DYNACAM 10 USER MANUAL

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INTRODUCTION

DYNACAM is a cam design and analysis program intended for use by engineers and other professionals who are knowledgeable in the art and science of cam design. It is assumed that the user knows how to determine whether a cam design is good or bad and whether it is suitable for the application for which it is intended. The program will calculate the kinematic and dynamic data associated with any cam design, but cannot substitute for the engineering judgment of the user. The cam theory and mathematics on which this program is based are shown in reference [1]. Please consult it for explanations of the theory and mathematics involved.

The authors and publishers are not responsible for any damages that may result from the use or misuse of these programs.

DYNACAM is one member of a family of programs by this author that share a common kernel for the overhead actions such as printing, plotting, etc. In this manual you will sometimes see references such as "these programs will . . .", which means that these features are common to the family. DYNACAM also can generate files for export to several of these programs e.g., FOURBAR, SIXBAR, SLIDER.

GENERAL INFORMATION

Hardware Requirements

These programs need a Pentium or better processor. DYNACAM is large and uses significant computer resources. A minimum of 1GB of RAM is desirable. DYNACAM may require that all other applications be shut off in order to run in a computer with otherwise insufficient memory. A CD-ROM drive is needed, as is a hard disk drive.

Operating System Requirements

DYNACAM 10 is written in Microsoft Visual Basic 2008 and works on any computer that runs Windows XP/Vista/Windows7

Demonstration Version

The demonstration version of this program is downloadable from

http://www.designofmachinery.com

and allows up to 10 runs over a period of 30 days from first installation. Certain features are disabled in the demonstration version, such as the ability to open or save files, and to output cam profile or linkage coordinate data. It does come with several example files that can be opened in the demonstration version. It also has a few cam profile files that can be used to test the process of importing the cam profile to a CAD system such as Solidworks or ProEngineer. Instructions for doing so with those programs are also included in the download package. If you wish to have the fully functional program, you must register it and pay the license fee defined on the *Registration* screen.

Installing the Software

The install file contains the executable program files plus all necessary Dynamic Link Library (DLL) and other ancillary files needed to run the programs. Run the **DYNACAM_Install.exe** file to automatically decompress and install all of its files on your hard drive. Accept all defaults as presented. When installed the program name will appear in the list under the *Start* button's *Program* menu after installation and can be run from there. See the Readme file included with the installation package for information on licensing the program.

Note that it can only be installed by an administrator on that computer. Also for it to run properly by a user who does not have administrator privileges, the folder *Program Files\Design of Machinery\DYNACAM10* must have **write privileges set for all users**. If it is installed under Vista or Windows 7, certain properties must be set on the DYNACAM.exe file. See the instructions with the install package for details.

Licensing the Software

If you want to buy a license for the program, click on the "I want to buy it now" button on the *Home* screen. This brings up the *Authorization* screen as shown in Figure A. Please follow the instructions in Figure A and on the *Authorization* screen. **Be sure to back up the license files to external media so you can recover the program from a disk crash or reformat.**

How to Use This Manual

This manual is intended to be used while running the programs. To see a screen referred to, bring it up within the program to follow its discussion.

PROGRAM OPERATION

All programs in the set have similar features and operate in a consistent way. For example, all printing and plotting functions are selected from identical screens common to all programs. Opening and saving files are done identically in all programs. These common operations will be discussed in this section independent of the particular program. Later sections will address the unique features and operations of each program.

Click on this button to create a text file that encapsulates the License Code shown.

Open this text file in Word, Wordpad, or other program and add your contact information. Also check the version of the program you want to buy. Arrange payment and email the file to the address shown

When you receive the unlock code, paste it into the yellow box and click on Activate License to register the program.

Follow the instructions to back up your license files to other media. Be sure to shut the program down before copying the license files or they will be worthless.

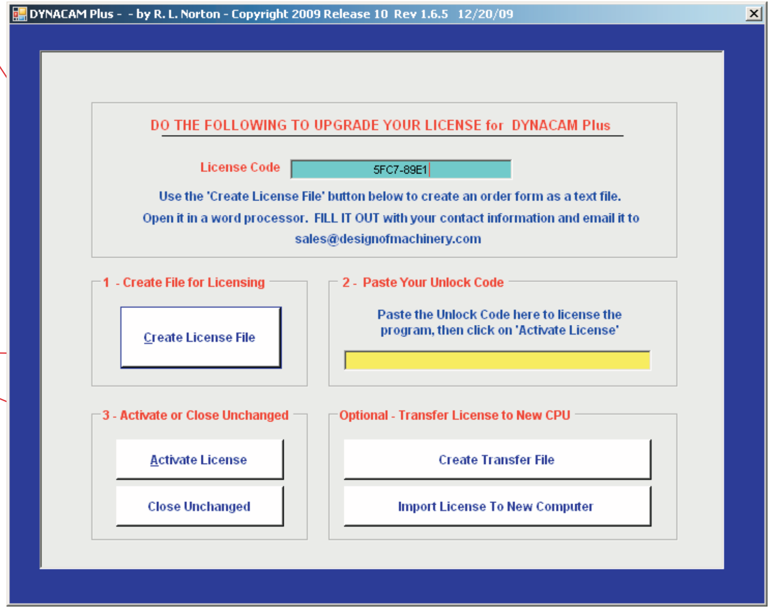

FIGURE A

Authorization screen for licensing the program

Running the Program

At start-up, a splash screen appears that identifies the program name, version, revision number, and revision date. Click the button labeled *Start* or press the *Enter* key to run the program. A *Disclaimer* screen next appears that defines the registered owner and allows the printing of a registration form if the software is as yet unregistered. A registration form can be accessed and printed from this screen.

The next screen, the *Title* screen, allows the input of any user and/or project identification desired. This information must be provided to proceed and is used to identify all plots and printouts from this program session. The second box on the *Title* screen allows any desired file name to be supplied for storing data to disk. This name defaults to **Model1** and may be changed at this screen and/or when later writing the data to disk. The third box allows the typing of a starting design number for the first design. This design number defaults to 1 and is automatically incremented each time you change the basic design during this program session. It is used only to identify plots, data files, and printouts so they can be grouped, if necessary, at a later date. When the *Next* button on the *Title* screen is clicked, the *Home* screen becomes available.

General User Actions Possible and Behavior of the Program

The program is constructed to allow operation from the keyboard or the mouse or with any combination of both input devices. Selections can be made either with the mouse or, if a button is highlighted (showing a dotted square within the button), the *Enter* key will activate the button as if it had been clicked with the mouse. Text boxes are provided where you need to type in data. These have a yellow background. Double-clicking on a text box will select its contents. In general, what you type in any text box is not accepted until you hit the *Enter* key or move off that box with the *Tab* key or the mouse. This allows you to retype or erase with no effect until you leave the text box. You can move between available input fields with the *Tab* key (and back up with *Shift-Tab*) on most screens. If you are in doubt as to the order in which to input the data on any screen, try using the *Tab* key, as it will take you to each needed entry field in a sensible order. You can then type or mouse click to input the desired data in that field. **Remember that a yellow background means typed input data is expected**. **Boxes with a cyan background feed information back to you, but will not accept input.**

Other information required from you is selected from drop-down menus or lists. These have a white background. Some lists allow you to type in a value different than any provided in the available list of selections. If you type an inappropriate response, it will simply ignore you or choose the closest value to your request. Typing the first few letters of a listed selection will sometimes cause it to be selected. Double clicking on a selectable item in a list will often provide a shortcut and sometimes a help screen.

LEAVING A SCREEN Note that when you enter a screen and begin changing values, **the new data will only be incorporated in your model if you** ***Calculate*** **on that screen** and exit with the *Next* button. If you have changed values in text boxes but have not yet recalculated the model **and** you exit the screen with the *Back* button, then the old values (not your changed ones) will be preserved and the model will remain unchanged. **Remember that the program thinks you changed your mind if you** ***Back*** **out of a screen and assumes you do not want to keep any changes made therein.** If you *Calculate,* then the changes are in the model. When you leave via the *Next* button the program assumes you are done with that task and updates other necessary information accordingly.

HOME SCREEN

All program actions start and end at the *Home* screen. It has several pull-down menus and buttons (*File*, *Screens*, *View*, *Units, Examples, License, User, Help, Preferences, About*). The *View* menu allows the home screen to be shown in one of three modes: *Full Screen, Compact,* or *Menus Only* as shown in Figure 1. The *Screens* menu allows access to the buttons shown on the Compact and *Full Screen* modes which is the only access to them in *Menus Only* mode.

The *View* menu also allows all screens to be **Centered** or **Floated** on opening and can force them to be **Topmost**, or not, as you choose. The defaults when the program is first run are: *Home* is *Full Screen* and all other forms are **Centered** and **Topmost**. The *Preferences* menu allows these and other choices to be set and remembered when the program closes. It will then wake up on subsequent runs in the preferred modes you previously set.

Units Menu

The *Units* menu defines several units systems to choose from. It is your responsibility to ensure that the data as input are in some consistent units system. Units conversion is done within the program. The *Units* menu selection that you make will convert any data (*a*) Menus only

(*b*) Compact

(*c*) Full screen

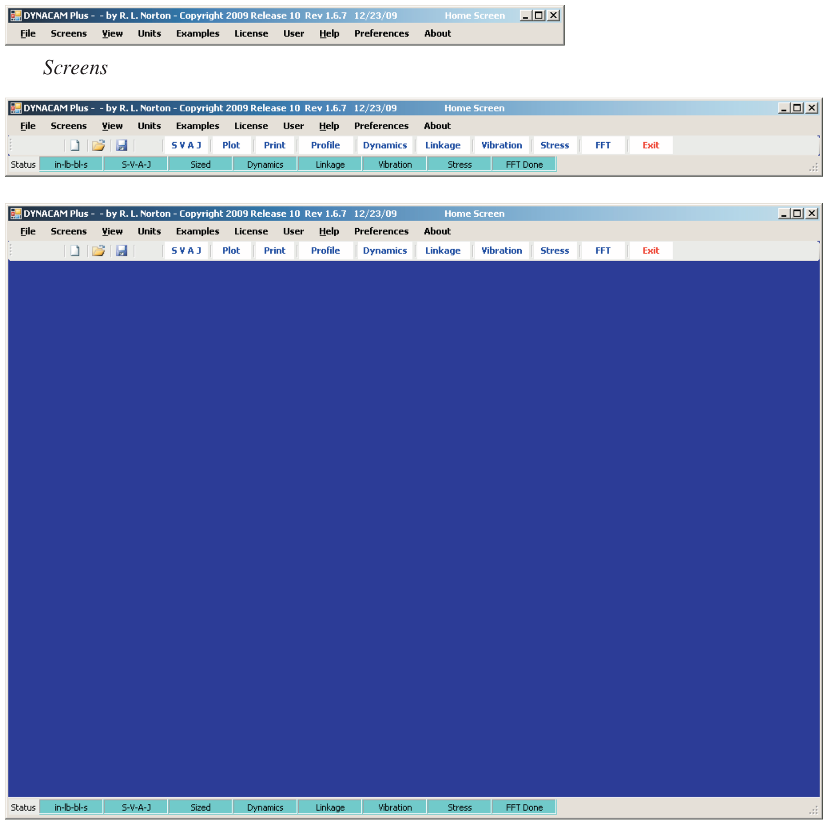

FIGURE 1

Home screen in each of its three sizes

that may already be present on any screen from the current unit system to the selected one. Five unit systems are supported: ips, fps, SI, and two mixed unit versions of SI: cm-kg-N-s and mm-kg-N-s. For the last two, length units are displayed in cm or mm, but lengths are converted to m before calculating any parameters that involve dynamic equations. Dynamic calculations are done in pure SI for all three metric systems and in English units for the other two. The *Units* menu also allows the independent variable for calculation to be set to one of: time, degrees, or radians.

Examples

The *Examples* pulldown menu on the *Home* screen provides a number of example cams that will demonstrate the program's capability. Selecting an example from this menu will cause calculation of the cam and open a screen to allow viewing the results. In some cases, you may need to hit a button marked *Calculate*, *or Run* on the presented screen to see the results. Examples can also be accessed from a drop-down menu from within the input (SVAJ) screen.

About Menu

The *About* pulldown menu on the *Home* screen will display a splash screen containing information on the edition and revision of your copy of the program. The *Disclaimer* and *Registration* form can also be accessed from this menu.

License Menu

The *License* pulldown menu on the *Home* screen gives information on the program's license status. It also allows the license to be transferred to another computer or upgraded to obtain additional features.

User Menu

The *User* pulldown menu on the *Home* screen gives information on the user name, computer name, filename, and location of saved data.

Preferences Menu

The *Preferences* pulldown menu on the *Home* screen lets you set the defaults that will obtain when the program opens. These are saved to a text file in the folder where the program file resides. This file is read each time the program opens and rewritten at your request from the Preferences menu. See the *Preferences Help File* in the program for more information.

Help Menu

The *Help* menus on some screens provide on-line access to this manual as well as specific instructions for various functions within the screens. Help files download from a website and run automatically in their own browser window. An instructional video that runs in *Windows Media Player* or any similar program is also accessible from the help menu on the *Home* screen. You must be connected to the internet to access the on-line help and videos.

Exiting a Program

Choosing either the *Quit* button or *Quit* on the *File* pulldown menu on the *Home* screen will exit the program. If the current data has not been saved since it was last changed, it will prompt you to save the model using an appropriate suffix. It will ask you to confirm that you want to quit. If you choose yes, the program will terminate and any unsaved data will be gone at that point. Note that the *Home* screen has a check box at its upper right corner that can be used to close the program. This will close the program immediately without asking you to save data or confirm the action.

Creating New, Saving, and Opening Files (*File Menu*)

The standard *Windows* functions for creating new files, saving your work to disk, and opening a previously saved file are all accessible (in licensed installations) from the pulldown menu labeled *File* on each program's *Home* screen. Selecting *New* from this menu will zero any data you may have already created within the program, but before doing so will give warning and prompt you to save the data to disk.

The *Save* and *Save As* selections on the *File* menu prompt you to provide a file name and disk location to save your current model data to disk. The data are saved in a custom format and with a three-character suffix unique to the particular program. You should use the recommended suffix on these files as that will allow the program to see them on the disk when you want to open them later. If you forget to add the suffix when saving a file, you can still recover the file as described below.

Note that the default settings of the program do not allow a data file to start the program running when double-clicked. The reason for this is that double-clicking on a file that is not on the same drive as the program's executable file will lock up the program license. This is an anomaly of the particular commercial licensing program used. This restriction can be overridden on the *Preferences* screen (use *Preferences* menu), but should not be enabled if users of the program might try to run it from a file on an external drive or memory stick. This is inevitable if the program is used by students in a server installation. If you are a single user on an isolated machine and remember not to double click on a data file on your memory stick or external drive, then it will be safe to turn on this feature. If you lock the license, you can restore it from your license backup copies.

Selecting *Open* from the *File* menu prompts you to pick a file from those available in the disk directory that you choose. If you do not see any files with the program's suffix, use the pulldown menu within the *Open File* dialog box to choose *Show All Files* and you will then see them. They will be read into the program properly with or without the suffix in their name as long as they were saved from the same program.

Copying Screens to Clipboard or Printer (*Copy*)

Any screen can be copied as a graphic to the clipboard by using the standard *Windows* keyboard combo of *Alt-PrintScrn*. It will then be available for pasting into any compatible *Windows* program such as *Word* or *Powerpoint* that is running concurrently in *Windows* and print from that program. This is the recommended approach to printing hard copy.

Exporting Spreadsheet Data

On the *Home* screen, the *File* pulldown menu has an *Export* selection, within which is a selection for *Spreadsheet*. This choice will generate a tab-delimited text file containing all the data calculated in DYNACAM. It is essentially a memory dump. Data are arranged in labeled columns for identification and a header is written that identifies the model data. This file can be opened in Excel. See the section **Exporting Cam Contour Data** for instructions on exporting a cam profile. *Export/Spreadsheet* should **not** be used for that purpose.

Support

Support is available only to licensed users. Please direct questions about program use or problems by emailing *norton@designofmachinery.com*.

CREATING A CAM

Initially, only the *SVAJ* and *Quit* buttons are active on the *Home* screen. Typically, you will start a cam design with the *SVAJ* button, but for a quick look at a cam as drawn by the program, one of the examples under the *Example* pulldown menu can be selected and it will draw a cam profile. If you activate one of these examples, when you return from the *Cam Profile* screen you will find all the other buttons on the *Home* screen to be active. We will address each of these buttons in due course below.

Input Data (*SVAJ Button*)

Much of the basic data for the cam design is defined on the *Input (SVAJ)* screen shown in Figure 2, which is activated by selecting the *SVAJ* button on the *Home* screen. When you open this screen for the first time, it will be nearly blank, with only one segment's row visible. (Note that the built-in examples can also be accessed from this form at its upper right corner.) If you had selected an example cam from the pulldown menu on the *Home* screen, making the *Input (SVAJ)* screen nonblank, and want to start a new model please now select the *Clear All* button on the *Input (SVAJ)* screen to zero all the data and blank the screen, in order to better follow the presentation below. We will proceed with the explanation as if you were typing your data into an initially blank *Input (SVAJ)* screen.

If you use the *Tab* key, it will lead you through the steps needed to input all data as indicated by the circled numbers in Figure 2. On a blank *Input* screen, *Tab* first to the *Cam Omega* boxes in the upper left corner (1) and type in the speed of the camshaft in rpm or rad/s as you prefer. *Tab* again (or mouse click if you prefer) to the *Number of Segments*

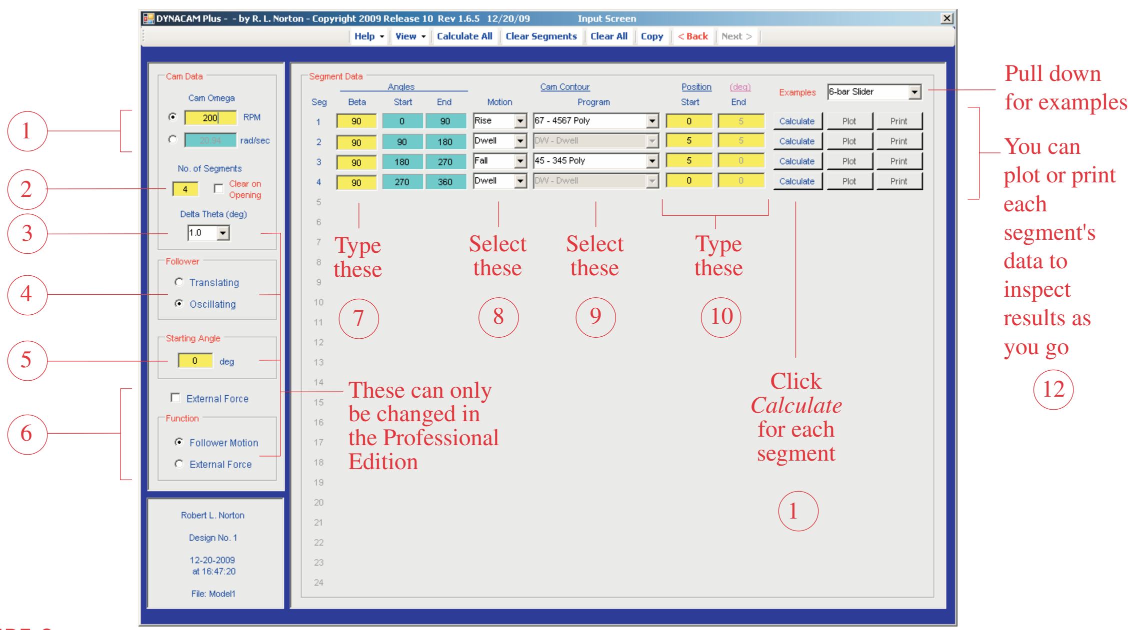

FIGURE 2

S V A J Input screen for program DYNACAM box (2) and type in any number desired between 1 and 24. That number of rows will immediately become visible on the *Input* screen. If the *Clear on Opening* checkbox is checked, changing the number of segments will erase all content present in the segment rows. Leaving it unchecked allows one to add or subtract segments while preserving existing data.

Tab or click to the *Delta Theta* pulldown (3) and select one of the offerings on the menu. No other values than those shown may be used. Next select either *Translating* or *Oscillating* for the follower motion (4).

Choose either *Translating* or *Oscillating* for the follower motion. Note that the units of the *Start* and *End* values change from length units for translating followers to degrees for oscillating followers.

The *Starting Angle* box (5) allows any value to be typed to represent the machine angle on the timing diagram at which you choose to begin the first segment of your cam, i.e., where you choose cam zero. Unless the timing diagram places machine zero within a motion event, this can be left as zero, making cam zero the same as machine zero (the default). If machine zero is within a motion (rise or fall) you cannot start the cam design at that point. Also, you should always place cam zero at the beginning of a motion, not at or in a dwell.*

The *External Force* check box and the *Motion/Force* option buttons (6) are provided for situations in which the cam follower is subjected to a substantial external force during operation, such as in a compactor mechanism. Checking this box temporarily converts the cam design program into a force-time function design program in which the shape of the force-time (or force-angle) function can be defined as if it were a cam displacement function with units of force instead of length. When calculated, the force data is stored for later superposition on the follower's dynamic forces due to motion. When *External Force* is checked, a dialog box pops up with information on how to use it.

Another *Tab* should put your cursor in the box for the *Beta* (segment duration angle) of segment 1 (7). Type any desired angle (in degrees). Successive *Tabs* will take you to each *Beta* box to type in the desired angles. The *Betas* must, of course, sum to 360 degrees. If they do not, a warning will appear.

As you continue to *Tab* (or click your mouse in the appropriate box, if you prefer), you will arrive at the boxes for *Motion* selection (8). These boxes offer a pulldown selection of *Rise, Fall, Poly*, *Dwell*, and *Spline*. You may select from the pull-down menus with the mouse, or you can type the first letter of each word to select it. *Rise*, *Fall*,, and *Dwell* have obvious meanings. The *Poly* choice indicates that you wish to create a customized polynomial function for that segment, and this will later cause a new screen to appear on which you will define the *order* and *boundary conditions* of your desired polynomial function. The *Spline* choice indicates that you wish to create a customized *B-Spline* function for that segment, and this will later cause a set of new screens to appear on which you will define the *boundary conditions*, *order*, and *knot locations* of your desired *B-Spline* function.

The next set of choices that you will *Tab* or mouse click to are the *Program* pulldowns (9). These provide a menu of standard cam functions such as *Modified Trapezoid, Modified Sine,* and *Cycloid,* as well as a large number of specialized functions as described in reference [1]. Also included are portions of functions such as the first and

* If you intend to do any dynamic analysis of your follower train within DYNACAM, AND IF you start your motion at a dwell, the numerical differential equation solver will fail to converge because when started on a dwell, it cannot make any progress with its computtions. If you do not intend to do any dynamic analysis, shame on you, but then you can start the cam design at or within a dwell.

second halves of cycloids and simple harmonics that can be used to assemble piecewise continuous functions for special situations. The standard double-dwell polynomials, 3-4-5 and 4-5-6-7, as well as a symmetrical single-dwell 3-4-5-6 rise-fall function are provided as menu picks though they can also be created with a *Poly* choice and subsequent definition of their boundary conditions.

After you have selected the desired *Program* functions for each segment, you will *Tab* or *Click* to the *Position Start* and *End* boxes (10). *Start* in this context refers to the beginning displacement position for the follower in the particular segment, and *End* for its final position. **Note that if you selected a translating follower, then the displacement values are defined in length units, but if you chose an oscillating follower, they must be in degrees.**

You may begin at the "top" or "bottom" of the displacement "hill" as you wish, but be aware that **for a radial cam**, **the position values of the follower must be in a range from zero to some positive value over the whole cam**. In other words, **you cannot include any anticipated base or prime circle radius in these position data**. These position values represent the excursion of the so-called *S* diagram (displacement) of the cam and cannot include any prime circle information (which will be input later). **If you intend to make a barrel cam or a linear cam, then the requirement that the start and end values include a zero value is no longer applicable and the values can be over any range desired.**

As each row's (segment's) input data are completed, the *Calculate* button (11) for that row will become enabled. Clicking on this button will cause that segment's *S V A J* data to be calculated and stored. After the *Calculate* button has been clicked for any segment's row, the *Plot* and *Print* buttons for that segment will become available (12). Clicking on these buttons will bring up a plot or a printed table of data for *S V A J* data for that segment only. More detailed plots and printouts can be obtained later from the appropriate button on the *Home* screen. The plots and prints are enabled at this location to allow you to determine the values of boundary conditions as you work your way through a piecewise function.

Polynomial Functions

If any of your segments specified a *Poly* motion, clicking the *Calculate* button will bring up the *Boundary Condition* screen shown in Figure 3. The cursor will be in the box for *Number of Conditions Requested*. Type the number of boundary conditions (BCs) desired, which must be between 2 and 50 inclusive. When you hit *Enter* (and you must hit *Enter*) the rest of the screen will activate, allowing you to type in the desired values of BCs. Note that the start and end values of position that you typed on the *Input (SVAJ)* screen are already entered in their respective *S* boundary condition boxes at the beginning and end of the segment. Type your additional end of interval conditions on *V*, *A*, *J*, and *P* as desired. If you also need some additional BCs within the interval, click or tab to one of the boxes in the row labeled *Local Theta* at the top of the screen and type in the value of the angle at which you wish to provide a BC. That column will activate and you may type whatever additional BCs you need.

The box labeled *Number of Conditions Selected* monitors the BC count, and when it matches the *Number of Conditions Requested,* the *Next* button becomes available. Note

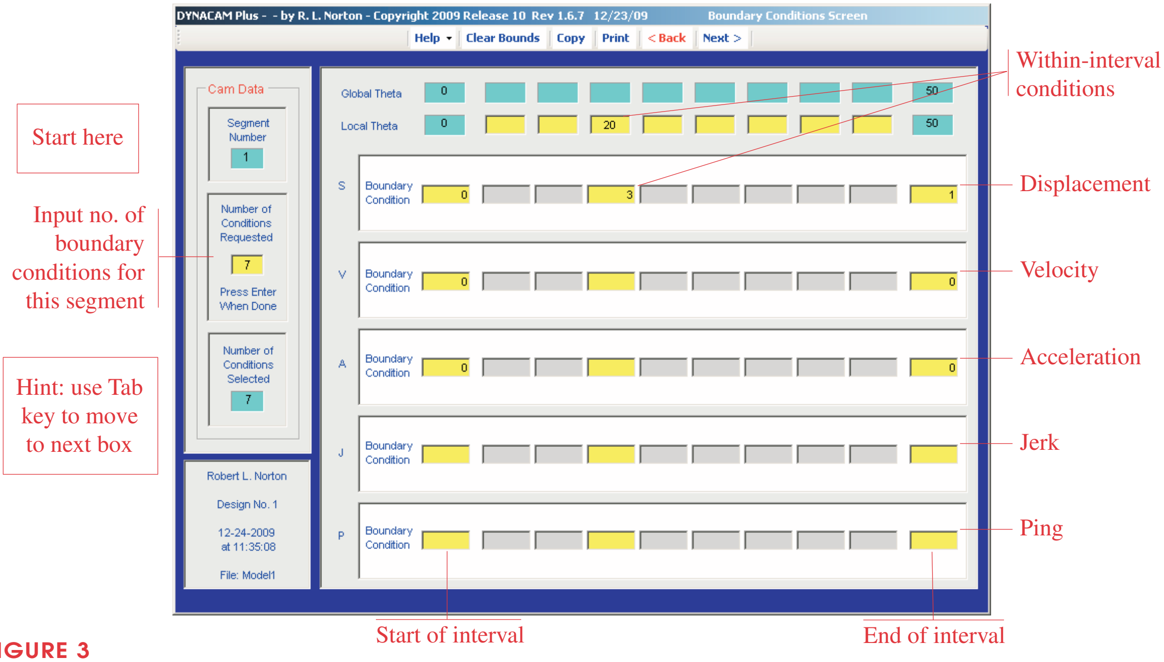

FIGURE 3

Boundary Condition Input screen for polynomial functions in program DYNACAM—3-4-5-6 single-dwell function shown

that what you type in any (yellow) text box is not accepted until you hit *Enter* or move off that box with the *Tab* key or the mouse, allowing you to retype or erase with no effect until you leave the text box. (This is generally true throughout the program.)

Selecting the *Next* button from the BC screen calculates the coefficients of the polynomial by a Gauss-Jordan reduction method with partial pivoting. All computations are done in double precision for accuracy. If an inconsistent set of conditions is sent to the solver, an error message will appear. If the solution succeeds, it calculates *s v a j* for the segment. When finished, it brings up a summary screen that shows the BCs you selected and the coefficients of the polynomial equation that resulted as shown in Figure 4. You may at this point want to print this screen to the printer or copy and paste it into another document for your records. You will only be able to reconstruct it later by again defining the BCs and recalculating the polynomial.

Spline Functions

If any of your segments specified a *Spline* motion, clicking the *Calc* button will bring up the same *Boundary Condition* screen shown in Figure 3 that is used for polynomial functions. These are defined in exactly the same way as described for polynomials in the preceding section.

Once you finish selecting boundary conditions for your spline and hit the Next button, it takes you to the *Spline Function* screen shown in Figure 5. This screen shows the current segment, the number of boundary conditions that were selected, and requires

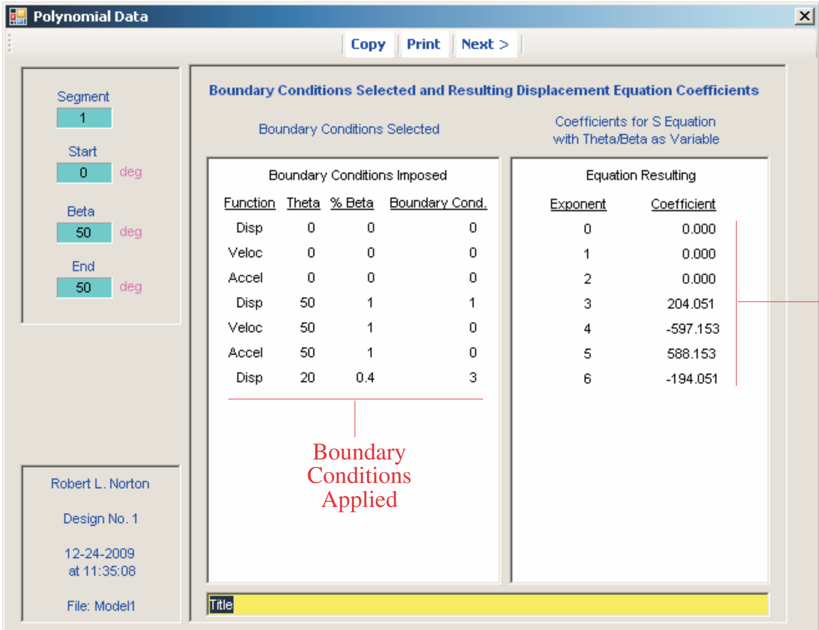

FIGURE 4

Result of calculation of the polynomial function

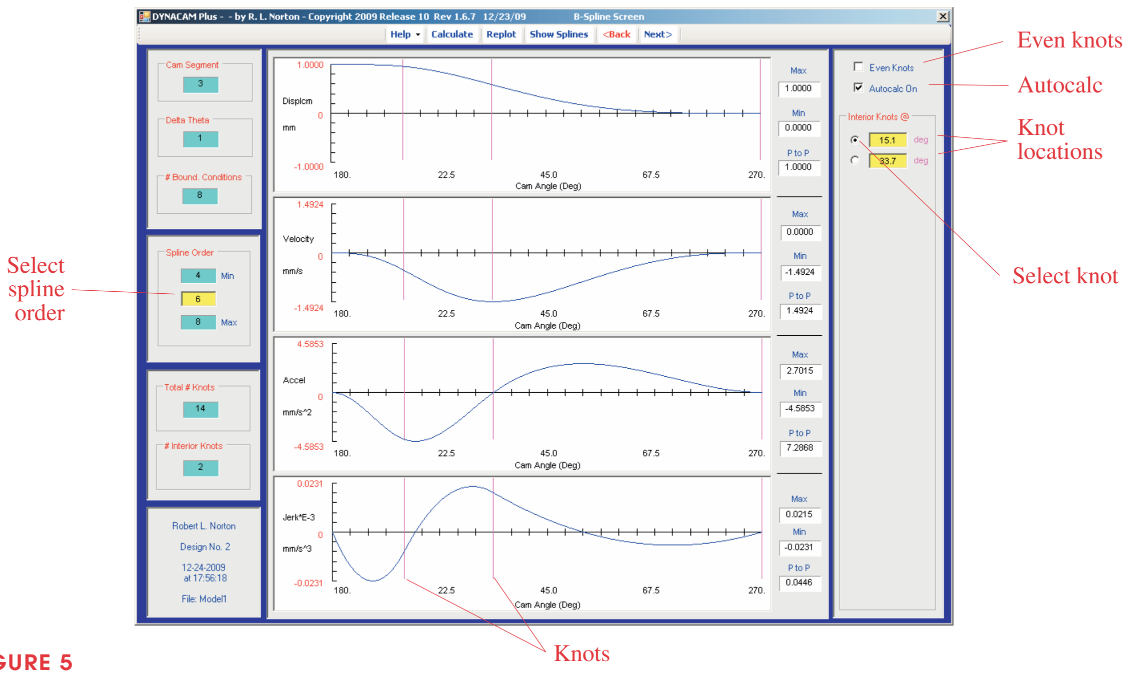

FIGURE 5

Spline function screen with adjustable interior knot locations you to choose a spline order between four and the number of boundary conditions previously selected. It then displays the total number of spline knots used and the number of those available for distribution as interior knots. It also calculates the spline functions and displays their *S V A J* functions for the default assumption of evenly spaced interior knots. The current locations of the knots (in degrees) are displayed in the right side-bar.

The shape of the spline can be manipulated as described in Chapter 5 of ref. [1] by moving the interior knots around. There are several ways to do this. One is to select a knot with its radio button in the right side-bar and type the angle to which you want to move it in its yellow text box. Alternatively, you may select a knot with its radio button and then click the mouse on any one of the *SVAJ* plots at any location that you want that knot to move to. A shortcut to select a knot is to *Shift Click* near the knot you want to activate and this will select its radio button for you. Then a *Click* will move that selected knot. Note that because knots must be in ascending order, it will refuse to violate their order if you request an inappropriate knot location. The plots and extreme values will update immediately unless you uncheck the *Autocalc On* box at upper right. If you are making a large number of knot changes, turning off *Autocalc* will speed the process by suppressing the screen updates. It may also avoid tripping error messages engendered by a poor initial distribution of multiple knots until you can get them more or less where you want them before allowing it to recalculate the splines.

The *Back* button returns you to the *Boundary Condition* screen if you wish to change them. The *Show Splines* button will display the basis functions that make up the B-Splines. *Plot Functions* returns to the B-Spline plots. *Next* returns you to the *Input (SVAJ) Screen*.

Back to the *Input* Screen

Completing a polynomial or spline function returns you to the *Input (SVAJ)* screen. When all segments have been calculated, select the *Next* button on the *Input (SVAJ)* screen (perhaps after copying it to the clipboard and pasting it into a Word file to serve as a record of your design). Selecting *Next* will bring up the *Continuity Check* screen as shown in Figure 6.

Continuity Check Screen

The screen in Figure 6 provides a visual check on the continuity of the cam design at the segment interfaces. The values of each function at the beginning and end of each segment (i.e., between the segments) are grouped together for easy viewing. The fundamental law of cam design requires that the *S, V,* and *A* functions be continuous over the entire interval. This will be true if the boundary values for those functions shown grouped as pairs are equal. If this is not true, then a warning dialog box will appear when the *Next* button is clicked. It displays any errors between adjacent segments in both absolute and percentage terms. You must decide if any errors indicated are significant or are due only to computational round-off error. The message will give information to make this judgment. If the error is very small, and can be safely ignored, the message will say so. *Cancel* will return you to the *Input Data* screen to correct the problem and *OK* will take you to the *Home* screen.

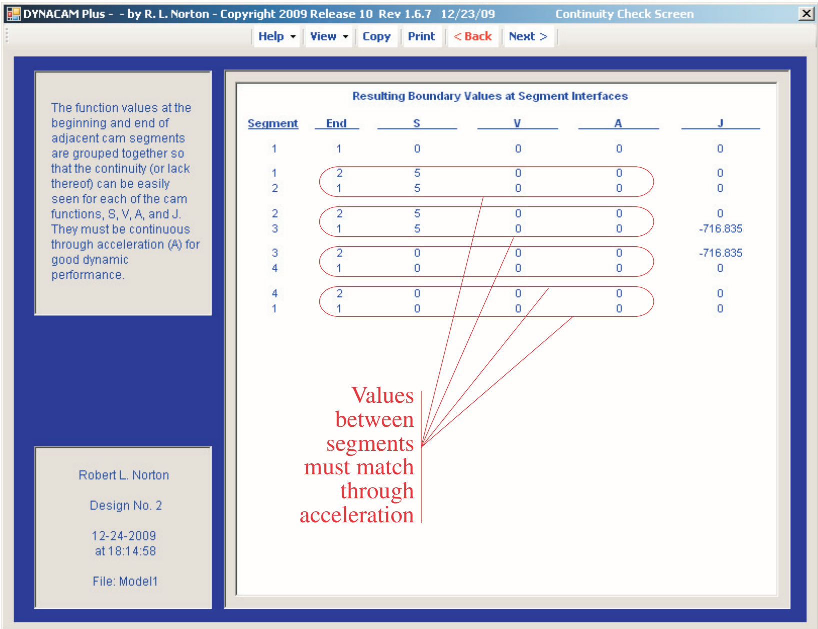

FIGURE 6

Continuity check screen

Plotting Data (*Plot* Button)

The *Plot* button on the *Home* screen brings up the *Plot* screen (Figure 7). Most variables in this program are plotted on Cartesian axes. The cam profile can also be plotted in cylindrical coordinates (a polar plot).

Two arrangements for selecting the functions to be plotted are provided. One provides preselected collections of functions as shown in Figure 7, and the other allows selection of up to four functions from those available on the pulldown menus as shown in Figure 8. Figures 9 and 10 show other examples of the various plot types available. Experiment with the selections of number of functions, plot windows and axes to see the variety available. The plots can be augmented with gridlines, fills, lines denoting the cam segments, and circles on the joints between cam segments by using the check boxes at upper right of the screen. Right clicking on the plot area will bring up a menu that allows other changes to many plot parameters such as color to be made. A cursor can be turned on at upper right and it will display the coordinates of the functions as the cursor is hovered over the plotted line.

From the *Plot* screen, you may copy to the clipboard for pasting into another application by using Alt-Printscreen. *Next* returns you to the *Home* screen.

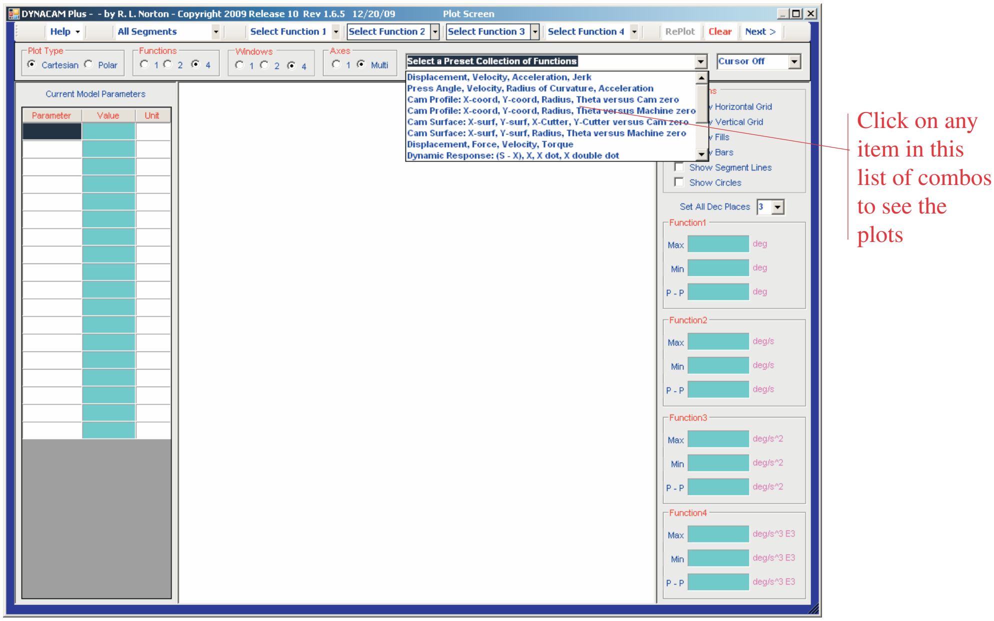

FIGURE 7

The *Plot* screen has a collection of preset conbinations of functions to choose from

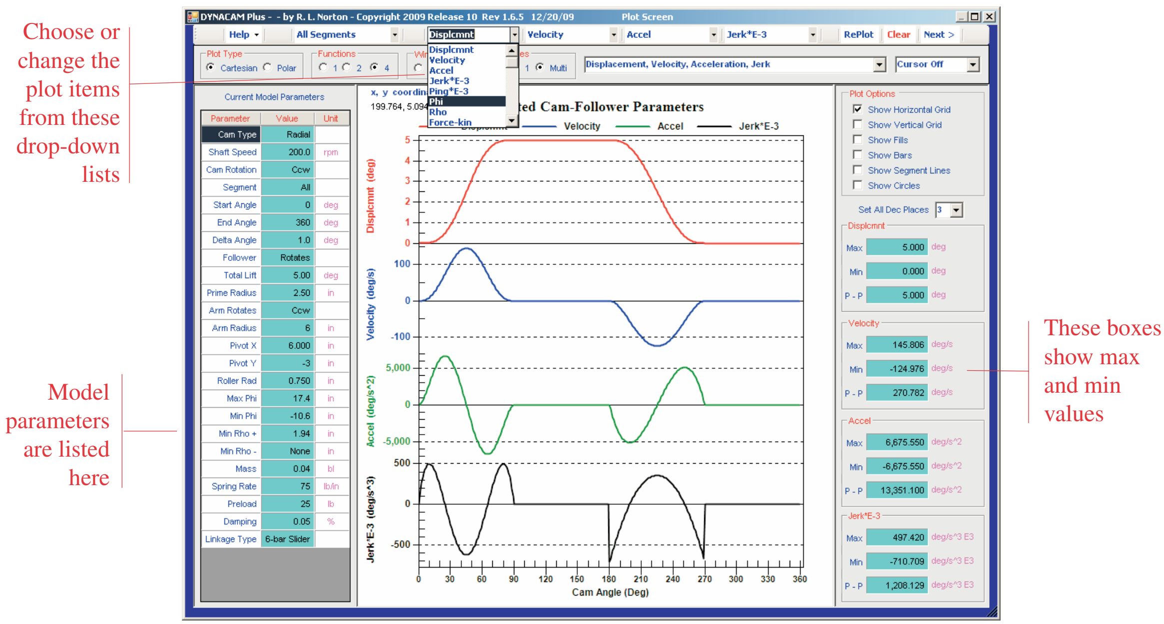

FIGURE 8

An example of four plots in separate windows and individual dropdown menus to choose plot items

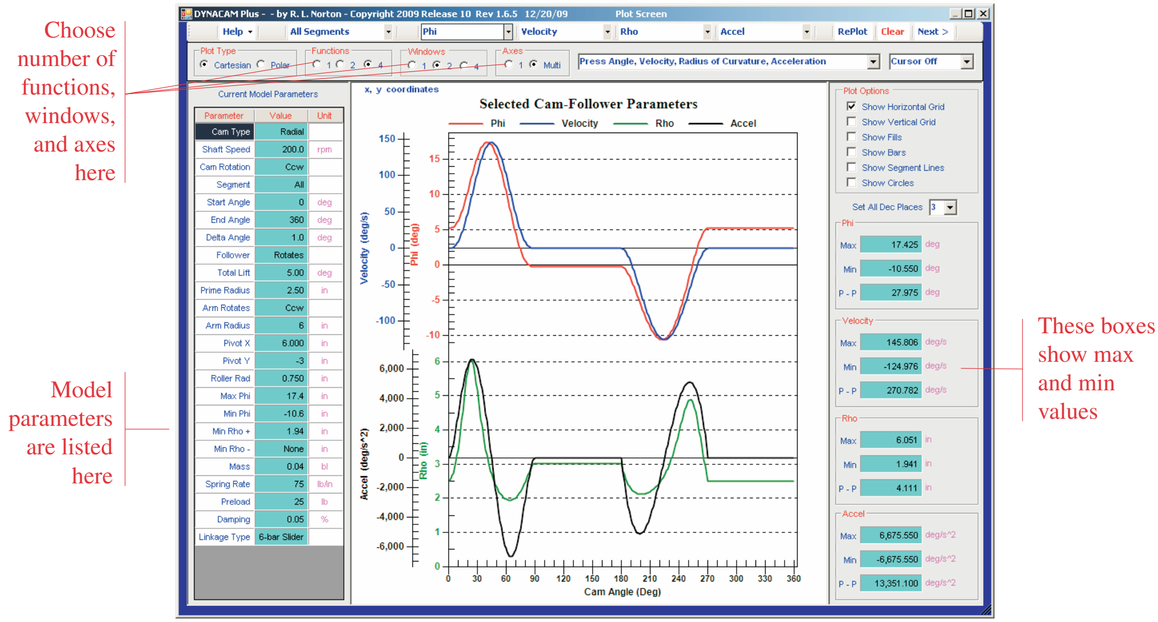

FIGURE 9

An example of superimposed plots in multiple windows with multiple axes per window

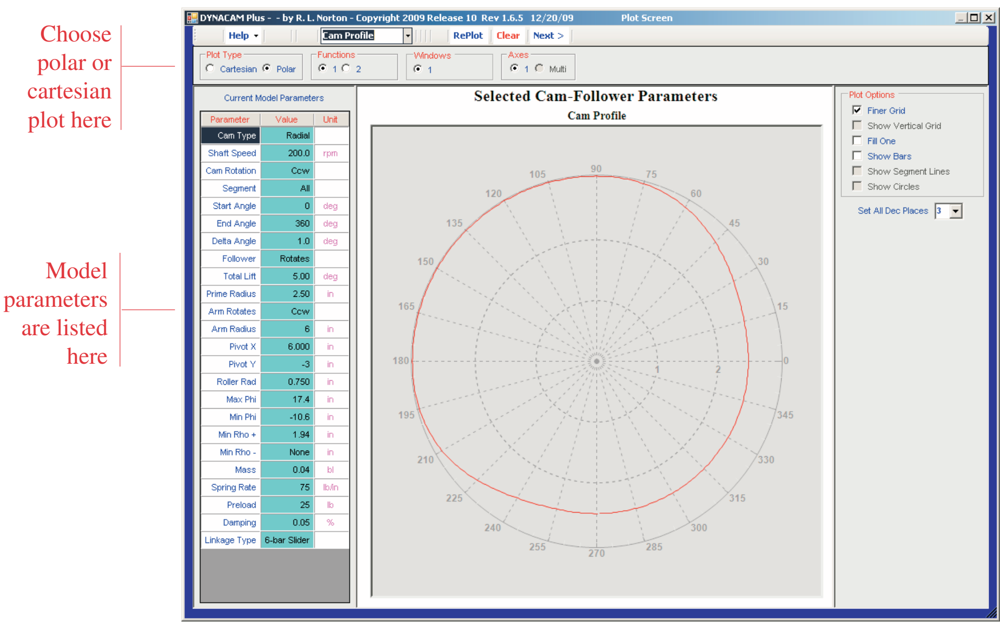

FIGURE 10

Polar plot of the cam profile

Printing to Screen and Disk Files (*Print* Button)

Selecting the *Print* button from the *Home* screen will open the *Print Screen* (see Figure 11) containing lists of variables that may be printed. A drop-down menu at the top right of this screen can be used to direct the printed output to *Screen* or *Disk*. This choice defaults to *Screen* and so must be clicked each time the screen is opened to obtain either of the other options.

Selecting *Scree*n will result in a scrollable screen window full of the requested data. Scrolling will allow you to view all data requested serially. This data screen can be copied to the clipboard, but this clip or dump will typically show only a portion of the available data, i.e., one screen-full.

Selecting *Disk* as the output device will cause your selections to be sent to the file of your choice in a tab delimited ASCII text format that can be opened in a spreadsheet program such as *Excel*. You can then do further calculations or plotting of data within the spreadsheet program.

The *Print* screen has two modes for data selection. One provides preselected sets of two or four variables for printing. Drop-down menus at the top of the screen allow selection of up to four calculated variables for printing. You can print one, two, or four variables at a time in either mode. You can also select other ancillary parameters such as the number of decimal places and the frequency of data to be printed.

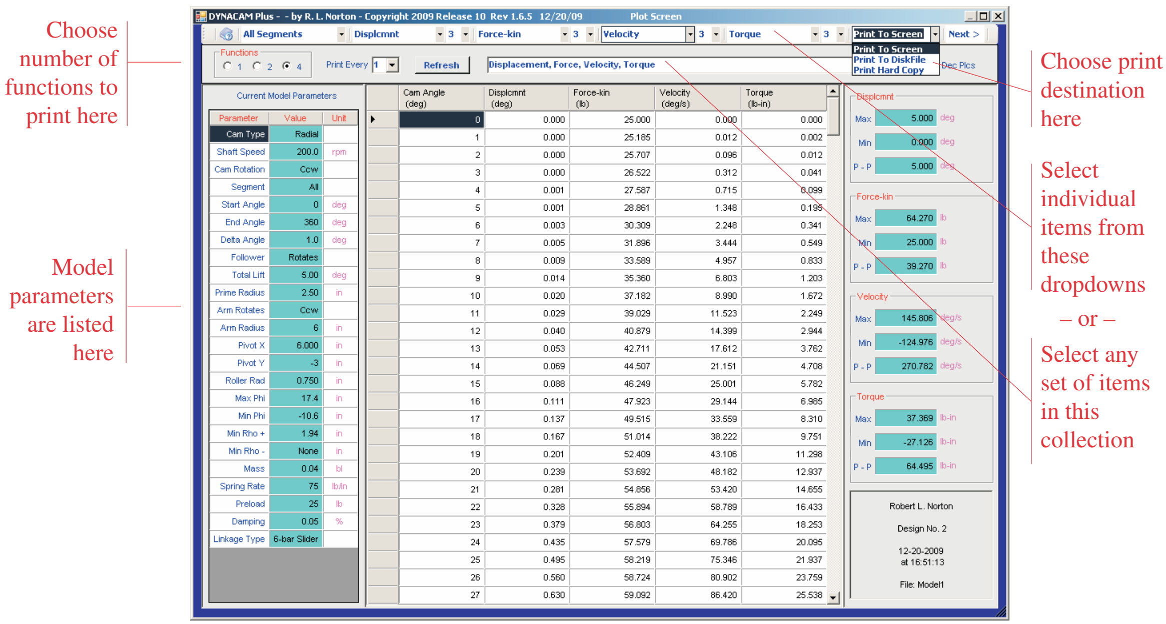

FIGURE 11

The *Print Screen*

Creating the Cam Profile

Once the *S V A J* functions have been defined to your satisfaction, it remains to size the cam and determine its pressure angles and radii of curvature. This is done from the *Profile* screen shown in Figure 12, which is accessible from the button of the same name on the *Home* screen. The *Profile* screen allows the cam rotation direction and follower type (flat or roller) to be set. The cam type (radial, barrel, or linear) and follower motion (translating or oscillating) can also be selected. The cam start angle (cam zero) as chosen on the *S V A J* screen is shown and a drop down box allows the keyway location versus machine zero to be selected among four cardinal positions.

The prime circle radius, (base circle for a flat follower), roller radius (if any), and cutter radius can be typed into their respective boxes. For a translating follower, its offset and angle of translation versus the positive x-axis can be specified. For an oscillating follower, the location of the arm pivot and the length and rotation direction of the arm must be provided. When a change is made to any of these parameters, the schematic image of cam and follower is updated.

Select the *Calculate* button to compute the cam size parameters and the cam contour. The max and min pressure angles and radii of curvature are shown at bottom right and a more detailed summary can be seen by using the *Details* button. Radial cams can be animated but barrel and linear cams are displayed statically.

In a radial cam profile drawing, an arrow indicates the direction of cam rotation. The initial position of a translating roller follower at cam angle θ = 0 is shown as a filled circle

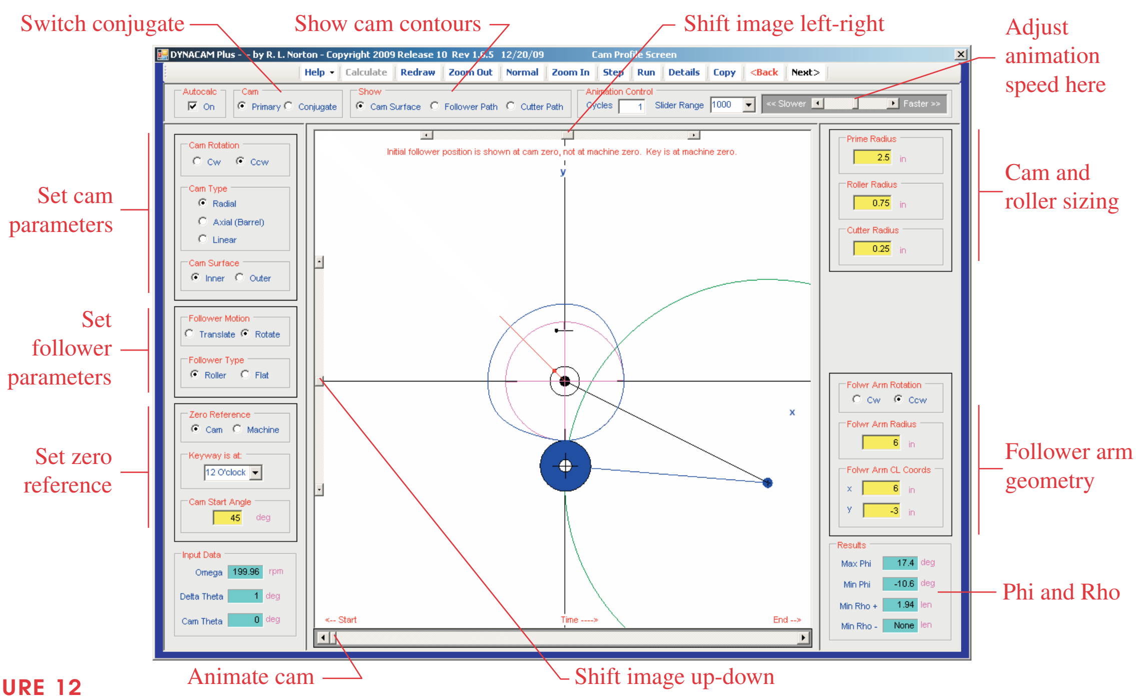

FIGURE 12

The cam profile screen

with rectangular stem, and of a flat-faced follower as a filled rectangle. Any eccentricity shows as a shift up or down of the roller follower with respect to the *X* axis through the cam center. The smallest circle on the cam centerline represents the camshaft, and its keyway is shown as a solid red dot. The larger circle is the base circle. The prime circle is not drawn.

The default image of a radial cam shows the inner cam surface. Check boxes on the left allow the inner or outer surface to be displayed. Check boxes at the top select the cam surface, follower path, or the cutter path around the cam When the follower path is shown, the pitch curve is drawn through the locus of the roller follower centers.

The check box labeled *Zero Reference* phase-shifts the cam contour to either cam zero or machine zero and redisplays it. In the case of an oscillating arm follower, the cam contour is reoriented to put the keyway at the selected o'clock position. For a translating follower, the follower is kept in a fixed orientation along the *x* axis and the keyway rotated to the correct relative position. These phase shifts incorporate the start angle, follower angle, and keyway location.

The magenta radial lines that form pieces of pie within the base circle represent the segments of the cam. If the cam turns counterclockwise, the radial lines are numbered clockwise around the circumference and vice versa.

The cam profile is now ready for export. Whether the *Primary* or *Conjugate* radio button was selected when *Next* was clicked determines which of those two cam contours will be the one exported. So to generate profile data for a pair of conjugate cams requires sequential calculation and export of their respective data to separate files. The state of the *Cam Surface* radio buttons at the time *Next* was clicked also dictates which cam surface will be exported. Generating both cam surfaces also requires sequential calculation and export of data. Only one set of cam surface contour data is stored in memory at a time.

The cam profile for a radial cam can be displayed at any time from the *Home* screen with the *Profile* button. So, for creation of multiple cam surfaces or conjugates of radial cams, it is necessary to revisit the *Profile* screen. Clicking *Next* on the *Profile* screen returns you to the *Home Screen* where a dialog box appears with instructions on exporting the cam contour data for manufacturing.

Exporting Cam Contour Data

There is more than one way to get the cam contour data out of DYNACAM for manufacturing, but only one of these is set up specifically for that purpose, and it is strongly recommended that you use it in order to avoid errors in manufacturing. On the *Home* screen, the *File* pulldown menu has an *Export* selection, within which are selections for *Spreadsheet* and *Profile*.

File/Export /Profile is the recommended choice. Depending on the type of cam designed (radial, barrel, or linear) and the type of follower (roller or flat), the selections under *Profile* will vary. They typically will provide one or several choices that may include surface coordinates, cutter centerline, and roller follower centerline coordinates as appropriate. These data can be output as referenced to cam zero or to machine zero, as desired. If these two angles differ it is probably because machine zero is within a motion segment of the cam. In that case, one should NOT begin cutting the cam contour at machine zero which is within a motion. However, if one is importing the profile data to a CAD model, then machine zero is probably the better choice for export in order to get it properly phased with other cams in the system.

The data exported for radial cams is only provided in cartesian coordinates in order to avoid confusion and possible error by the manufacturer that could occur if they were given polar coordinates, especially for oscillating followers or for translating followers with offsets. For compatibility with 3-D CAD/CAM systems, three coordinates are provided, x, y, and z, with z set to zero for radial cams. The z column is easily deleted in a spreadsheet if not needed.*

The exported data for barrel and linear cams is in 3-D cylindrical coordinates, R, λ, z, with R set to a constant value equal to the prime cylinder radius; λ is the cam angle for each data point and will not be equispaced for oscillating arm followers or for surface data of any cam, and z is the axial follower displacement at R, λ.*

If you insist on being ornery and want to have your cam cutter data in some other form, choose the *Spreadsheet* option and you will get every piece of data that DYNACAM has calculated for this cam. But don't complain when you pick the wrong columns of data to give to the shop and your cam doesn't work!

ANALYSIS

Kinetostatic Analysis

When the cam has been sized, the *Dynamics* button on the *Home* screen will become available. This button brings up the *Dynamics* screen shown in Figure 13. Text boxes are provided for typing in values of the effective mass of the follower system, the effective spring constant and spring preload for a force-closed follower, and a damping factor. By effective mass is meant the mass of the entire follower system as reflected back to the cam-follower roller centerline or cam contact point as defined in Chapter 8 of reference [1]. Any link ratios between the cam-follower and any physical masses must be accounted for in calculating the effective mass. Likewise the effective spring in the system must be reflected back to the follower. The damping is defined by the damping ratio ζ, as defined for second-order vibrating systems. See Chapters 8 and 9 of reference [1] for further information.

The journal diameter and the coefficients of friction are used for calculating the friction torque on the shaft. The *Start New* or *Accumulate* switch allows you to either make a fresh torque calculation or accumulate the torques for several cams running on a common shaft. The energy information in the window can be used to calculate a flywheel needed for any coefficient of fluctuation chosen as described in Chapter 9 of reference [1]. The program calculates a smoothed torque function by multiplying the raw camshaft torque by the coefficient of fluctuation specified in the box at lower right of the screen.

Dynamic Analysis

True dynamic vibration analysis, as described in Chapter 10 of reference [1], is available from the *Vibration* button on the *Home* screen once the kinetostatic calculation has been done. This brings up the *Model Type* selection screen shown in Figure 14. Four dynamic models of the types described in Chapter 10 of reference [1] are available from this screen.

* Some CAD programs require cam profile data to "complete the circle," which requires that the data repeat the first (zero deg) point as the last (360 deg) data point. This requires 361 data sets for 1-deg increments. Other CAD systems want to "complete the circle" themselves and require the data to stop short of the last point. This requires 360 data sets for 1-deg increments. This mode can be set in the program to match the CAD system of choice by using the *Help/Preferences* panel on the *Home* screen.

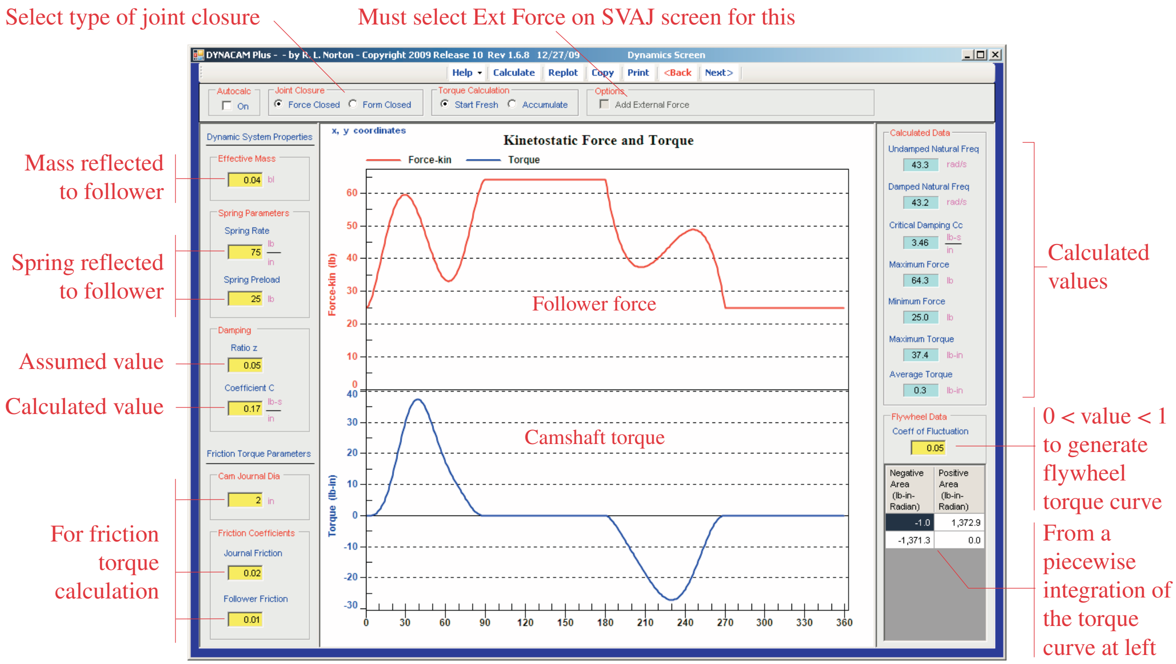

FIGURE 13

Dynamics screen in program DYNACAM

A fifth model for the case of a form closed follower train is also provided, but is directly invoked without passing through this screen when form closure has been selected on the *Dynamics* screen.

Each model diagram has an *Help* button that will display a message describing its purpose and application. Either selecting the model's radio button and hitting *Next*, or double-clicking on the image of the desired model will take you to the next screen.

Figure 15 shows the *Vibration* screen for the 1-DOF model of an industrial cam-follower system. Text boxes are provided for the input of the relevant effective mass and effective spring data, along with assumed levels of damping.

The box at lower left provides control over the parameters for the 4th-order adaptive step Runge-Kutta ODE solver. It is suggested that these be left at their default values. The end time's value defaults to, and cannot be set to less than, two cycles of the camshaft, but can be set longer. Thus, the calculation solves for at least 2 cam $\dot{x}$ evol $\ddot{x}$ tions and displays the results in plots of displacement error, *s–x*, *x*, , and along with their extreme values. The data is saved only for the second revolution in order to discard the effects of any numerical convergence start-up transients. The center bar shows calculated values of the system natural frequencies, natural periods and various dynamic ratios, as described in of reference [1]. Clicking the *Next* button at this point returns you to the *Home* screen.

POLYDYNE AND SPLINEDYNE CALCULATION The *Vibration* screen provides a check box to make a polydyne or splinedyne cam of the current design. Checking it brings up a

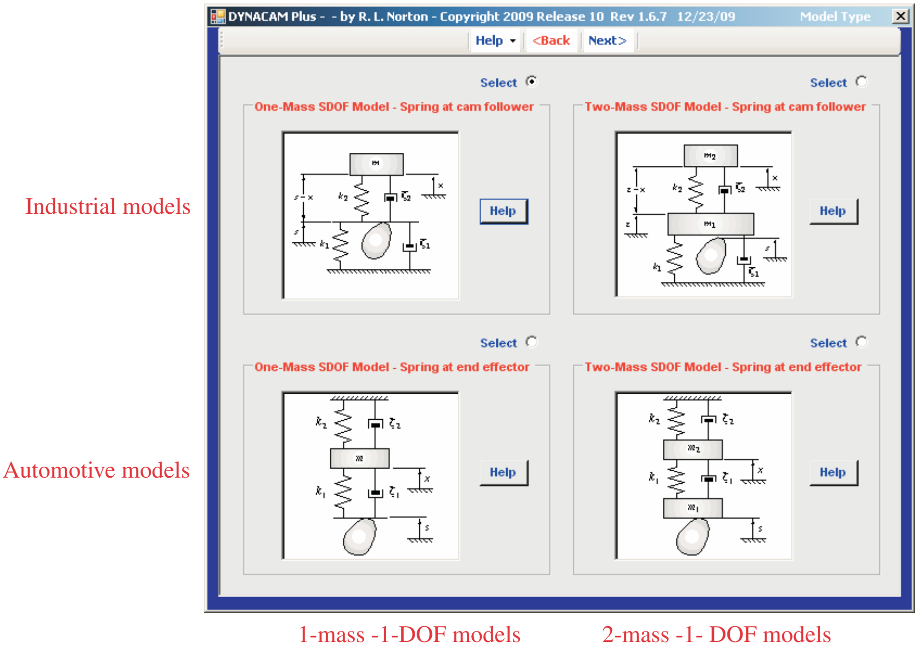

FIGURE 14

Select Vibration Model screen in program DYNACAM

FIGURE 15

Vibration screen in program Dynacam

dialog box with some instructional information. Proceeding causes the follower dynamics to be recomputed as a polydyne or splinedyne function. The dynamic plots are updated and should show marked improvement in their dynamic behavior.

Clicking the *Next* button at this point brings up the *Profile* screen in order to recalculate the cam contour coordinates with the polydyne or splinedyne modifications. Retain the existing values on this and the next screen, and click on *Next* until you are back at the *Home* screen. The cam contour data now awaiting export is that of the polydyne or splinedyne cam, though the original nonpolydyne contour has been saved in another location so that comparison plots and printouts can be made from the *Plot* and *Print* menus if desired.

Stress Analysis

The *Stress* button on the *Home* screen becomes available only after either a kinetostatic or dynamic analysis has been done. If only the former was done, then the kinetostatic forces will be used to calculate the stresses. If the *Vibration* button has been exercised, then its more accurate dynamic forces are used for the stress calculation instead. The *Stress* screen is shown in Figure 16. The material parameters for both cam and follower must be supplied but are defaulted to steel for both. The appropriate algorithm for surface stress will be used based on the earlier choice of flat or roller follower, as described in Chapter 12 of reference [1]. If a roller follower is used, then you must specify it as cylindrical or crowned and provide the relevant dimensional information. A box is provided for the input of a follower weight force if applicable. If an external force function was calculated on the *S V A J* form, then the check box to include it will become available and it can be included or excluded from the stress calculation as desired.

The calculate button creates and displays the maximum normal and maximum shear stress in cam and follower at each point around the cam and also shows the dynamic force and cam radius of curvature used in the calculation. *Next* returns you to the *Home* screen.

Fourier Transform (FFT)

The Fourier transform of any function calculated within DYNACAM can be formed by pulling down the menu labeled *FFT* on the *Home* screen. Figure 17 shows the *Fourier Transform* screen. Any one cam segment or the entire cam can be selected for transformation from the upper drop-down menu. The middle drop-down menu allows any calculated follower function to be chosen for transformation. The lower drop-down menu chooses the number of harmonics desired in the Fourier spectrum. The *RMS Sum* and the *Spectral Power* are displayed in the right side-bar. Once a Fourier calculation is done, the spectral information for the chosen follower function will be available for plotting, printing, and export from those *Home* screen buttons. This *FFT* data can be used to recreate the functions from the Fourier series harmonics as continuous functions of time in an equation solver, for example.

LINKAGES

DYNACAM allows four types of linkage follower trains to be created, Fourbar linkage, Sixbar linkage, Fourbar slider and Sixbar slider as shown in Figure 18. There are samples of each linkage on the Examples menu (*Home* screen) and these can be used to seed your

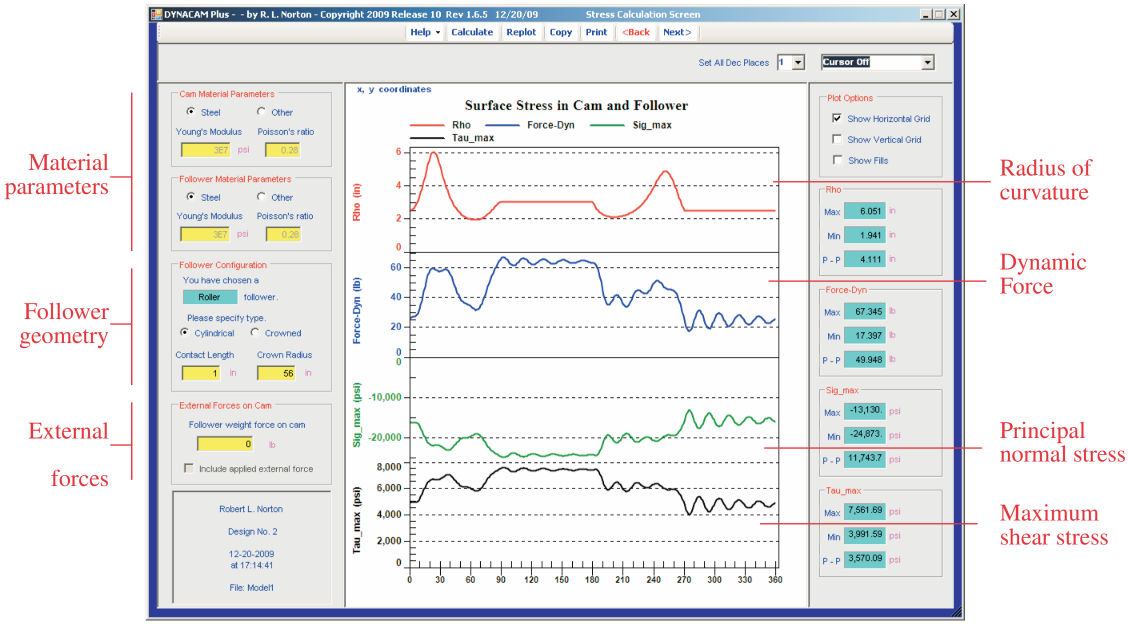

FIGURE 16

Stress analysis screen in program DYNACAM

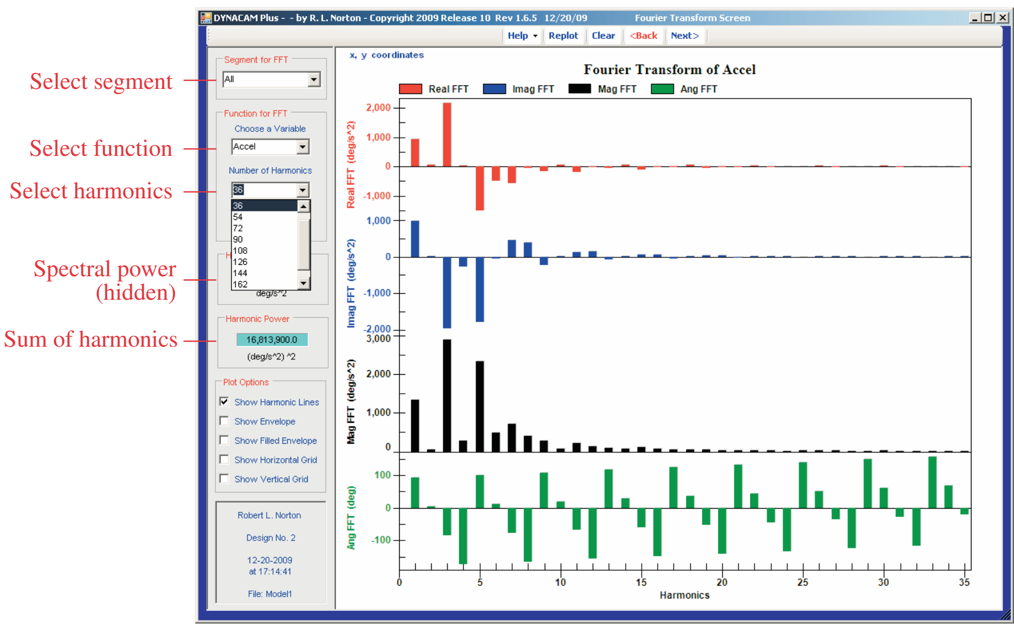

FIGURE 17

Fourier transform screen in program Dynacam model and give you a set of compatible links to start with. The cam's SVAJ functions can be applied either to the input link of the linkage (the arm carrying the roller) or to the output end of the linkage (the end effector). In the latter case, the cam contour will be modified to account for distortion caused by the linkage geometry.

The geometry of the follower arm as defined on the *Profile* screen is automatically imported to all linkage screens thus defining the location of link two's ground pivot versus the cam center. The global coordinate system origin is at the cam center in all cases and the orientation is as previously defined on the *Profile* screen.

DYNACAM does only a kinematic analysis of the linkage train, calculating only angular displacements, velocities and accelerations of all the links. These can be plotted in DYNACAM. Mass properties of the links can be entered on a separate screen but these are not used for dynamic calculations in this program. They are used only for the lumped model approximations on the *Dynamics* and *Vibration* screens. Rather, the linkage geometry and mass data along with all the cam SVA data can be exported in a text file that in turn can be imported into a linkage analysis program such as FOURBAR, SIXBAR, or SLIDER for further analysis. Those programs will do a complete kinematic and dynamic analysis of the linkage using the SVA cam functions from DYNACAM to drive it.

Fourbar Linkage Follower Train

Figure 19 shows the input screen for a fourbar linkage. The *Fourbar Mode* defines the kinematic circuit of the linkage which can be either open or crossed as desired. For a definition of these terms see reference 2. The "Angle from Line of Link 2 to Roller Arm"

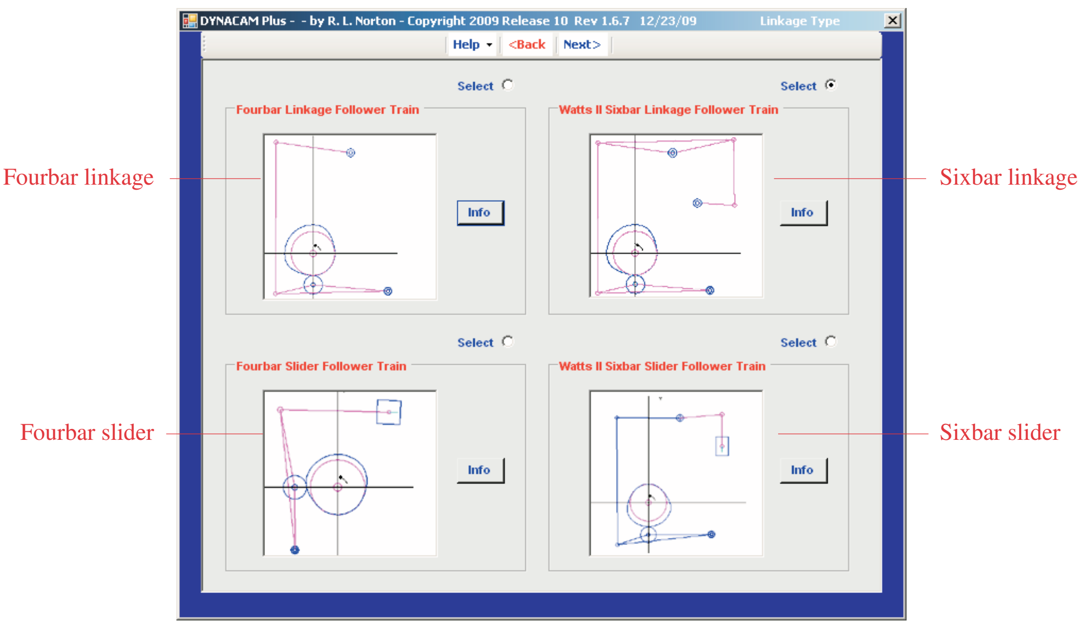

FIGURE 18

Linkage Type selection screen in Dynacam parameter defines the included angle between the kinematic link 2 and the arm radius to the roller. This is often zero, but can be nonzero if desired as shown in the figure. The link lengths are always defined as the pin-to-pin distances of each link. Link numbering is standardized with link 1 always the ground link, link 2 the link directly driven by the cam and pivoted to ground, link 3 a floating coupler or connecting rod, and link 4 the output link in this case, pivoted to ground. Ground pivots are labeled O_n with n = link number. The coordinates of pivot O_4 must be supplied in the cam XY coordinate system.

Note that is possible to input a set of linkage data that is impossible to solve as the links may not be able to connect if their lengths are not compatible. An error message will appear when the calculation is done if this is the case. Once calculated, the linkage can be animated by using the *Run* or *Step* buttons or by dragging the slider bar at the bottom of the screen to left or right. The *Mass Prop* button goes to the *Mass Properties* screen described below.

Fourbar Slider Follower Train

Figure 20 shows the input screen for a fourbar slider linkage. The *Fourslide Mode* defines the kinematic circuit of the linkage which can be either open or crossed as desired. For a definition of these terms see reference 2. The "Angle from Line of Link 2 to Roller Arm" parameter defines the included angle between the kinematic link 2 and the arm radius to the roller. The link lengths are always defined as the pin-to-pin distances of each

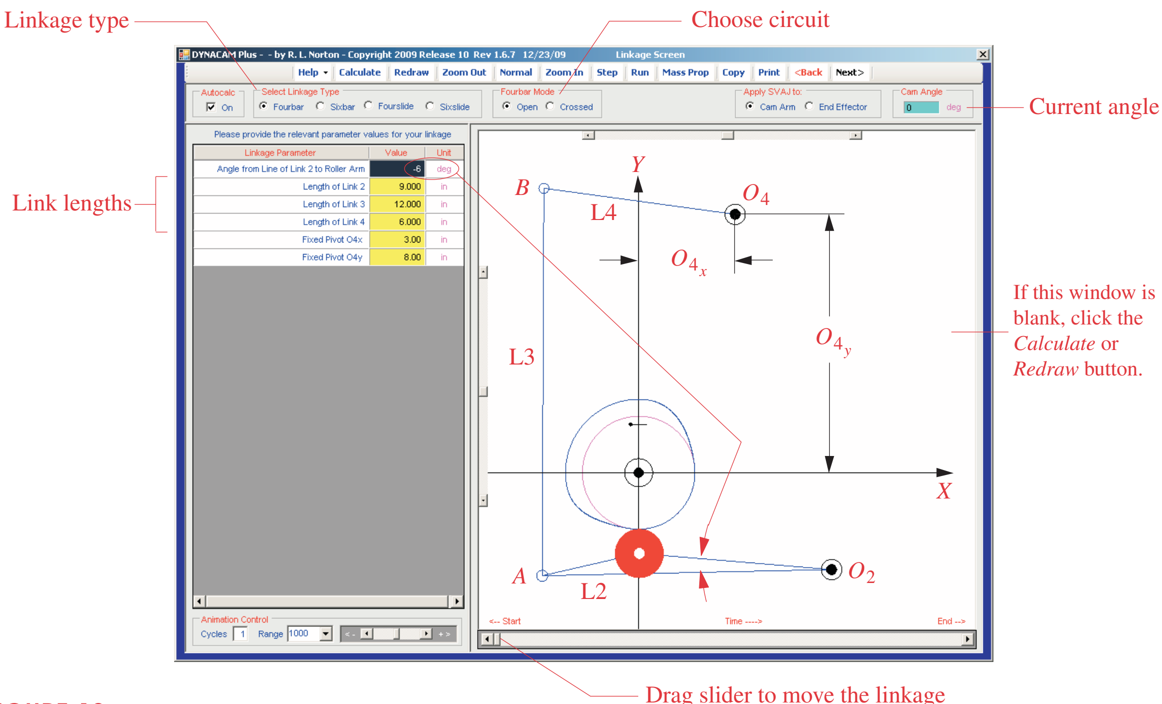

FIGURE 19

Input Data screen for a Fourbar Linkage cam-follower train link. Link numbering is standardized with link 1 always the ground link, link 2 the link directly driven by the cam and pivoted to ground, link 3 a floating coupler or connecting rod, and link 4 the output slider in this case, running against ground. The Offset is the perpendicular distance between the axis of sliding and the pivot O_2. The Slider Angle is the angle between the global X axis and the axis of sliding.

Note that is possible to input a set of linkage data that is impossible to solve as the links may not be able to connect if their lengths are not compatible. An error message will appear when the calculation is done if this is the case. Once calculated, the linkage can be animated by using the Step button to advance it one cam increment at a time or by dragging the slider bar at the bottom of the screen to left or right. The *Mass Prop* button goes to the *Mass Properties* screen described below.

Sixbar Linkage Follower Train

Figure 21 shows the sixbar linkage screen . The *Stage 1 and Stage 2 Modes* define the kinematic circuits of each stage of the linkage, which can independently be either open or crossed. For a definition of these terms see reference 2. The "Angle from Line of Link 2 to Roller Arm" parameter defines the included angle between the kinematic link 2 and the arm radius to the roller. The link lengths are always defined as the pin-to-pin distances of each link. Link numbering is standardized with link 1 always the ground link, link 2 the link directly driven by the cam and pivoted to ground, link 3 a floating coupler or con-

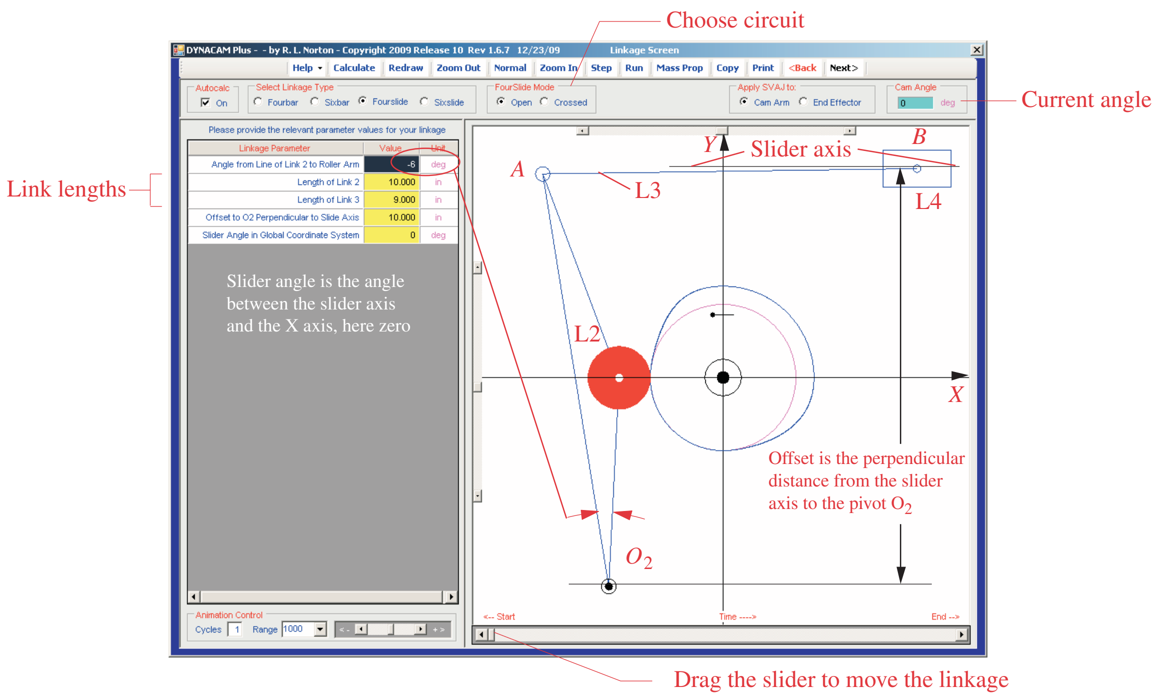

FIGURE 20

Input Data screen for a Fourbar Slider cam-follower train necting rod, link 4 a rocker pivoted to ground at O_4 that connects the two couplers, link 5 the second coupler, and link 6 the output rocker, pivoted to ground at O_6. The global coordinates of both O_4 and O_6 must be defined in the cam *XY* coordinate system. Link 4 has two branches, the one labeled 4 and shown in black that connects link 3 to O_4, and the one labeled 4a in color that connects O_4 to link 5 at I_{45}. The angle between branches 4 and 4a (which are part of the same link) must be defined also.

It is possible to input a set of linkage data that is impossible to solve as the links may not be able to connect if their lengths are not compatible. An error message will appear when the calculation is done if this is the case. Once calculated, the linkage can be animated by using the *Step* or *Run* buttons or by dragging the slider bar at the bottom of the screen to left or right. The *Mass Prop* button goes to the *Mass Properties* screen described below.

Sixbar Slider Follower Train

Figure 22 shows the input screen for a sixbar slider linkage. The Linkage Modes define the kinematic circuits of each stage of the linkage which can independently be either open or crossed. For a definition of these terms see reference 2. The "Angle from Line of Link 2 to Roller Arm" parameter defines the included angle between the kinematic link 2 and the arm radius to the roller. Link lengths are defined as the pin-to-pin distances of each link. Link 1 is the ground link, link 2 the link directly driven by the cam and pivoted to ground, link 3 a floating coupler, link 4 a rocker pivoted to ground at O_4 that connects

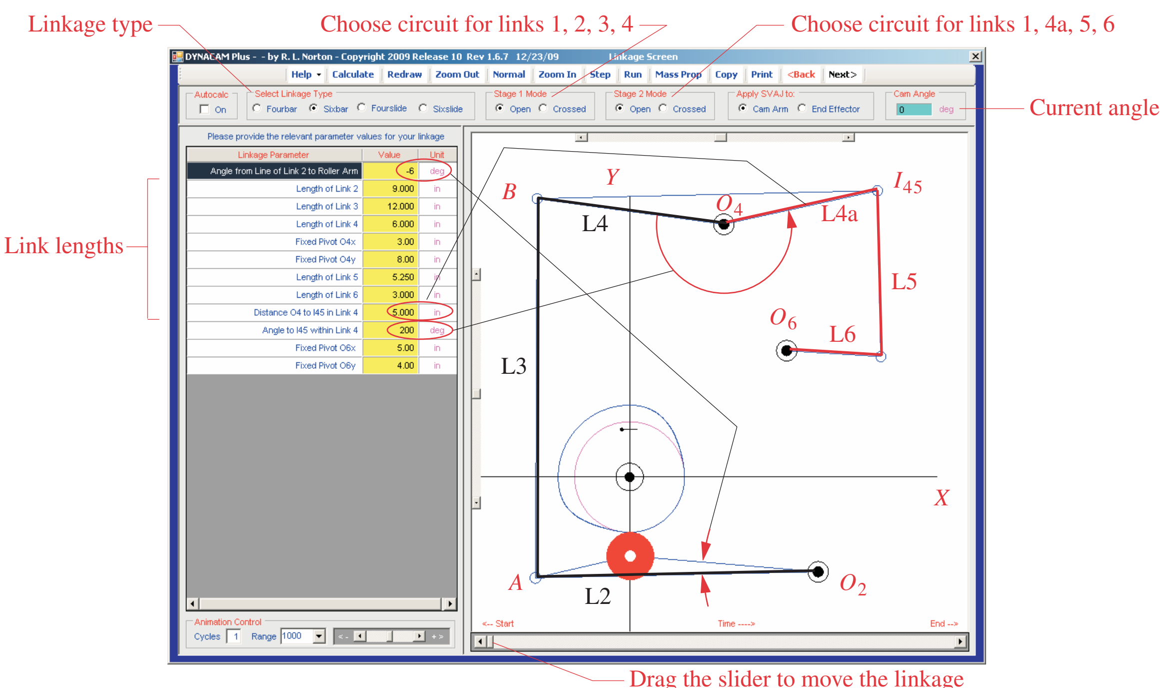

FIGURE 21

Input Data screen for a Sixbar Linkage cam-follower train the two couplers, link 5 the second coupler, and link 6 the output slider, running against ground. The global coordinates of O_4 must be defined in the cam XY coordinate system. Link 4 has two branches, the one labeled 4 and shown in black that connects link 3 to O_4, and the one labeled 4a in color that connects O_4 to link 5 at I_{45}. The angle between branches 4 and 4a (which are part of the same link) must be defined. Offset is the perpendicular distance between the axis of sliding and the pivot O_2. The Slider Angle is the angle between the global X axis and the axis of sliding.

It is possible to input a set of linkage data that is impossible to solve as the links may not be able to connect if their lengths are not compatible. An error message will appear when the calculation is done if this is the case. Once calculated, the linkage can be animated by using the *Run* or *Step* buttons or by dragging the slider bar at the bottom of the screen to left or right. The *Mass Prop* button goes to the *Mass Properties* screen described below.

Mass Properties Screen

Figure 23 shows the *Mass Properties* screen. The CG locations and mass properties of each link may be entered here. Proper units must be used. The stiffness parameters for each link can also be entered. When calculated, this screen will compute the effective mass and effective spring values for the dynamic models in the program, these data will be automatically transferred to those screens. The raw data will be exported to the linkage files for import to other programs.

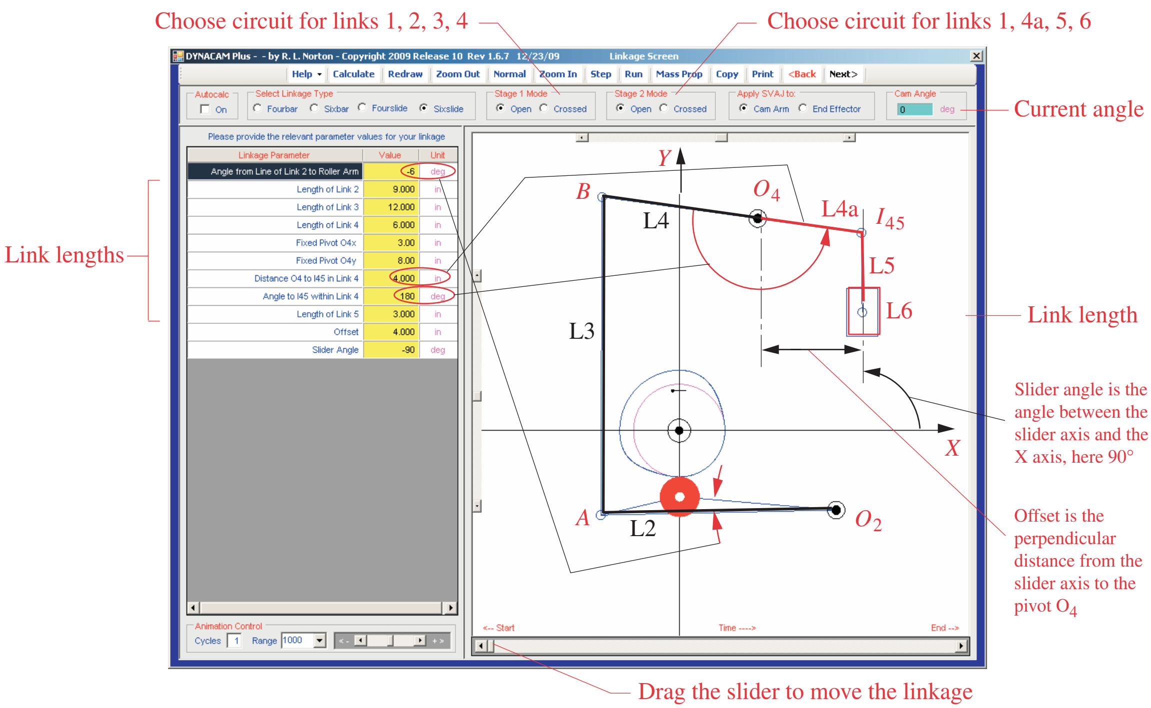

FIGURE 22

Input Data screen for a Sixbar Slider cam-follower train

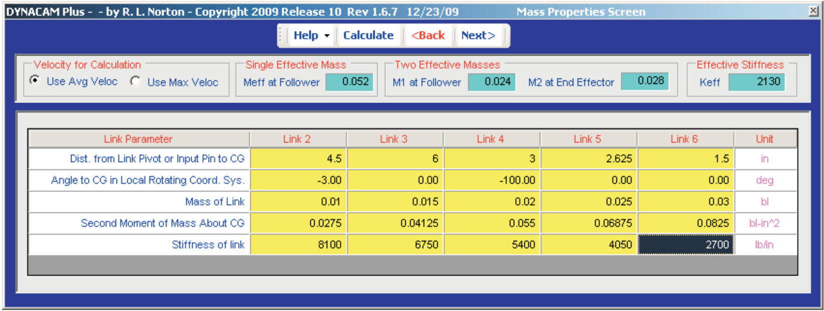

FIGURE 23

Mass Properties screen in Dynacam

IMPORTING MEASURED CAM DATA

Sometimes one needs to reverse engineer an existing cam for which there may be no data available on its design or mathematical functions. If a cam profile has been measured with reasonable accuracy, those data can be imported to DYNACAM and it will fit an interpolating function to approximate the cam's displacement, velocity and acceleration functions. Figure 24 shows the *Import* screen. Instructions are available from the Help menu on the screen. In brief, the measured data must be in *R-Theta* coordinates and can be at any uniform angular increments. The data must be placed in a text file, one pair of tab-separated R-theta numbers per line. DYNACAM will determine how many pairs are in the set when reading the data. There should not be any header information in the file, just data.

Three interpolation methods are provided, cubic spline, cubic spline with Lanzcos smoothing, and Fourier series. The cubic spline methods are preferable if dwells are present because the Fourier series will add ripple to dwells. But the Fourier method may do a better job of smoothing noisy data.

The desired angular increment at which the interpolation is to be done should be selected from the drop-down at the left before importing data. The units system should also be preselected. The *Import Data* button will open a browser to find the file, import it and display the raw contour as an *S*-diagram in the upper window. The *Fit Functions* button will do the interpolation. First the selected function is fitted to the imported data then it is differentiated analytically (not numerically) to get velocity and acceleration. These functions are then resampled at the chosen delta theta increment for display and export.

The *Show Data* button will display the original imported data and the displacement function fitted as shown in Figure 24. The *Show Derivatives* button will show the velocity and acceleration functions from the interpolated curve as shown in Figure 25. *Save Functions and Exit* stores the interpolated functions in the normal locations for DYNACAM data, making them available for plotting, printing, and further calculation.

Exiting this screen return you to the *Home* screen where the SVAJ button will be grayed out so as to prevent inadvertent overwriting of the imported data. All other program functions can be applied to the interpolated cam functions.

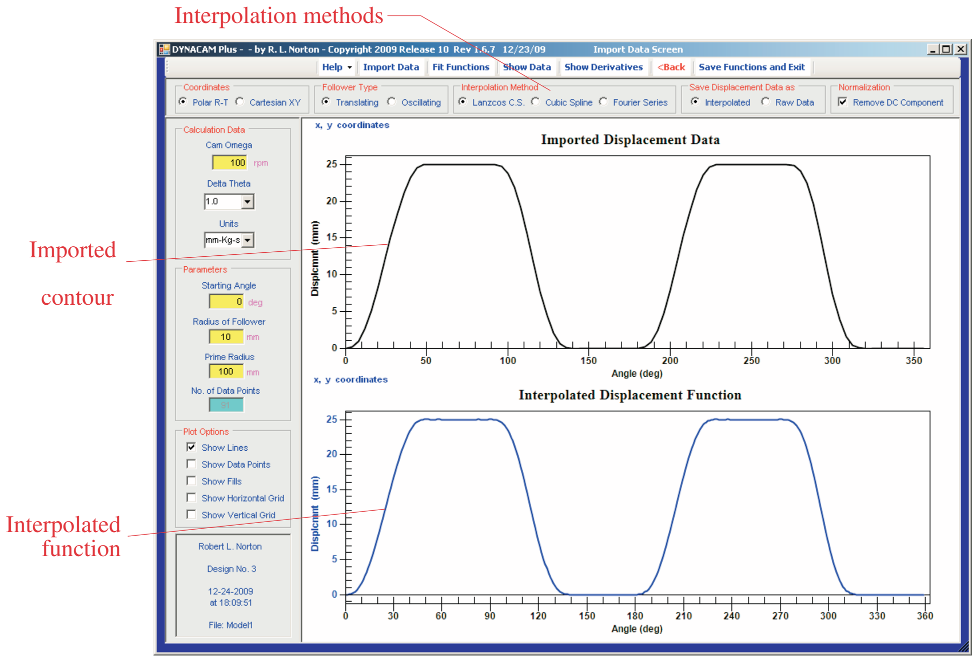

FIGURE 24

Import Data screen in Dynacam

Probably the best way to utilize this feature in DYNACAM is to use the interpolated derivatives to determine what functions may have been used in the original cam design and where the dwells start and stop. With this information, a new cam can be designed using DYNACAM's built-in functions. This approach will result in a more accurate and dynamically superior cam than will using the interpolated functions as is.

OTHER

All the data calculated at each stage is saved and becomes available for plotting, printing, or exporting to disk. See General Program Operation for information on *New, Open, Save, Save As, Plot, Print, Units*, and *Quit* functions.

REFERENCES

1 **Norton, R. L.** *Cam Design and Manufacturing Handbook 2ed*. Industrial Press: New York. 2008.

2 **Norton, R. L.** *Design of Machinery 4ed*. McGraw-Hill: New York. 2008.

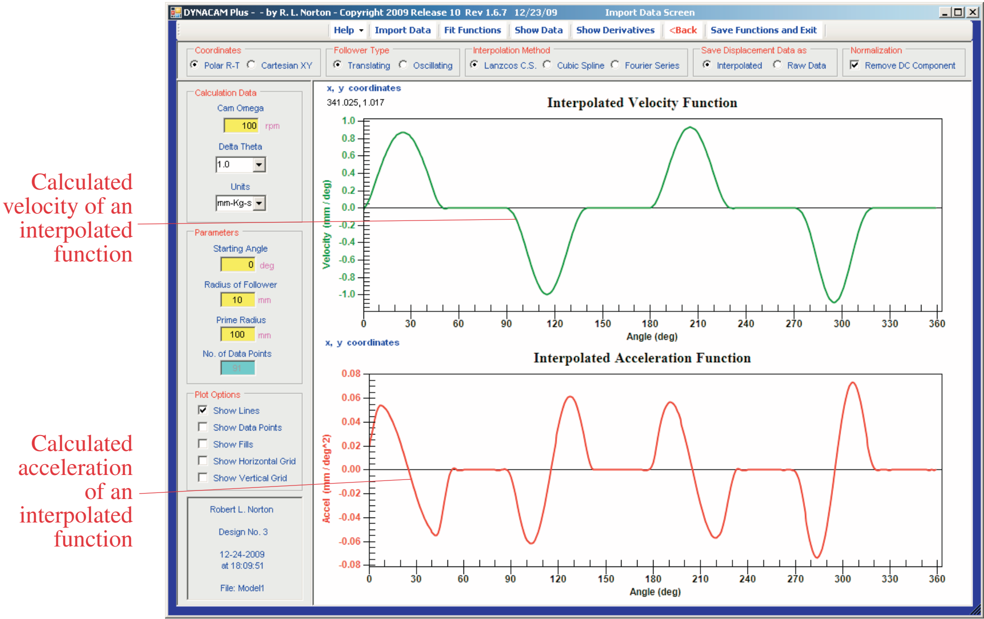

FIGURE 25

Velocity and acceleration of an imported and interpolated function

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Appendix

THE HISTORY OF PROGRAM DYNACAM

I wrote the first version of this program in 1979 when working as a senior engineer at Polaroid Corp. The graphics minicomputer had recently been invented and Polaroid had purchased an early example, a Hewlett Packard. Recognizing that the company needed a better means to design cams for their production machines and wanting to learn how to program the HP, I wrote an interactive program for cam design and called it ANACAM.

This program was left behind when I went on to teach mechanical engineering at WPI in 1981. WPI had recently purchased five Apple II computers, which were among the vanguard of graphics microcomputers just becoming available at the time. These were then the only graphics-capable computers at the school. The school had a Vax mainframe for all general computation, but graphics terminals for it were still in the future. The Apples were sitting unused in a locked classroom and I asked to use them. To learn how to program them and to create teaching tools for kinematics, I rewrote a much reduced version of ANACAM on the Apple II and renamed it DYNACAM.

The Apple II version was fairly crude, menu driven, memory limited, and slow, but it served the purpose as a teaching tool, along with other programs I wrote for student use such as FOURBAR, FIVEBAR, SLIDER, SIXBAR, ENGINE, and MATRIX. Over the next decades, computers went through huge changes. WPI followed the trends, migrating to Macintosh, DOS, and Windows in all its gestations (95, 98, 2000, XP, Vista, 7). Each time the school switched computers and operating systems, I was forced to rewrite these programs so that students could still use them. Languages used were Apple Basic, DOS Basic, QuickBasic, Visual Basic 4 through 6, and now Visual Studio VB.NET.

As the program was rewritten, it also grew with the addition of features and capabilities. Some of these were the result of student projects done at WPI. Those students are credited in the program's splash screen. The biggest changes came about as a result of a sabbatical done at The Gillette Company in Boston in 1996, where I found a number of my former students using their student copy of DYNACAM to actually design cams for production machines. DYNACAM was a very limited, menu-driven, DOS program at the time. For example, it only handled translating followers and most of Gillette's cams have oscillating followers. So, I began adding features while working at Gillette on that sabbatical and took great advantage of interactions with their engineers to define what they needed the program to do. They also served as my beta testers (and still do). I simultaneously rewrote the code from scratch in Visual Basic. The result was what is now called the Professional Edition of DYNACAM. Release 9 became a mature, useful and well-debugged program for cam design used by over 70 companies worldwide.

DYNACAM 10 is a complete rewrite of release 9 from scratch and retains its feature set but has streamlined and more robust code. The old program had "grown like Topsy" and was somewhat convoluted and a bit of a patchwork that had become difficult to maintain. The new program is simpler to use with fewer screens and has much improved plotting capability. Suggestions for improvements are always welcome.

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