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SolidCAM iMachining (2D): A Simulation Study of a Spur Gear Machining and G-code Generation for CNC Machine

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Abstract: SolidCAM is a popular add-in of SolidWorks. SolidCAM is the manufacturing suite for easiest, fastest, most efficient CNC (computer numerical control) simulation and programming facility that can be done directly inside SolidWorks. It provides a seamless single window integration and full associativity with the SolidWorks model. SolidCAM iMachining is a real breakthrough in CNC milling tool path technology. The iMachining technology uses intelligent, patented algorithms for specific operations to optimize the tool path, reduce machining time, tool wear, etc. A great variety of machining operations on different stock objects for producing various products can be easily defined by using this suite which results in increased flexibility. The simulation process makes it possible to observe the operations in real time conditions and makes the G-code flawless for physical operation. In this paper, SolidCAM iMachining is studied and the detailed procedures of the machining process of a spur gear from stock material are described step by step by using SolidCAM 2014 2D iMachining technology. After the steps are defined, the whole process is simulated in various modes. Finally, the G-codes are automatically generated for the practical use in CNC machine. SolidCAM helps understand the concept, operation and importance of using CAM software in modern day manufacturing industries. Moreover, by using SolidCAM the steps of operation, parameter details can be set in a way to save time, cost, tool lives, etc.

Keywords: CAM (computer-aided manufacturing), SolidCAM iMachining, CNC (computer numerical control), simulation, G-code.

1. Introduction

CAM (computer-aided manufacturing) is the computerized process of manufacturing. This is currently applied by most of the heavy and medium industries in developed and some developing countries. CAM can be defined as the use of computer systems or software to plan, manage, and control the operations of a manufacturing plant through either direct or indirect computer interface with the plant's production resources [1]. An important action of CAM includes controlling the CNC (computer numerical control) machines for the desired production.

CNC can be defined as a form of programmable automation in which the process is controlled by numbers, letters and symbols. In CNC, the numbers, symbols form an instruction based program designed for a particular work or job [2]. These instructions are called G-code. Computer numerical control works as the automated system that transforms the codes into machine language and gives the machine the ability to perform the task.

At present, most of the renowned industries are using CNC machines and CAM process to produce small, medium to large complex, intricate shapes. The process of CAM can be done either by writing G-code in the software for the control of particular operations in CNC or by using CAM software to design the output product with stock material and define the machining steps and then generate G-code automatically. Writing the G-code is very much difficult as it requires very deep machine knowledge and time to learn. Written codes may have faults which without performing the operations is very difficult to find. Trial and error method is needed to identify the problems and make a successful product. Prototypes are built in this purpose. Modern CAM software is very much user friendly. By using a CAM suite the previous problems can be easily solved as it eliminates the necessity of learning G-code. It also simulates the operation in real like conditions which helps the users to find any kind of problems and eliminate those. As a result, trial and error method, prototypes are not needed.

There are many CAM suites available in the market to fulfill the purposes. SolidCAM is in a leading position in this field. It provides intelligent machining options, optimum tool path, multi-axis machining, simulation, G-code facilities and many more. An attempt is made to study about SolidCAM iMachining software and to define the steps to machine a spur gear along with G-code generation as an example.

2. Literature Review

Sethi, et al. [3] elaborately discussed the various kinds of flexibility in manufacturing with the purposes, means and measurements in details. The primary flexibility considerations included machine, material handling and operation. The secondary considerations were product, process, volume and program flexibility. The use of CAM and CNC machines can improve all the above flexibilities greatly.

Boogert, et al. [4] developed a module to automatically calculate tool paths and cutting conditions for metal cutting operations in which the necessary algorithms had been designed to generate reliable numerically controlled programs. The developed module is an example of CAM based CNC simulation system.

Barbosa, et al. [5] used CNC parametric programming to get higher flexibility of the manufacturing process by simulating the operation in Siemens NX7^R. The ball-end milling process was simulated and verified in a virtual model of the machine tool created in Siemens NX7^R. After that, the real process was carried out on the shop floor to machine the test surface. The output showed that the virtual machine tools are an effective resource to simulate and verify the performance of machining processes controlled by CNC programs. The process of accurately simulating the CNC program reduces the risk of its implementation.

Ficko, et al. [6] researched about the automatic programming of CNC machine tools. They explored the various ways of programming in CNC machines and made differences among those. The necessity and benefits of automated programming for producing the complex shapes was elaborately discussed. The roles of CAM and CNC programmers were made clear to make the best use.

Uzun [7] manufactured a concave-convex spur gear in vertical-spindle CNC milling machine and compared the resulting values against conventional manufacturing values to differentiate between the two methods. The output products expressed that the use of CNC machines significantly improve the quality.

At first, the researchers explored how to improve the flexibility of manufacturing. After that, algorithms were used to generate NC programs to calculate tool paths and cutting conditions. Later, some attempts were made to simulate the process before actual operation was done in CAM software to ensure higher flexibility. The importance of automatic programming in CAM was established by then. It was found that use of CAM suites can drastically increase the product quality which was absent before. Though all the previous works tried to explore the various dimensions of how the CAM process can be improved those are yet to use the intelligent machining systems like SolidCAM iMachining. It integrates the various factors and conditions of CNC machines and tools together and finds the optimum selection of processes, tools, tool paths and reduces total cost, machining time, increases tool life and output quality. The main scope of this study is to know about SolidCAM iMachining in detail and perform a simulation using iMachining 2D.

3. SolidCAM iMachining^{TM}: The Leaders in Integrated CAM

SolidCAM iMachining is the de-facto standard Gold-Certified integrated CAM-Engine for SolidWorks. It provides seamless, single-window integration and full associativity to the SolidWorks design model. All machining operations are defined, calculated and verified, without leaving the SolidWorks window.

This is widely used in the mechanical manufacturing, electronics, medical, consumer products, machine design, automotive and aerospace industries, as well as in mold die and rapid prototyping shops. SolidCAM supports the complete range of major manufacturing applications in Milling, Turning, Mill-Turn and Wire cut EDM (electro discharge machining) [8]. And with its powerful iMachining technology, SolidCAM is revolutionizing the CAM industry. The successful manufacturing companies of today (Yamaha, Honda, Aircraft Phillip, Intel, HP, etc.) are using integrated CAD/CAM systems to get their products to market faster and reduce costs [9].

iMachining uses advanced, patented algorithms to generate smooth tangent tool paths, coupled with matching conditions, that together keep the mechanical and thermal load on the tool constant, whilst cutting thin chips at high cutting speeds and deeper than standard cuts (up to 4 times diameter). The patented iMachining is completely unique in its tool path that increases the cutting speed and devours hard material, even with the smallest cutting tools, and also increases tool life dramatically. The exclusive iMachining technology wizard provides automatic, optimal feed and speed values for different materials and CNC machines to ensure "first-cut" success [10].

4. SolidCAM 2D iMachining Methodology

For the purpose of study and simulation, SolidCAM 2014 trial version is used. This section describes the steps required to virtually machine a spur gear previously designed in SolidWorks 2014 in details with the help of figures and necessary directions. The radius of the stock material is 50 mm and height is 38 mm. The general procedure of 2D iMachining is demonstrated in Fig. 1.

4.1 Setting SolidCAM and Entering Preliminary Milling Data

After opening SolidWorks, SolidCAM settings are accessed from SolidCAM tab, kept the unit in metric, made gMilling_Haas_SS_3x the default milling CNC-controller, selected the CAM-part as external, all boxes are unchecked from automatic CAM-Part definition submenu and the settings are applied. Open SolidCAM tab->New->Milling->Ok. A new window has appeared at the left side of the screen where the CNC-machine, coordinate system, stock and target model dialog boxes are shown. CNC-machine is set to the default one. In order to set the coordinate system define is clicked, then the top face of the stock model is

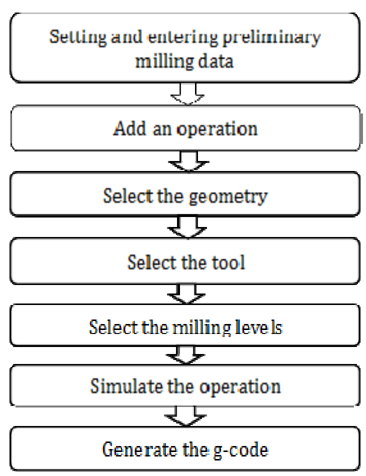

Fig. 1 The overall steps involved for defining 2D iMachining milling operations.

clicked and applied. After that stock and target model should be defined. By clicking on the stock button and selecting 3D model from "defined by" option, the stock model is selected by marking the 3D stock material from which the final product could be machined. Then in order to select the target model target button is clicked and the final shape of the product is selected. If we notice at the bottom of the milling data manager, iMachining data needs to be entered. In machine database Haas_SS, in material database Aluminium_100BHN_60HRB, machining level 3 are selected and the window is closed properly by clicking the right icon. In this way the CAM-Part is completely defined [11]. The above mentioned steps are shown in Figs. 2-6, consecutively.

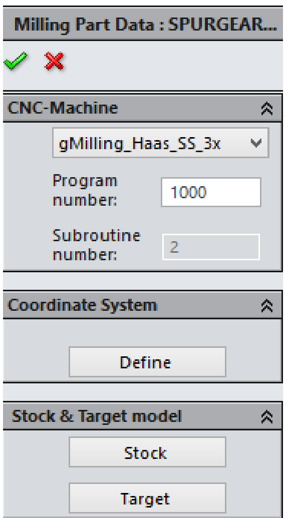

Fig. 2 Top half of the milling data manager.

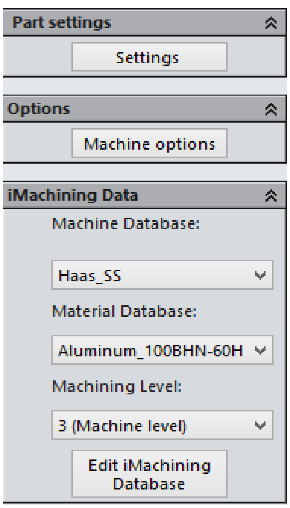

Fig. 3 Bottom half of the milling data manager.

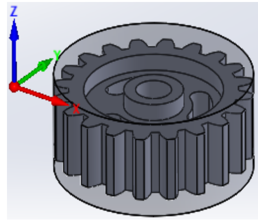

Fig. 4 Coordinate system selection.

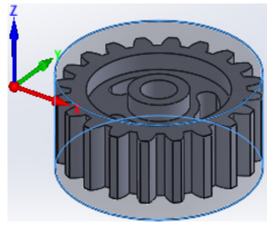

Fig. 5 Stock model selection.

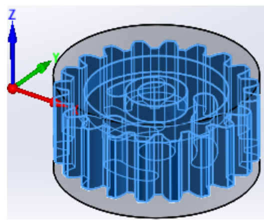

Fig. 6 Target model selection.

4.2 Defining the Operations

From SolidCAM manager on the left side of the window, right click operations->Add milling operation->2D iMachining. A new window named iMachining operation appeared. After selecting the iRough option from technology box from the top of the window, first the geometry then the tool are selected. After that the level of cutting should be selected. In the upper level option the upper face of the stock is selected and in the pocket depth the depth to which the cutting should take place. The other options will remain unchanged. When these are done, the work is saved by clicking save and calculate which is located at the bottom of the window and click simulate [12]. The procedures of geometry, tool and level selection are illustrated in Fig. 7-12.

4.3 Simulating the Operations and Applying iFinish Technology

After clicking simulate new window appeared that is called simulation. In this window, there are various

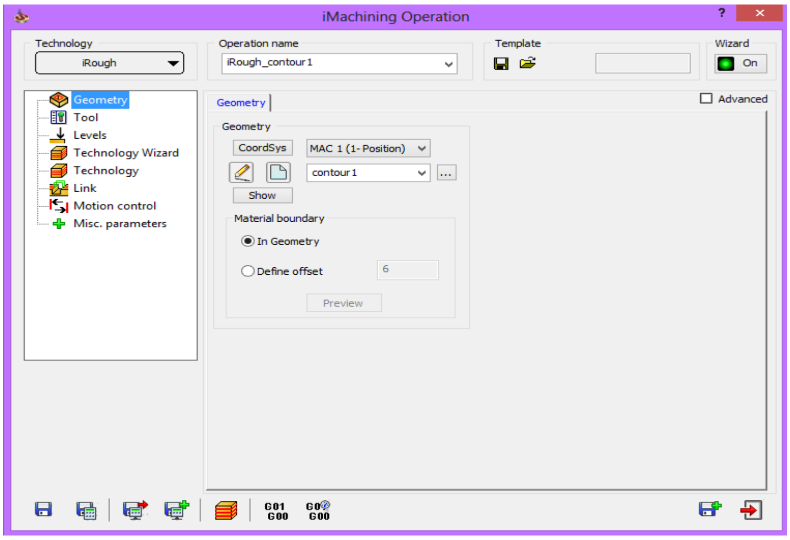

Fig. 7 Geometry selection of 2D iMachining window.

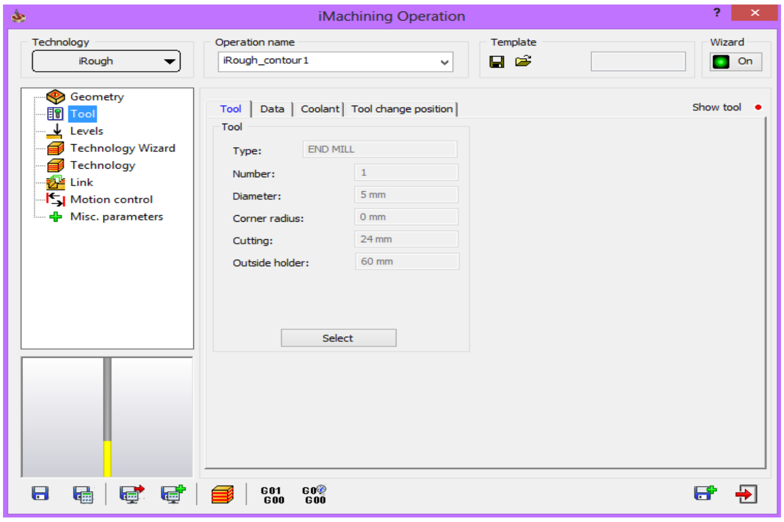

Fig. 8 Tool selection window.

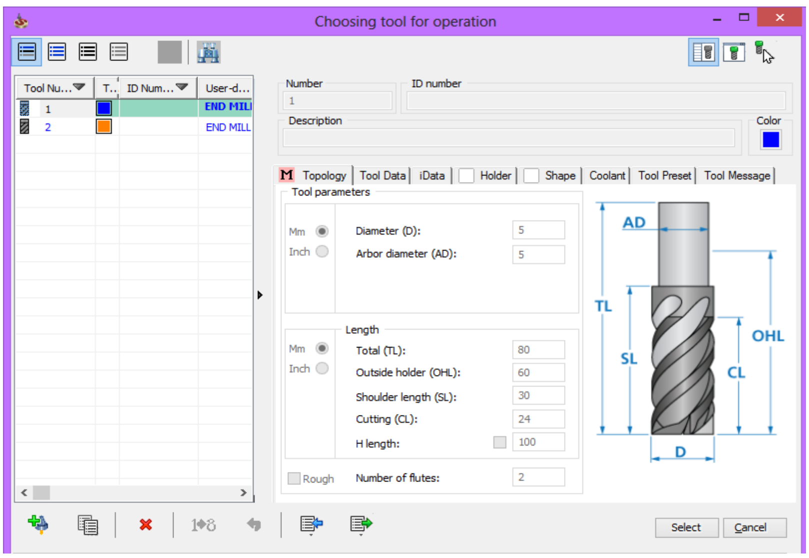

Fig. 9 Selecting tool from the tool database and setting the parameters of the tool architecture.

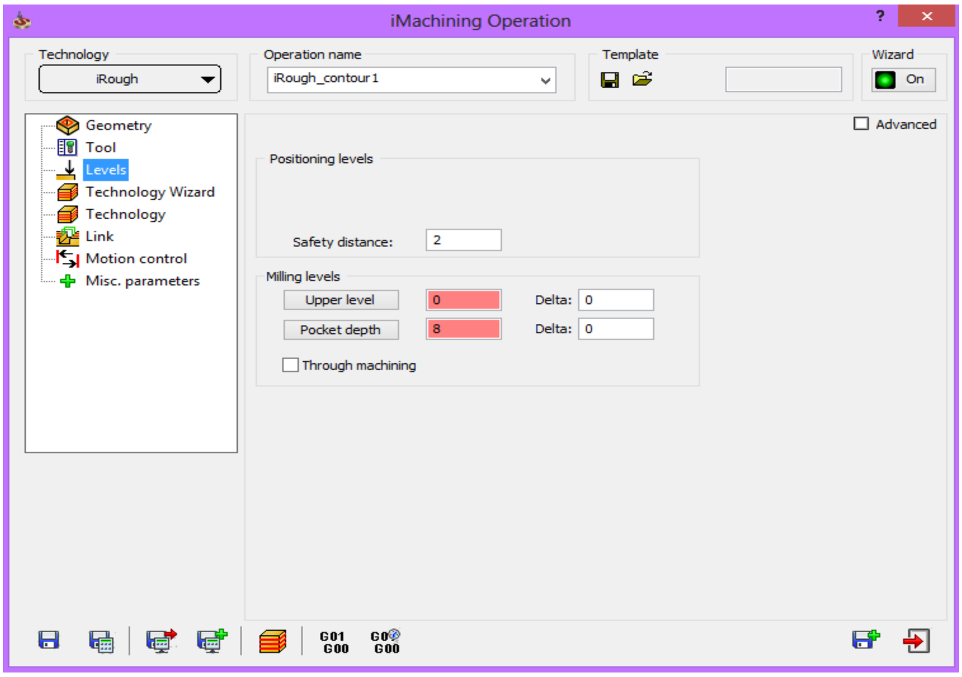

Fig. 10 Milling level selection.

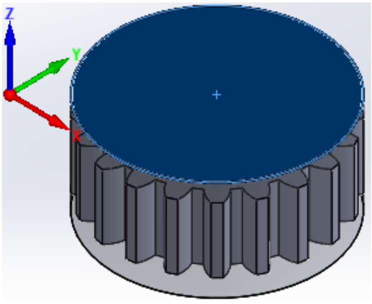

Fig. 11 Selection of upper level.

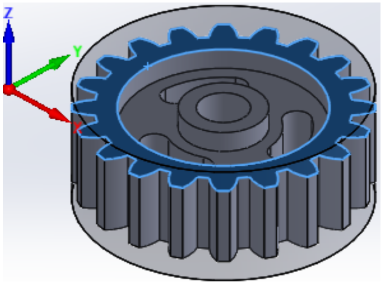

Fig. 12 Selection of pocket depth.

modes of simulation such as Host CAD, SolidVerify, SolidVerify for 3D, Machine Simulation, etc. There is a slider in the window that controls the simulation speed. It can be adjusted as per requirements'. There are options such as "show tool path", "show trail", "show tool 3D", "show stock", etc., which makes it very much interesting to find the simulation close to reality. Single step mode and operation step mode facilitates to notice the machining by single step or single operation. Different modes of simulation are very useful to notice how the work will be carried out in practical. At the end of the simulation, the window is closed and, saved and copied from the bottom of the iMachining window and iFinish from the technology tab is selected. Again save and calculate and simulate to apply a finishing operation [11]. The simulation window, SolidVerify for 3D mode, machine simulation mode and machine statistics are demonstrated in Figs. 13-16.

4.4 Generating the G-code

At the end, remaining work is the generation of G-code which will be later used in the CNC machine. To do this, generate G-code icon from the bottom of the iMachining window of the specific operation is clicked and the CAM engine will do the work [11]. Saving the code is necessary for the future use. As the codes are very lengthy, a lot of space is required for the full code. So instead of iRough operation, the full G-code for the iFinish operation is given in Table 1.

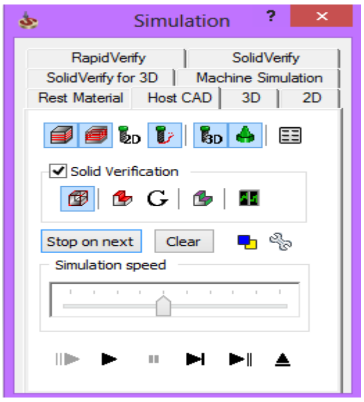

Fig. 13 Simulation window.

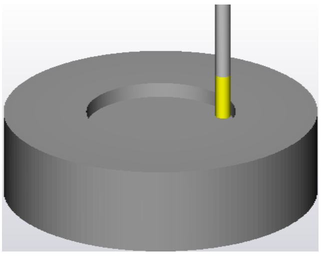

Fig. 14 Solid Verify for 3D simulation mode.

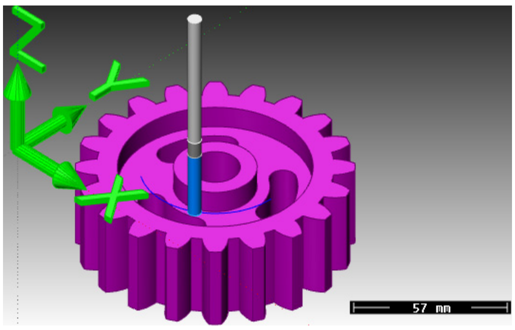

Fig. 15 Machine simulation mode.

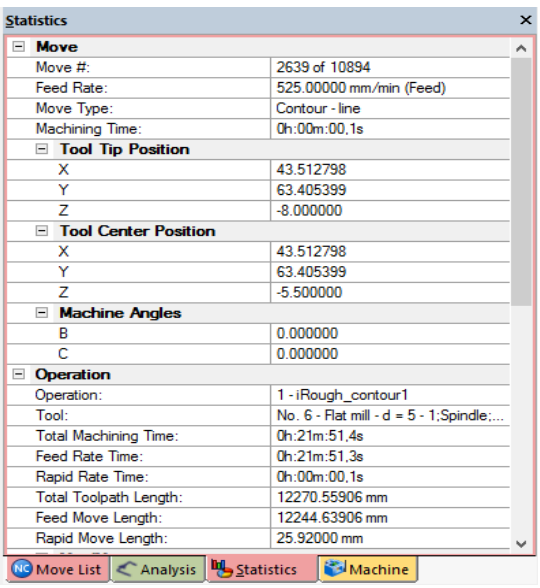

Fig. 16 Machine statistics for a single operation.

Table 1 G-code for iFinish operation.

```
%
01000 (SPURGEAR121)
N100 (COMPENSATION-WEAR)
N102 (REV-0.70)
N104 (SEP-20-2015-3:26:53PM)
N106 (TOOL 1-DIA 5)
N1 G90 G17 G40 G80 G00
N108 M06 T1 ()
N110 (iFinish-counter1)
NN112 S9921 M03
N114 G00 G54 G90 X97.0454 Y49.3901
N116 G43 H1 Z50
N118 S8818
N120 Z10
N122 Z2
N124 G01 Z-7.92 F3801
N126 X97.1882 Y49.2473 F1124
N128 G03 X97.5 Y50. Z-8. I-0.7527 J0.7527
N130 X97.5 Y50. I-47.5 J0
N134 X97.1782 Y51.2305 Z-7.92 I-1.0645 J-0.0108
N136 G01 X97.0368 Y51.0863
N138 G00 Z10
N140 G00 G28 G91 X-15.0 Y0
N144 G90
N146 M06 T1
N148 M30
%
```

4.5 Other Required Operations to Complete the Spur Gear in Brief

After completing the first iRough and iFinish operations two more iRough and iFinish operations are required for the necessary geometry and level to produce the required shape. In order to cut the gear teeth, profile operation is applied. At the end of simulation, the codes are generated for practical use. First two iRough and iFinish operations are applied for the second time after flipping the work piece to cut the rest of the material from the bottom of the stock to complete the spur gear [12]. The main steps of each of the remaining iRough operations are illustrated in Figs. 17-28.

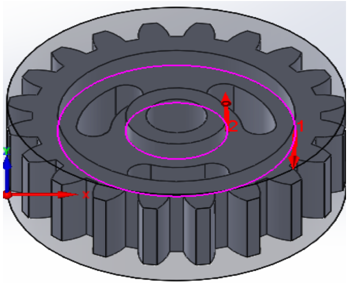

Fig. 17 iRough_contour2 geometry.

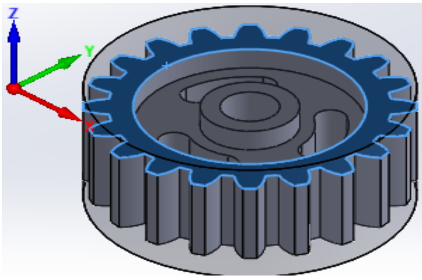

Fig. 18 iRough_contour2 upper level.

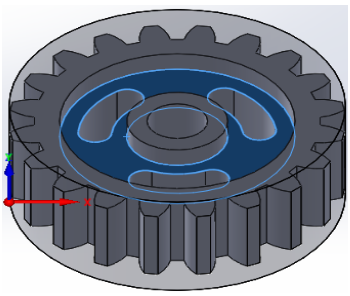

Fig. 19 iRough_contour2 pocket depth.

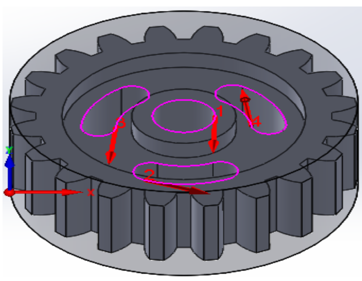

Fig. 20 iRough_contour3 geometry.

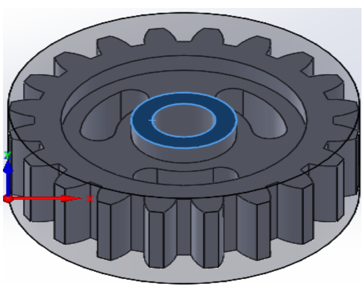

Fig. 21 iRough_contour3 upper level.

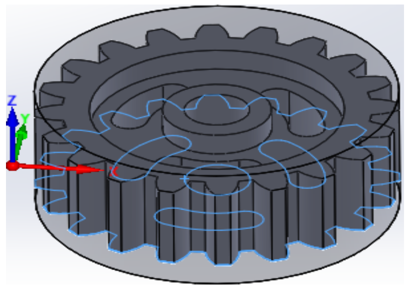

Fig. 22 iRough_contour3 pocket depth.

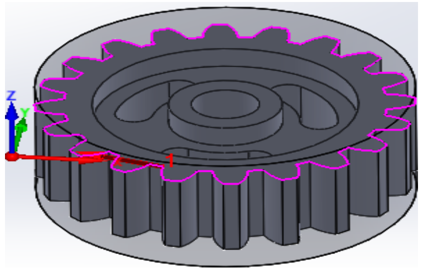

Fig. 23 Profile operation geometry.

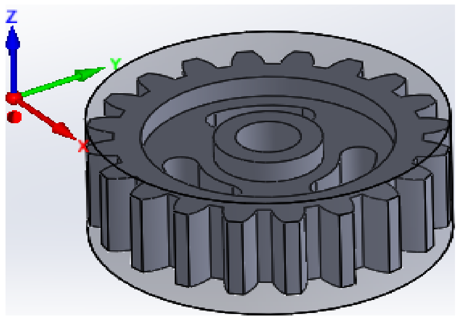

Fig. 24 Profile operation upper level.

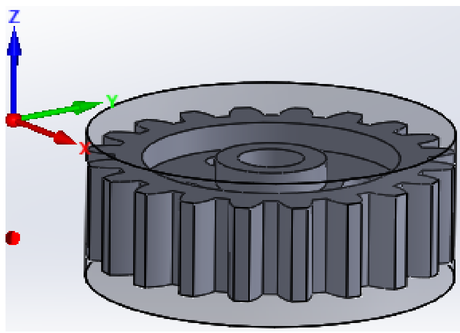

Fig. 25 Profile operation profile depth.

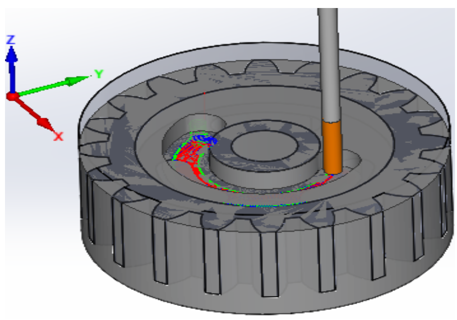

Fig. 26 iRough_contour2 operation.

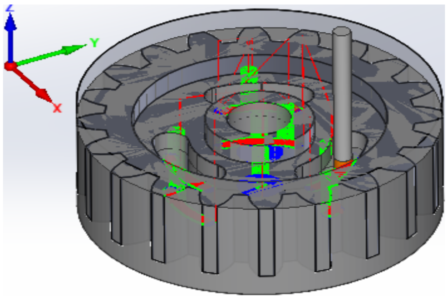

Fig. 27 iRough_contour3 operation.

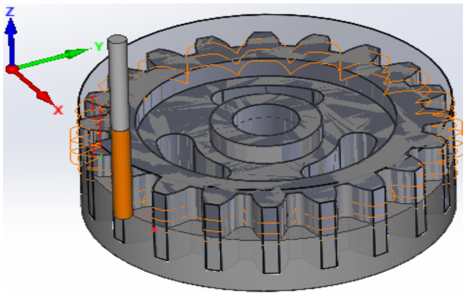

Fig. 28 Profile operation teeth cutting.

5. Result

The generated G-codes are used in the CNC machine to machine the spur gear from the stock material and the validation of the G-codes is tested. The other procedures' selected parameters play an important part in the formation of the code. It is observed that if all the tasks are performed in appropriate way this can reduce the machining time, tool wear by a lot of margin and improve the surface finish and product quality at the same time.

6. Conclusions

In this paper, the significant importance of SolidCAM iMachining in manufacturing industries for making prototypes is illustrated through using 2D iMachining module for machining a spur gear. In machine shop, the iMachining module of SolidCAM streamlines the manufacturing process optimally. Simpler operations and use of the same tool for multiple operation make it optimal to program. The future work is directed towards the experimental machining in CNC machine by using the g-codes and analyzes the outcome to verify the benefits in full perspective for complex product.

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