integrate the CAD/CAM System towards High Speed Machining and discuss the challenges and its remedies. A methodology has been employed which provides all necessary information for machining products automatically. Use of these system results in reduced machining lead times and cost through designing machinable components, using available cutting tools, improving machining efficiency.

The system is menu driven with a user friendly interface. CAD/CAM integration is regarded as a solution for bridging the gap between design and manufacturing, one of the ultimate goals for concurrent engineering. Since the advent of CAD and CAM numerous attempts have been made to integrate these technologies, however, a full CAD/CAM integration is not yet achieved. This paper goes one step closer towards achieving a full CAD/CAM integration with High Speed Machining.

Keywords: **CAD/CAM, CIM, HighSpeed Machining, Integration design, Manufacturing, Machinability.**

1. INTRODUCTION

CAD/CAM (computer-aided design and computer-aided manufacturing) refers to computer software that is used to both design and manufacture products.CAD is the use of computer technology for design and design documentation. CAD/CAM applications are used to both design a product and program manufacturing processes, specifically, CNC machining. CAM software uses the models and assemblies created in CAD software to generate tool paths that drive the machines that turn the designs into physical parts. CAD/CAM software is most often used for machining of prototypes and finished parts.The current standard to program NC machine tools has had no significant change since the early 1950’s when the first NC (numerical control) machine was developed at M.I.T. (Massachusetts Institute of Technology), U.S.A. These early NC machines and today’s NC machines continue to use the same standard for programming namely G & M codes based on the ISO 6893 standard. Industrial world has witnessed significant improvements in product design and manufacturing since the advent of computer aided design (CAD) and computer aided manufacturing (CAM) technologies. Although CAD and CAM have been significantly developed over the last three decades, they have traditionally been treated as separate activities.

Many designers use CAD with little understanding of CAM. This sometimes results in design of non machin able components or use of expensive tools and difficult operations to machine non-crucial geometries. In many cases, design must be modified several times, resulting in increased machining lead times and cost. Therefore, great savings in machining times and costs can be achieved if designers can solve machining problems of the products at the design stage. This can only be achieved through the use of fully integrated CAD/CAM systems. In most of the systems developed, user still must determine crucial manufacturing parameters such as Cutting tools, cutting speeds, feed rates, cutting depths, etc., requiring expertise and considerable amount of time.

In addition, contributions made to integrate CAD and CAM systems for milling operation are very limited, while this operation forms a considerable amount of machining operations. This paper describes development of an integrated CAD/CAM system for High Speed Machining operations.

The History of CAD / CAM:

It was more than 2,300 years after Euclid that the first true CAD software, a very innovative system (although of course primitive compared to today's CAD software) called "Sketchpad" was developed by Ivan Sutherland as part of his PhD thesis at MIT in the early 1960s. Sketchpad was especially innovative CAD software because the designer interacted with the computer graphically by using a light pen to draw on the computer's monitor. It is a tribute to Ivan Sutherland's ingenuity that even in 2004, when operations which took hours on 1960s computer technology can be executed in less than a millionth of a second and touch-sensitive TFT combination display/input devices are readily available, there is no leading CAD software that has yet incorporated such directness into its user interface. Sketchpad was the world's first CAD software but the first commercial CAM software system, a numerical control programming tool named PRONTO, had already been developed in 1957 by Dr. Patrick J. Hanratty. For that reason it is Dr. Hanratty who is most often referred to as "the father of CAD CAM".

Due to the very high cost of early computers and to the unique mechanical engineering requirements of aircraft and automobiles, large aerospace and automotive companies were the earliest commercial users of CAD software. First-generation CAD software systems were typically 2D drafting applications developed by a manufacturer's internal IT group (often collaborating with university researchers) and primarily intended to automate repetitive drafting chores. Dr. Hanratty co-designed one such CAD system, named DAC (Design Automated by Computer) at General Motors Research Laboratories in the mid 1960s.

Proprietary CAD software programs were also developed by McDonnell-Douglas (CADD released in 1966), Ford (PDGS released in 1967), Lockheed (CADAM released in 1967) and many others.

2D Time: The first CAD systems served as mere replacements of drawing boards. The design engineer still worked in 2D to create technical drawing consisting from 2D wireframe primitives (line, arc, B spline ...). Productivity of design increased, but many argue that only marginally due to overhead – design engineers had to learn how to use computers and CAD. Nevertheless modifications and revisions were easier, and over time CAD software and hardware became cheaper and affordable for mid size companies. CAD programs grew in functionality and user friendliness. (1973)

3D Time: 3D wireframe features were developed in the beginning of the sixties, and in 1969 MAGI released Syntha Vision, the first commercially available solid modeler program. Solid modeling further enhanced the 3D capabilities of CAD systems. NURBS, mathematical representation of freeform surfaces, appeared in 1989 -- first on Silicon Graphics workstations. In 1993 CAS Berlin developed an interactive NURBS modeler for PCs, called NöRBS.

Parametric Design: In 1989 T-FLEX and later Pro/ENGINEER introduced CADs based on parametric engines. Parametric modeling means that the model is defined by parameters. A change of dimension values in one place also changes other dimensions to preserve relation of all elements in the design. MCAD systems introduced the concept of constraints that enable you to define relations between parts in assembly. Designers started to use a bottom-up approach when parts are created first and then assembled together. Modeling is more intuitive, precise and later analysis, especially kinematics easier.

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Present: CAD/CAE/CAM systems are now widely accepted and used throughout the industry. These systems moved from costly workstations based mainly on UNIX to off-the-shelf PCs. 3D modeling has become a norm, and it can be found even in applications for the wider public, like 3D buildings modeling in Google Maps, house furnishing (IMSI Floorplan), or garden planning. Advanced analysis methods like FEM (Finite Element Method as for structural analysis), flow simulations are an ubiquitous part of the design process. CAM systems are used for simulation and optimization of manufacturing, and NC code is created and loaded to NC machines.

Future: The past of CAD has been full of unmet expectations; this continues. Some anticipate 3D modeling without flat screens or mouse pointers -- a fully immersive 3D environment where modeling tools include special gloves and goggles. In the future, designing will be closer to sculpting than painting.

Up to now, 3D goggles cause nausea, immersive technologies are expensive and complex, and most designers prefer using a keyboard, stylus, and mouse.

While some of these optimistic predictions may come true, the more likely course is that the future changes will evolve in ways we do not see now. Still, some trends seem more likely to succeed and be widely adopted than others.

The following speculations are separated into strong probability of adoption, medium, and weak.

- CAD format standardization based on XML (strong)
- Full virtual prototypes (strong)
- CAD specialization (strong)
- Real time ray tracing (strong)
- Development of open source CAD (medium)
- Small scale and rapid manufacturing (medium)
- Dynamic Physical Rendering (weak)
- CAD based on genetic programming (weak)

2. BACKGROUND

2.1. **CAD/CAM:** CAD/CAM (computer-aided design and computer-aided manufacturing) refers to computer software that is used to both design and manufacture products.

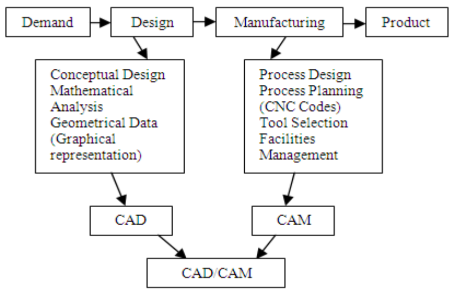

Figure.1 : Structure of CAD/CAM

In the past fifteen years the interactive computer graphics and CAD/CAM technology have been impacting the drafting, design, and manufacturing tools significantly. CAD/CAM has been utilized in different ways by different people. Some of the applications of this technology are:

- Production of drawings and design documents
- Visualization tool for generating shaded images and animated displays
- Engineering analysis of the geometric models (finite element analysis, kinematic analysis, etc.)
- Process planning and generation of NC part programs.

2.2. **CIM:** Computer-integrated manufacturing (CIM) is the manufacturing approach of using computers to control the entire production process. This integration allows individual processes to exchange information with each other and initiate actions.

2.3. **High Speed Machining:** High speed machining typically refers to making light milling passes at high spindle speed and feed rate to achieve a high metal removal rate. This practice can be effective for machining intricate core and cavity geometries in mold machining, and for quickly machining large, complex aircraft structural components out of solid blocks of aluminum.

2.4. **Integration design:** It is an approach to design which brings together design specialisms usually considered separately.

2.5. **Manufacturing:**The process of converting raw materials, components, or parts into finished goods that meet a customer's expectations or specifications. Manufacturing commonly employs a man-machine setup with division of labor in a large scale production.

2.6. **Machinability:**Characteristic of a material that make it easier to cut, drill, grind, shape, etc.

3. RELATED WORK

Literature Survey:

Computer-aided design (CAD) involves creating computer models defined by geometrical parameters. These models typically appear on a computer monitor as a three-dimensional representation of a part or a system of parts, which can be readily altered by changing relevant parameters. CAD systems enable designers to view objects under a wide variety of representations and to test these objects by simulating real-world conditions.

Computer-aided manufacturing (CAM) uses geometrical design data to control automated machinery. CAM systems are associated with computer numerical control (CNC) or direct numerical control (DNC) systems. These systems differ from older forms of numerical control (NC) in that geometrical data are encoded mechanically. Since both CAD and CAM use computer-based methods for encoding geometrical data, it is possible for the processes of design and manufacture to be highly integrated. Computer-aided design and manufacturing systems are commonly referred to as CAD/CAM.

Commercial mechanical CAD/CAM packages provide a rather low level of automation of process planning tasks and a weak connection between their CAD and CAM/NC part programming modules. Automated process planning involves two important tasks; machining feature extraction and feature-based process planning. The CAD model of the part and the stock is exported via STEP from the commercial CAD system to an external machining feature recognition system.The development of CAD and CAM and particularly the linkage between the two overcame traditional NC shortcomings in expense, ease of use, and speed by enabling the design and manufacture of a part to be undertaken using the same system of encoding geometrical data. This innovation greatly shortened the period between design and manufacture and greatly expanded the scope of production processes for which automated machinery could be economically used. Just as important, CAD/CAM gave the designer much more direct control over the production process, creating the possibility of completely integrated design and manufacturing processes.

The rapid growth in the use of CAD/CAM technologies after the early 1970s was made possible by the development of mass-produced silicon chips and the microprocessor, resulting in more readily affordable computers. As the price of computers continued to decline and their processing power improved, the use of CAD/CAM broadened from large firms using large-scale mass production techniques to firms of all sizes.

The scope of operations to which CAD/CAM was applied broadened as well. In addition to parts-shaping by traditional machine tool processes such as stamping, drilling, milling, and grinding, CAD/CAM has come to be used by firms involved in producing consumer electronics, electronic components, molded plastics, and a host of other products. Computers are also used to control a number of manufacturing processes (such as chemical processing) that are not strictly defined as CAM because the control data are not based on geometrical parameters.

- **Integration:** Seamless integration with Inventor 3D CAD software and Solid Works offers an intuitive user experience.
- **Performance:**Native multicore, 64-bit CAM engine makes easier work of the most demanding tool path calculations and post-processing jobs.

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- **Quality:** Efficient tool paths reduce cycle time, reduce machine and tool wear, and produce the highest-quality finished parts.

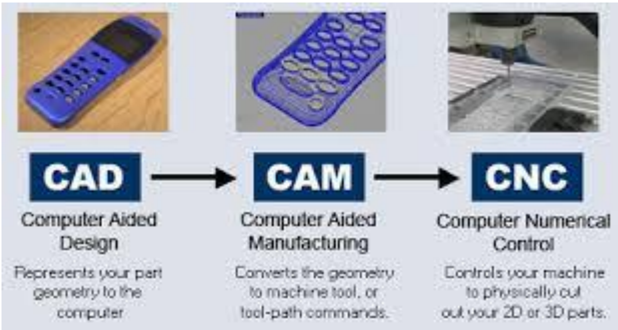

Figure.2: View of Different Systems

Integration of CAD/CAM System: There has been successful integration of CAD/CAM system.

Computer Aided Design (CAD): Used for creating solid models of the components to be designed, (Output is a Design.)

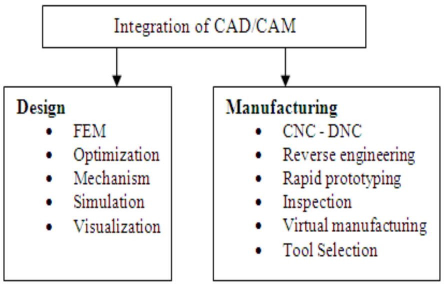

Figure.3: CAD/CAM Structure

Computer Aided Manufacturing: M stands for Manufa cturing; Manufacturing includes every step that is involved in creating the designed component, converting it from raw material into final form. (Output is a manufactured product).

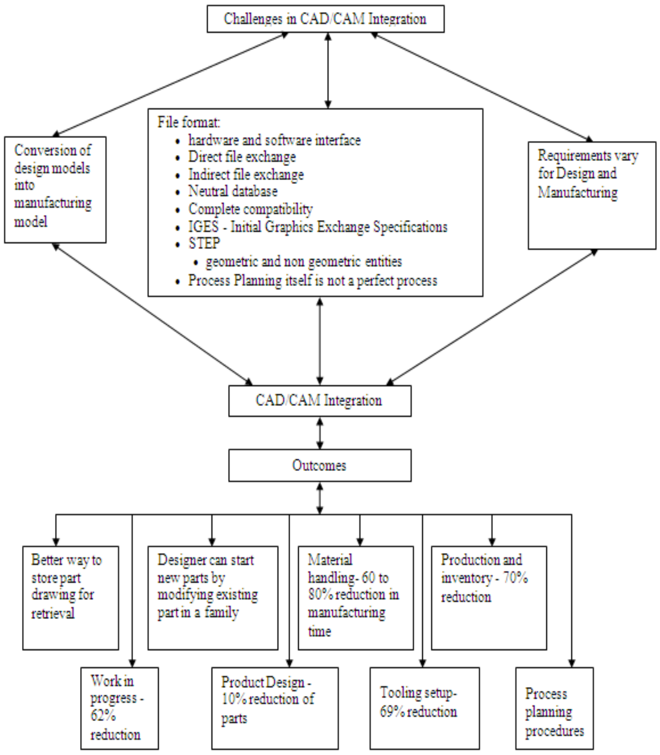

Figure.4: CAD/CAM Integration

4. REASEARCH WORK

Existing System:

PRODUCT DEVELOPMENT: The need to be right first time every time has changed the approach to design. The initial phase of design consists of conceptual design, design analysis and performance simulation. The phase is highly iterative as shown in fig. 1. The techniques like concurrent engineering, failure mode and effect analysis etc., are used to ensure a reliable and quality design at this stage. This is followed by detailed design, tool design, prototype manufacture and evaluation and documentation.

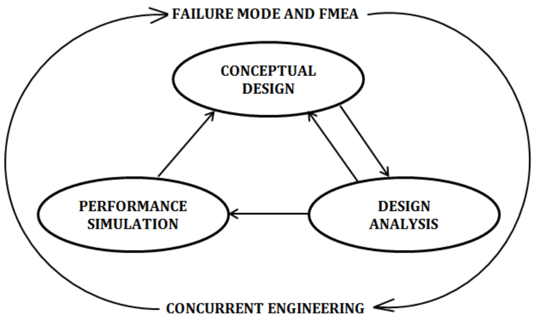

Figure.5: Product Development Life cycle Stages

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The next phase of product development involved second phase of engineering where the design may be further refined. Here focus is on manufacturing planning, data management, supply chain management and manufacture.

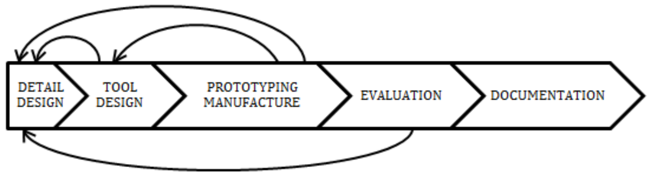

Figure: Prototyping stage of Product Development

The time compression in product development has also necessitated:

- Avoidance of design errors, rework of components and tooling,
- Better data management,
- Improved supply chain management,
- Attaining higher and higher levels of performance,
- Providing quality levels superior to what is offered by competitors,
- Above all supplying the product at the lowest possible cost.

Figure.6: Process of CAD/CAM system

PRODUCT DEVELOPMENT AND MANUFACTURE STAGES: CAD/CAM as an enabling technology for product development and manufacture Developments in computers and software relating to CAD/CAM has made CAD/CAM an indispensable enabling technology for time compression in product development. This is made possible by an integrated approach to carry out different activities in product development through seamless data transfer. (Fig. 3) CAD/CAM technologies help to simulate and the manufacturing methodologies in the following ways:

- **Assemble Analysis** With the help of today's CAD/CAM technology, design team can work in a top down and bottom up manner to create a complete electronic product mock up. Once an assembly is completed, solids based kinematic analysis can be used to simulate complex motions of mechanisms as well to carry out tolerance analysis.
- **CAD/CAM System using Better Tool Design and Optimize Manufacturing Processes:** Manufacturing simulation uses a set of powerful CAD/Cam tools which seek to create virtual manufacturing environment. Many uncertainties which may result in time delay, rework or production of defective parts can be eliminated through simulation or manufacturing, whether it is CNC machining, plastic injection moulding, casting, forging or welding.

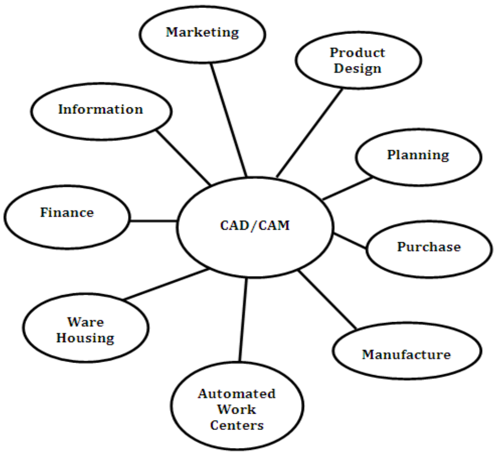

Figure.7: CAD/CAM Database System

Characteristics of Manufacturing: There are many characteristics of agile manufacturing such as show in following:

- Rapid new product development
- Short lead times, cycle times
- Use of superior CAD/CAM
- Modular design and technology
- highly flexible machines and equipment
- Short and fast order processing
- Fast supplier deliveries

- Very Short time to market
- Short guide times and short cycle times
- Highly flexible and responsive processes
- Modular assembly
- Use of Solids model

Advantages of HSM:

- ✓ In HSM applications, cuts are shallow and the engagement time for the cutting edge is extremely short. The feed is said to be faster than the time for heat propagation.
- ✓ Low cutting force gives a small and consistent tool deflection. This, in combination with a constant stock for each operation and tool, is one of the prerequisites for a highly productive and safe process.
- ✓ As the depths of cut are typically shallow in HSM, the radial forces on the tool and spindle are low. This saves spindle bearings, guide-ways and ball screws. HSM and axial milling is also a good combination, as the impact on the spindle bearings is small and it allows longer tools with less risk for vibrations.
- ✓ HSM allows for a productive cutting process in small sized components. Roughing, semi-finishing and finishing is economical to perform when the total material removal is relatively low.
- ✓ HSM also achieves productivity in general finishing and it is possible to achieve extremely good surface finishes, often as low as Ra ~ 0.2 microns.
- ✓ The machining of very thin walls is also possible. Down milling tool paths should be used, and the contact time between edge and work piece must be extremely short to avoid vibrations and deflection of the wall. The micro geometry of the cutter must be very positive and the edges very sharp.
- ✓ Geometrical accuracy of dies and moulds provides easier and quicker assembly. Human skill levels cannot compete with a CAM/CNC-produced surface texture and geometry. Additionally, increased time and focus on the machining phase can reduce time-consuming manual polishing work as much as 60-100%.
- ✓ Production processes as hardening, electrode milling and EDM can also be minimised, lowering investment costs and simplifying the logistics. Fewer EDM equipment also means the requirement of less floor space. HSM also gives dimensional tolerance of 0.02mm, while the tolerance with EDM is 0.1-0.2mm.
- ✓ The Durability, and tool life of the hardened die or mould can sometimes be increased when EDM is replaced with machining.
- ✓ EDM, if incorrectly performed, can generate a thin, re-hardened layer directly under the melted top layer. The re-hardened layer can be up to ~20 microns thick and have a hardness of up to 1000Hv. As this layer is considerably harder than the matrix it must be removed, requiring a time-consuming and difficult polishing process.
- ✓ EDM can also induce vertical fatigue cracks in the melted and resolidified top layer. These cracks can, during unfavourable conditions, lead to a total breakage of a tool section.With HSM, design changes can be made quickly using CAD/CAM, particularly in cases where there is no need for new electrodes.

Disadvantages of HSM:

- ✖ Higher acceleration and deceleration rates, and spindle start and stop result in faster wear of guide ways, ball screws and spindle bearings, leading to higher maintenance costs.
- ✖ HSM also requires specific process knowledge, programming equipment and interfaces for fast data transfer needed. Consequently, find suitably trained staff can be difficult.
- ✖ HSM can involve a considerable "trial and error" period. Good work and process planning is necessary, along with significant safety precautions and safety enclosing (bullet proof covers).
- ✖ Tools, adapters and screws need to be checked regularly for fatigue cracks. Only tools with posted maximum spindle speed can be used.

Proposed System :

The main objective of this work is to propose a new methodology of challenging remedies and challenges of High Speed Machining cycle is effective work done using various process.

Machining process: Most machining progresses through many stages, each of which is implemented by a variety of basic and sophisticated strategies, depending on the material and the software available.

Roughing: This process begins with raw stock, known as billet, and cuts it very roughly to shape of the final model. In milling, the result often gives the appearance of terraces, because the strategy has taken advantage of the ability to cut the model horizontally. Common strategies are zig-zag clearing, offset clearing, and plunge roughing, rest-roughing.

Semi-f: This process begins with a roughed part that unevenly approximates the model and cuts to within a fixed offset distance from the model. The semi-finishing pass must leave a small amount of material so the tool can cut accurately while finishing, but not so little that the tool and material deflect instead of sending. Common strategies are raster passes, waterline passes, constant step-over passes, pencil milling.

Finishing: Finishing involves a slow pass across the material in very fine steps to produce the finished part. In finishing, the step between one pass and another is minimal. Feed rates are low and spindle speeds are raised to produce an accurate surface.

Contour milling: In milling applications on hardware with five or more axes, a separate finishing process called contouring can be performed. Instead of stepping down in fine-grained increments to approximate a surface, the work piece is rotated to make the cutting surfaces of the tool tangent to the ideal part features. This produces an excellent surface finish with high dimensional accuracy.

The system restores technological data determined by different components in the manufacturing data file (MDF) for use by the manufacturing module. MDF provides all necessary data for each step of machining operations that are required for NC program generation. An IGES file generated by the CAD system provides the geometric data. It is noteworthy that IGES is the most common method for data exchange in current CAD systems. Using these data, the manufacturing module generates required tool paths for each step of machining operation and determines all cutter locations. User can either accept generated tool paths or modify them. Upon confirmation of generated tool paths, the required NC program is generated using an existing postprocessor. The NC machine to produce the product can then use the generated program.

Accuracy: A major benefit of HSM is the ability to machine parts accurately, with minimal thermal distortion and good surface finish. It's surprising to see how often the tolerances used to create the part model are coarser than the final machining tolerances. A potential source of accuracy problems is data exchange. Parts are frequently designed in one CAD system and then transferred to different systems for additional design work and for machining.

Each data transfer requires geometry to be converted from one format to another, and some of these conversions involve approximation to some finite tolerance. The effects of these tolerances are cumulative, so it is essential to make sure that they are set to be significantly (at least ten times) smaller than the finish machining tolerance.

Trimming: Most parts are represented in CAD systems by a patchwork of ―trimmed‖ surfaces – similar to the way clothes are assembled from several complex-shaped pieces of material. The accuracy with which these surfaces meet at their edges can have a critical effect on the quality of toolpaths. **Fig. 4** shows in exaggerated form what may happen when a cone is capped with a trimmed plane.

The cone is exactly circular, but the planar cap is a polygon that may overlap the top of the cone in some positions. If these overlaps are significant they may result in unexpected spikes in the toolpaths and visible marks on the finished part.

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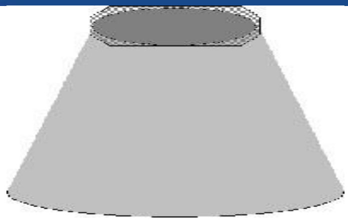

Figure.8: Trimming Errors

The bellow Figure shows a more complex model with badly trimmed surfaces where a number of surfaces meet. This kind of problem is most often the result of using an unsuitable modeling tolerance, but trimming problems can sometimes be introduced by data exchange errors.

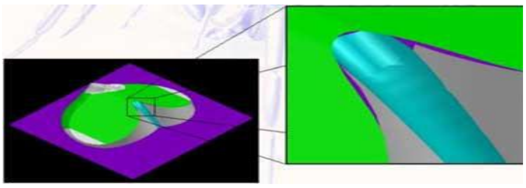

Figure.9: Poorly Trimmed Modal

Incomplete Models: Many CAD/CAM operators have developed shortcuts to keep modeling time to a minimum. An often used shortcut is to omit fillets from internal corners on the basis that they will be formed directly by a milling cutter of a suitable radius. This approach requires that the tool be driven right into the sharp corner. This temporarily increases the load on the tool by a factor of about 8, 9 compared with straight line cutting conditions.

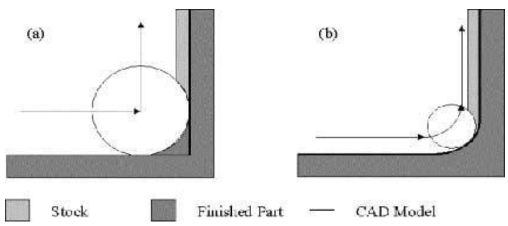

Figure.10: Cutting Internal Files

Some CAD/CAM systems provide functions to cure this problem, but it is much better to prevent it in the first place by ensuring that the CAD model accurately represents the shape to be machined. It is best to form internal fillets using a cutter of smaller radius, so that the toolpath can flow smoothly round the corner rather than turning sharply. A tool radius of 70% or less of the fillet radius is suitable, and reduces the cutter load by a factor of about 3 compared with the sharp corner.

Un-machinable Features: Although HSM increases the range of features that can be milled directly, complex parts often include details that must be produced by EDM. The majority of parts also have holes that will simply be drilled. If the CAD model includes these features, most CAM systems will attempt to machine them. Typically the result is unwanted areas of toolpath where the tool dives into holes or runs into sharp corners.

CAM operators can waste a significant amount of time avoiding and correcting these effects. If possible, features that are not to be milled should be excluded from the CAD model used for generating toolpaths. Depending on the type of CAD system being used, this may be done my suppressing features or by covering them with additional surfaces.

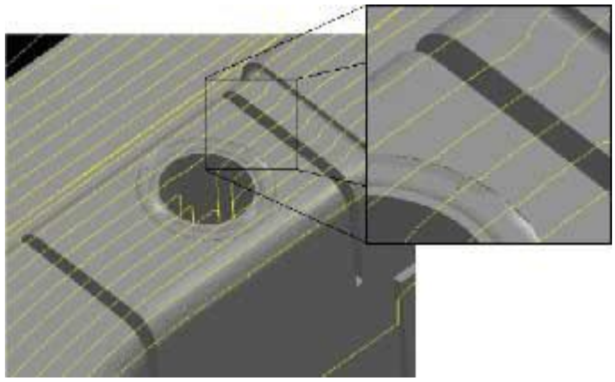

Figure.11: Un-machinable Features

CAD/CAM for HSM: Despite years of research, nobody seems to have come up with a concise, accepted definition of HSM or a simple explanation of how it really works. The basic idea is that by taking light cuts at high speed, material can be removed faster than by taking heavy cuts at lower speed. Lighter cuts mean reduced cutting forces, so distortion and vibration effects are reduced. High cutting speeds enable very hard materials to be cut with suitable tooling.

High cutting speeds also result in most of the energy of the process being dissipated as heat in the chips,

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reducing thermal distortion of the part. None of these benefits will be seen of the machining strategy is inappropriate. Poor strategies usually cause unacceptably short tool life or catastrophic failure. A critical fact to remember is that HSM does not simply mean running existing toolpaths with increased spindle speed and feed rate.

HSM Toolpaths: A toolpath for High Speed Machining has to satisfy a number of constraints. Most of these are obvious when they are written down.

- The tool must not gouge the part
- The cutting load must be within the capabilities of the tool
- The toolpath should leave cusps no larger than the specified limit
- Abrupt changes in the rate of material removal should be avoided
- Speeds and accelerations must be within the capabilities of the machine
- The cut direction (climb/conventional) should be maintained
- Sharp changes of direction should be avoided
- Non-cutting moves should be minimized
- Toolpath execution time should be minimized

However, given a particular part it is often far from obvious how to generate a toolpath that satisfies them all. In fact, it is usually impossible to meet all of these constraints when finish machining real, complex-shaped parts. In this situation we must do the best we can, but where necessary relax one or more of the constraints. Some are clearly more critical than others, and I've listed them above in approximate priority order.

Finish machining poses a particular problem for HSM because the shape of the part is a constraint that cannot be relaxed, and compromises in cutting conditions frequently show up as visible marks on the finished surface. Of course these can be polished out, but that undermines the case for using HSM in the first place. Roughing and semi-finishing can be easier to optimize, because the CAD/CAM operator has some choice of the shape of the part after the operation, and any marks will be removed by finishing operations

Programming Capacity: Good HSM programs execute very quickly on the machine tool, but they can take a lot of time and effort to produce. In industries like mould and die making, where parts are produced in one-off quantities, it is common for machines to be held up waiting for programs. Clearly this is not an ideal strategy. To get the best out of HSM it is essential to provide adequate CAD/CAM capacity to keep machines fully loaded with high-quality programs.

- Choose CAD/CAM software that provides automatic HSM features. This will reduce the amount of effort operators must put into optimizing their programs.
- Choose CAD/CAM software that calculates gouge-free tool paths quickly. Batch calculation features allow complex programs to be computed overnight.
- Use high-performance computers and keep them up to date. Ensure enough memory is installed to obtain maximum performance.
- Ensure you have enough CAD/CAM operators to keep up with the machines. Training and equipping machine operators to generate programs on the shop floor is one way to get the most out of on existing skills.
- Ensure operators are adequately trained to produce HSM programs.

Few examples of CAD/CAM Software's are using Implementing and Design layout in different module. Those are

- DDS-CAD Architect & Construction
- SAM
- RFEM
- Delta Design
- e-NC and esCAD Kaizen Master
- TARGET 3001
- TurboCAD Deluxe 2D/3D
- DesignCAD 3D Max
- CADWorx E&I
- Modaris

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- NCL
- DataWorks
- Electra, NX I-deas,
- GeoPath, ZWCAD, SoftPlan, WireCAD,

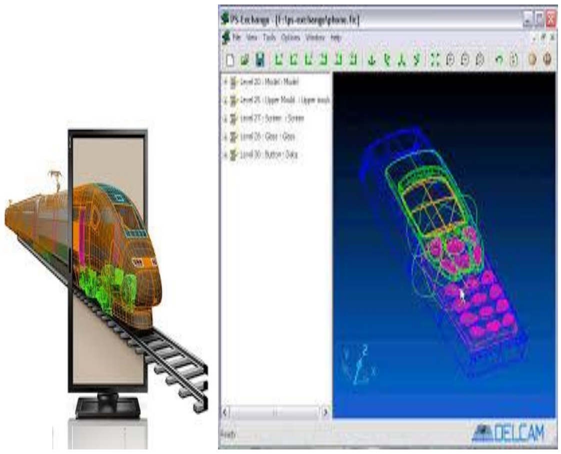

Figure.12: Software Design View

CONCLUSION

In this work, we have identified a challenge during the HSM places exacting requirements on all elements of the process. It is essential to use the right physical equipment, and this can be specified quite accurately. It is much harder to specify in concrete terms what is required from the CAD and

CAM functions; nevertheless these have a significant influence on the quality and stability of the HSM process.

It is essential that CAD/CAM models for HSM be prepared to represent accurately the shape that will be milled. This means both that the accuracy of the model must exceed machining tolerances, and also that features that are not to be milled should be excluded from the model if possible.

The investment in HSM equipment must be supported by sufficient programming capacity in order to keep the machines loaded with high quality programs. Enabling machinists to do some of the programming on the shop floor may be an effective way to boost programming capacity. Ensure CAD/CAM operators and machinists are properly trained and understand HSM thoroughly. Careful planning of the machining sequence is critical. Making appropriate use of the strategies provided by the CAD/CAM system is the best way to get successful results.

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