
SigFit

Release Notes
Version 2009R1



July 13, 2009

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Warning: Use of this program is subject to the terms of the Demo Software Agreement or the Software Agreement agreed upon in writing with the User's authorized representative(s). Installation of this software indicates acceptance of the Software Agreement.

Technical Support

IMPORTANT: When contacting technical support please provide the following:

1. Your .sig file defining your SigFit analysis.
2. All files referenced by the .sig file. This includes FEA model files, FEA results files, OLOAD files, VECTOR files, etc.
3. The nature of the problem and the error you are seeing, if any.

Licensing Issues

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For more information about Sigmadyne visit our website at: www.sigmadyne.com.

The background theory used in SigFit is discussed in the following book & short courses:

Doyle, K., Genberg, V., Michels, G., **Integrated Optomechanical Analysis**, TT58, SPIE Press, October, 2002.

Integrated Optomechanical Analysis short course available from Sigmadyne, Inc.

SigFit short course available from Sigmadyne, Inc.

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1 Summary

Version 2009-r1 includes the following new features: (see section 3)

- 1) Enhanced Line-of-Sight (LoS) Error Output
- 2) Decomposition of Drift and Jitter Components
- 3) Calculation of Jitter Induced MTF for LoS Error in Random Response Analysis
- 4) Expanded Documentation in Examples Manual
- 5) Double Field Format for NASTRAN Format LoS Error Equations
- 6) ANSYS Macro Improvements
- 7) ANSYS Format Support for LoS Error Equations
- 8) Expanded ANSYS Examples
- 9) Documentation of Results Plotting in ANSYS Workbench
- 10) Increased Control on Numbering in Equation Generation
- 11) No Model File Analysis Now Allowed
- 12) Internal Mesh Generation
- 13) New Surface Geometries
- 14) User Specifiable Units for Polynomial Surface Shapes
- 15) New Polynomial Fitting/Polynomial Disturbance/Polynomial Actuator Features
- 16) Polynomial Fitting of Legendre XY Polynomials
- 17) Polynomial Fitting of Fourier-Legendre Polynomials
- 18) Conic Constant Disturbance and Actuator
- 19) Model Slumping to Prescribed Optical Surface Shape
- 20) CSV Input/Output format for Grid Arrays (Hit Maps)
- 21) Center or Pixel Corner Grid Array Dimension Specification
- 22) Nodal Rotation Tolerance for ZEMAX Grid Sag Slope Data
- 23) Improved Warning for FE Geometry vs. Prescription Deviation Errors
- 24) Best-Fit Sphere Calculation on Undisturbed Optical Prescription
- 25) Increased FE Node Summary Output
- 26) Changes to ANSYS Format Nodal File
- 27) Change in Default DFREQ Parameter

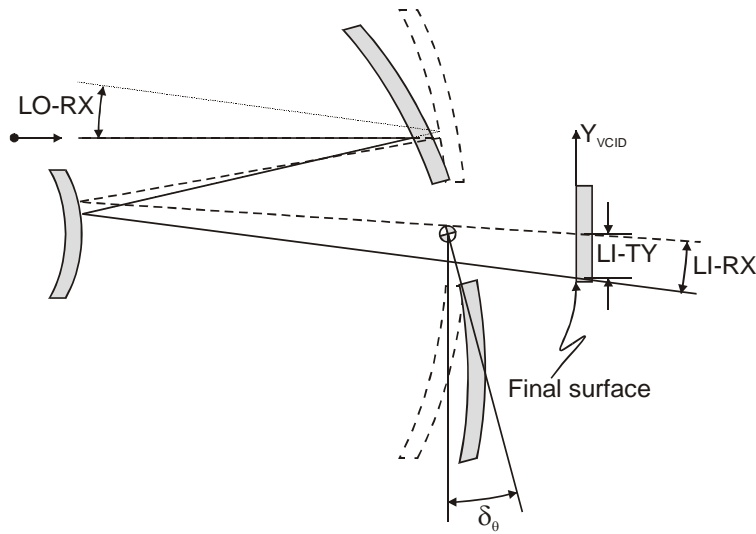
2 Installation and Upgrading:

Instructions for installing may be found in the Install-Instructions-v2009R1.pdf found at http://www.sigmadyne.com/sigweb/sigfit_download.htm.

3 New Features

3.1 Enhanced Line-of-Sight (LoS) Error Output

LoS error output has been extended to provide the angular LoS error in image space for use with afocal systems. The various LoS error measures are defined and labeled in the figure below.



For the telescope model in the Examples folder of the SigFit download, the output includes:

```
-----
Estimated Focal Length XZ Plane =      529.7132
Estimated Focal Length YZ Plane =      529.7132
Estimated Magnification XY Plane =       8.2234
Estimated Magnification YZ Plane =       8.2234
```

LoS Coefficients, Units= FEA units= in & rad

SID = surface Id

DOF = surface RB component in VCID system

LI = measured in focal plane VCID system

LI = Line-of-Sight in Image Space

LO = Line-of-Sight in Object Space

TX,TY = ray translation in X,Y directions in FE units

RX,RY = ray angle change about X,Y in Radians

SID	DOF	LI-TX	LI-TY	LI-RX	LI-RY	LO-RX	LO-RY
2	1	10.4343	0.0000	0.0000	0.1619	0.0000	0.0197
2	2	0.0000	10.4343	-0.1619	0.0000	-0.0197	0.0000
2	3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	4	0.0000	1059.4264	-16.4512	0.0000	-2.0000	0.0000
2	5	-1059.4264	0.0000	0.0000	-16.4512	0.0000	-2.0000
2	6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3	1	-9.4343	0.0000	0.0000	-0.1598	0.0000	-0.0178
3	2	0.0000	-9.4343	0.1598	0.0000	0.0178	0.0000
3	3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3	4	0.0000	-117.8252	2.0000	0.0000	0.2224	0.0000
3	5	117.8252	0.0000	0.0000	2.0000	0.0000	0.2224
3	6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5	1	-1.0000	0.0000	0.0000	0.0000	0.0000	-0.0019
5	2	0.0000	-1.0000	0.0000	0.0000	0.0019	0.0000
5	3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5	4	0.0000	0.0000	-0.9999	0.0000	0.0000	0.0000
5	5	0.0000	0.0000	0.0000	-0.9999	0.0000	0.0000
5	6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Rigid Body Error check on LoS Equations
 Unit Rigid Body motions given in CID= 1000
 RB Translation =1 FE unit, RB Rotation = 1 radian

For Centerline Ray, check the following
 For RB-TX & RB-TY: LI-TX = LI-TY = 0.0
 For RB-RX & RB-RY: LI-TX = LI-TY = Focal Length
 For RB-TX & RB-TY: LO-RX = LO-RY = 0.0
 For RB-RX & RB-RY: LO-RX = LO-RY = 1.0

Input DOF		LI-TX	LI-TY	LI-RX	LI-RY	LO-RX	LO-RY
RB-TX	1	0.0000	0.0000	0.0000	0.0021	0.0000	0.0000
RB-TY	2	0.0000	0.0000	-0.0021	0.0000	0.0000	0.0000
RB-TZ	3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
RB-RX	4	0.0000	529.7132	-8.2411	0.0000	-1.0000	0.0000
RB-RY	5	-529.7132	0.0000	0.0000	-8.2411	0.0000	-1.0000
RB-RZ	6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

The quantities LI-TX, LI-TY, LI-TV, LI-RX, LI-RY, LI-RV. LO-RX, LO-RY, LO-RV are output in dynamics file as transfer functions and PSD response functions.

3.2 Decomposition of Drift and Jitter Components

If the user desires the LoS errors to be decomposed into drift and jitter components then the integration time of the detector may be specified on the TIN field of the SYSDATA entry. The default value of TIN = 0.0 will result in no LoS drift calculation with all LoS error considered to be jitter LoS error. Example output is as follows:

LoS **DRIFT** Random Analysis Results:

1-sigma => contains peaks 68.3% time
 3-sigma => contains peaks 99.7% time [multiply 1-sigma results by 3]
 Zero-Xs => number zero crossings/unit time
 FP Surface Coordinate System used for X Y
 LI => Line of sight in Image Space
 LO => Line of sight in Object Space
 TX, TY => Translation in X, Y (FE units)
 RX, RY => Rotations about X, Y (Radians)
 TV, RV => Vector sum in XY plane

Results weighted for integration time (sec) = 0.010000

SID	Item	<---Displacement--->		<Velocity>	<Accel>
		1-sigma	Zero-Xs	1-sigma	1-sigma
DRIFT	LI-TX	8.2871E-04	0.0000E+00	4.8488E-01	3.5024E+02
DRIFT	LI-TY	2.1855E-11	0.0000E+00	1.1816E-08	7.9715E-06
DRIFT	LI-TV	8.2871E-04	0.0000E+00	4.8488E-01	3.5024E+02
DRIFT	LI-RX	3.6489E-13	0.0000E+00	1.9319E-10	1.2657E-07
DRIFT	LI-RY	1.3442E-05	0.0000E+00	7.7740E-03	5.5492E+00
DRIFT	LI-RV	1.3442E-05	0.0000E+00	7.7740E-03	5.5492E+00
DRIFT	LO-RX	4.1259E-14	0.0000E+00	2.2307E-11	1.5049E-08
DRIFT	LO-RY	1.5644E-06	0.0000E+00	9.1536E-04	6.6118E-01
DRIFT	LO-RV	1.5644E-06	0.0000E+00	9.1536E-04	6.6118E-01

LoS **JITTER** Random Analysis Results:

1-sigma => contains peaks 68.3% time
 3-sigma => contains peaks 99.7% time [multiply 1-sigma results by 3]

Zero-Xs => number zero crossings/unit time
 FP Surface Coordinate System used for X Y
 LI => Line of sight in Image Space
 LO => Line of sight in Object Space
 TX,TY => Translation in X,Y (FE units)
 RX,RY => Rotations about X,Y (Radians)
 TV,RV => Vector sum in XY plane

Results weighted for integration time (sec) = 0.010000

SID	Item	<---Displacement--->		<Velocity>	<Accel>
		1-sigma	Zero-Xs	1-sigma	1-sigma
JITTER	LI-TX	3.0390E-03	1.0270E+02	1.9613E+00	1.5418E+03
JITTER	LI-TY	7.1098E-11	9.8875E+01	4.4166E-08	3.4039E-05
JITTER	LI-TV	3.0390E-03	1.0270E+02	1.9613E+00	1.5418E+03
JITTER	LI-RX	1.1708E-12	9.6282E+01	7.0824E-10	5.3363E-07
JITTER	LI-RY	4.8746E-05	1.0169E+02	3.1149E-02	2.4317E+01
JITTER	LI-RV	4.8746E-05	1.0169E+02	3.1149E-02	2.4317E+01
JITTER	LO-RX	1.3422E-13	9.8875E+01	8.3378E-11	6.4259E-08
JITTER	LO-RY	5.7371E-06	1.0270E+02	3.7025E-03	2.9106E+00
JITTER	LO-RV	5.7371E-06	1.0270E+02	3.7025E-03	2.9106E+00

3.3 Calculation of Jitter Induced MTF for LoS Error in Random Response Analysis

As part of the LoS error response, MTF due to jitter will be output if the user supplies an LOSMTF entry. A total MTF is reported as the product of the MTF due to jitter and a nominal MTF that may be supplied by the user. Example output is as follows:

MTF function due to JITTER

Based on LI-TV 3.0390E-03 (1-sigma)

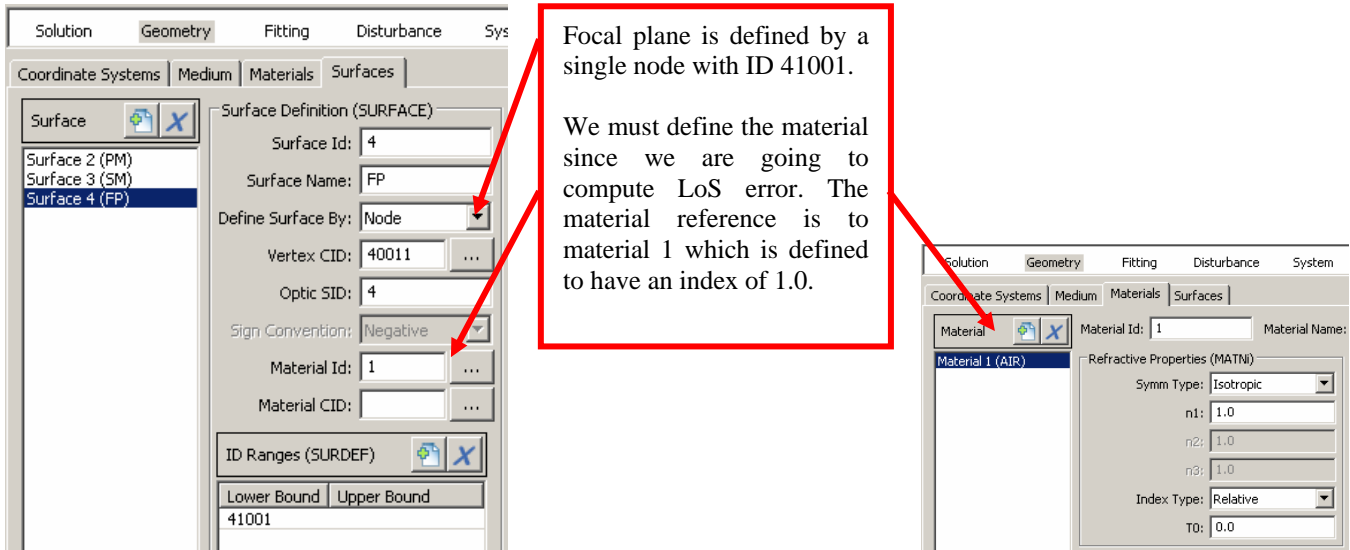
freq(cy/mm)	MTF-Jitter	MTF-Nom	MTF-Net
0.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00
1.0000E+00	8.8904E-01	8.0000E-01	7.1123E-01
2.0000E+00	6.2471E-01	6.0000E-01	3.7483E-01
3.0000E+00	3.4696E-01	4.0000E-01	1.3879E-01
4.0000E+00	1.5231E-01	2.0000E-01	3.0462E-02
5.0000E+00	5.2846E-02	0.0000E+00	0.0000E+00

Spatial frequency is input as cycles/mm or line-pair/mm. If MTF-Nom defaults to unity at all spatial frequencies if it is not specified otherwise. MTF-Net is the product of MTF-Jitter and MTF-Nom. The equations for MTF and the sensor weighting function are given in the SigFit Reference Manual.

As with other dynamic responses, both drift and jitter LoS error transfer functions and PSD response functions appear in the optional output file *jobname_dyn.csv*. Also each mode's percent contribution to the total appears in the *fit* file.

3.4 Expanded Documentation in Examples Manual

The documentation in the examples manual has been expanded including addition of labeled screen shots of the analysis input in VSigFit as shown below.



Focal plane is defined by a single node with ID 41001.

We must define the material since we are going to compute LoS error. The material reference is to material 1 which is defined to have an index of 1.0.

Optical models in ZEMAX and CODEV format have been included for some examples.

3.5 Double Field Format for NASTRAN Format LoS Error Equation

The single field NASTRAN format often does not allow enough precision for LoS equation to keep rigid body errors at an acceptable level. Therefore, generation of equations in double field format is now the default. The user may override the default and ask for single field. For the telescope example, a typical equation would be written as:

```

-----
$ Eqns for LoS, Units= FEA units= in & rad
GRID      9999000      3000      0.0      0.0      0.0      3000      36
GRID      9999001      3000      0.0      0.0      0.0      3000      1236
$
$ Image Space LIS-TX = Node id = 9999000 Component = 1
$--1----><-----2or6-----><-----3or7-----><-----4or8-----><-----5or9----->
mpc*
*          1          9999000          1 -1.00000000E+00
*          9002000          1  1.04343063E+01
*          9002000          5 -1.05942642E+03
*          9003000          1 -9.43431820E+00
*          9003000          5  1.17825200E+02
*          9005000          1 -1.00000000E+00
-----
    
```

3.6 ANSYS Macro Improvements

Several changes have been made to the macros used with ANSYS and ANSYS Workbench. The new macros can be found at C:/Program Files/Sigmadyne/SigFit/2009R1/ANSYS_Support.

3.7 ANSYS Format Support for LoS Error Equations

Equations for LoS error are now writable in ANSYS format in addition to the existing capability to write equations in NASTRAN format. ANSYS finite element entities are written in APDL command format and may be executed with the /input command or by File/Read Input From... in the GUI. SigFit will write nodes and RBE3's for each optical surface to compute rigid body motions during a solve in ANSYS. Nodes and CE constraint equation commands are then written to compute LoS error quantities. A dummy mass element is written for each node defined so that the nodes degrees of freedom will be added to the current DOF set. See the Reference Manual and Dictionary for more details. In addition Example 9 of the Examples Manual illustrates this feature in a telescope model.

3.8 Expanded ANSYS Examples

The set of SigFit examples using ANSYS finite element models has been greatly improved and expanded. ANSYS model files are now included as .inp files importable with the */input* command or *File/Read Input From...* GUI pick. See the folder location C:\Program Files\Sigmadyne\SigFit\2009R1\Examples\ansys for the ANSYS example set.

3.9 Documentation of Results Plotting in ANSYS Workbench

While there is currently no way to plot SigFit results directly in ANSYS Workbench, SigFit results may be plotted in ANSYS Classic quite easily from within the ANSYS Workbench environment. From the Project tab in ANSYS Workbench pick the desired analysis under *Open analysis in ANSYS*. Results from SigFit may then be plotted by following the plotting procedure for ANSYS Classic. See the section in the Reference Manual titled *Interfaces/Interface to Graphical Software/Interface to ANSYS*.

3.10 Increased Control on Numbering in Equation Generation

Entries EQNLOS, EQNPOL, and EQNRES have two new fields added, NUMSDIG and NUMPDIG. These fields allow the user to specify how many digits are to be used for surface number and polynomial term when finite element entities are generated. For example, the node and RBE3 ID used for computing rigid body motion will be assigned an ID of

$$\text{STRTDIGS} \times 10^{\text{NUMSDIG}} \times 10^{\text{NUMPDIG}} + \text{SID} \times 10^{\text{NUMPDIG}}$$

If STRTDIGS is 9 and NUMSDIG and NUMPDIG are both 3 then the rigid body motion grid ID for the surface whose SID = jjj will be 9,jjj,000. So surface 2 will have a rigid body motion ID of 9002000. If NUMSDIG and NUMPDIG are set to 2 then the ID will be 90200.

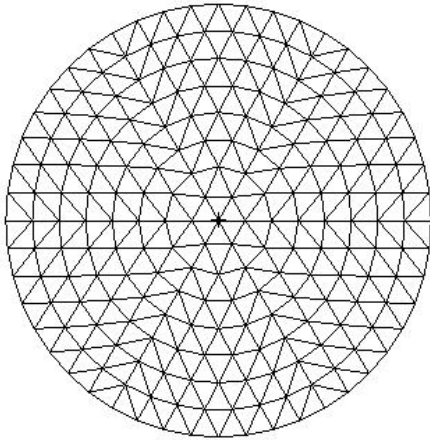
This is a very important control when using ANSYS because ANSYS allocates memory based on ID numbers and not on the actual number of nodes. A model with a single node 9000000 will require allocation of an extraordinary amount of memory and may not even run on some machines. Therefore, this control has been added to allow users of ANSYS to more effectively control the numbering of finite element entities in equation generation. For more details see the documentation for the EQNLOS, EQNPOL, and EQNRES entries in the Dictionary.

3.11 No Model File Analysis Now Allowed

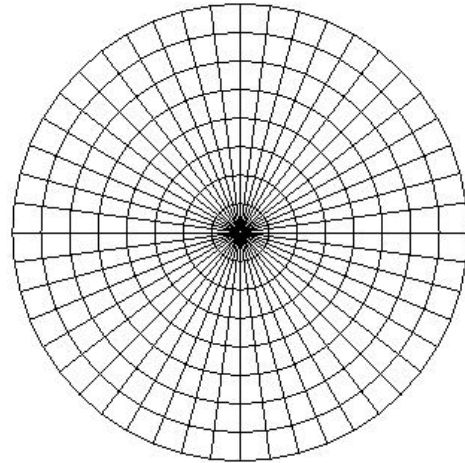
For some analyses a model file is not required. In such cases the user may now leave the model file specification blank. For example, in LoS error equation generation the only input required is the vertex coordinate system for each surface and the optical prescription. As long as the necessary data is included in the sig file, LoS equations will be generated. To use these in a finite element model, the user must connect the ‘dummy’ nodes created to the FE model. By specifying a finite element model and linking each surface to the finite element entities as previously required, these connections are generated automatically.

3.12 Internal Mesh Generation

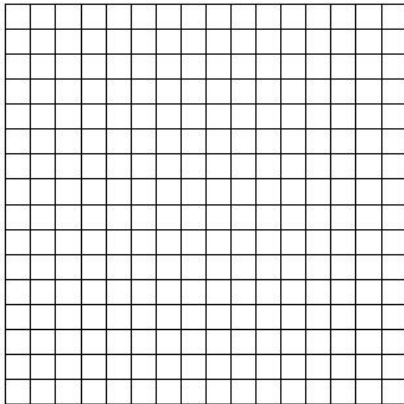
On the SURDEF entry SDEFINE may be set to MESH to request SigFit to internally create nodes and elements on the surface, rather than obtaining finite element entities from the model file. This is a useful option for viewing, combining, and converting polynomials and seeing the results graphically. The required new entry is SURMESH giving the shape and resolution of the meshed surface. Optional shapes are ellipse (circle), rectangle, hexagon, circle (with various polar mesh options) and cylindrical.



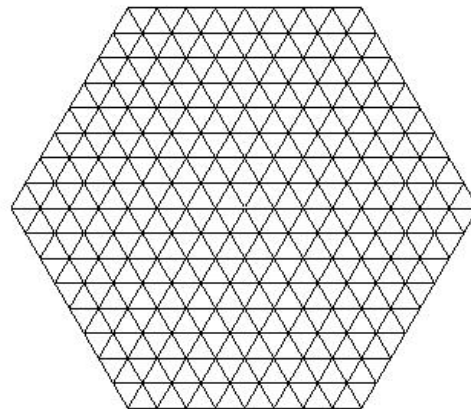
(a) Elliptical Mesh



(b) Polar Mesh



(c) Rectangular Mesh



(d) Hexagonal Mesh

3.13 New Surface Geometries

All existing surface polynomial types have been expanded so that the polynomials may be normalized to unit amplitudes or normalized to unit RMS. Normalization to unit amplitude is performed at locations defined by two new fields SNORM1 and SNORM2. Normalization to unit RMS is performed over the area defined by the same SNORM1 and SNORM2 fields. SNORM2 is not required in all polynomial formulations and the interpretations of SNORM1 and SNORM2 vary among the various polynomial types. An integer “1” is tagged to the polynomial name to indicate normalization to unit RMS. The surface polynomial prescription types are now compatible with all fitted types. The complete list of surface types supported in v2009R1 are as follows:

FLAT	Flat surface type. No geometry parameter cards required. (Default)
CONIC	Conic surface type. Uses ROC and CK to define the vertex radius-of-curvature and conic constant.
BICONIC	Biconic surface type. Uses ROC, ROC2, CK and CK2 to define the vertex radii-of-curvature and conic constants in the X and Y directions, respectively, of the VCID system.
ANAMOR	Anamorphic surface type. Uses ROC, ROC2, CK and CK2 to define the vertex radii-of-curvature and conic constants in the X and Y directions, respectively, of the VCID system as well as SURPOLY entries to define the anamorphic coefficients.

ASPH	Aspheric surface type. Uses ROC and CK to define the vertex radius-of-curvature and conic constant as well as SURPOLY entries to define the aspheric coefficients. Normalized to 1.0 at SNORM1
ASPH1	Same as ASPH except normalized to RMS=1.0
ASPHE	Aspheric surface type with only even powers. Uses ROC and CK to define the vertex radius-of-curvature and conic constant as well as SURPOLY entries to define the aspheric coefficients. Normalized to 1.0 at SNORM1
ASPHE1	Same as ASPHE except normalized to RMS=1.0
ZRN	Zernike surface type. Uses ROC and CK to define the vertex radius-of-curvature and conic constant as well as SURPOLY entries to define the Zernike polynomial coefficients. Normalized to 1.0 at SNORM1..
ZRN1	Same as ZRN except normalized to RMS=1.0
ZFR	Fringe Zernike surface type. Uses ROC and CK to define the vertex radius-of-curvature and conic constant as well as SURPOLY entries to define the Zernike polynomial coefficients. Normalized to 1.0 at SNORM1.
ZFR1	Same as ZFR except normalized to RMS=1.0.
AZRN	Zernike surface type. Uses ROC and CK to define the vertex radius-of-curvature and conic constant as well as SURPOLY entries to define the Zernike polynomial coefficients. Normalized to 1.0 at SNORM1.
AZRN1	Same as AZRN except normalized to RMS=1.0.
XY	XY polynomial surface type. Uses ROC and CK to define the vertex radius-of-curvature and conic constant as well as SURPOLY entries to define the XY polynomial coefficients. Normalized to 1.0 at SNORM1
XY1	Same as XY except normalized to RMS=1.0.
LEG	Legendre polynomial surface type. Uses ROC and CK to define the vertex radius-of-curvature and conic constant as well as SURPOLY entries to define the LEG polynomial coefficients. Normalized in X to 1.0 at SNORM1, in Y to 1.0 at SNORM2.
LEG1	Same as LEG except normalized to RMS=1.0
GRCONIC	Near cylindrical geometry for grazing incidence optics. Uses ROC and CK to define the vertex radius-of-curvature and conic constant.

Note that most optics programs use amplitude normalization to define surface geometry. Also most optics programs do not have AZRN or LEG surface types. This new feature allows surfaces to be defined as ZRN for CodeV normalization or ZRN1 for Zemax normalization. For LEG polynomials see the discussion of Legendre polynomials below. The GRCONIC surface is for the definition of grazing incidence surfaces which can be fit with Fourier-Legendre polynomials (see below).

3.14 User Specifiable Units for Polynomial Surface Shapes

The user may now specify the units used to express polynomial shapes used to define the optical prescription shape of surfaces. The options for this setting are shown below. Note that the default is backwards compatible with pre-v2009R1 operation.

OPT	Units of optic model. (Default)
FE	Units of FE model.
IN	Inches.
MM	Millimeters.
CM	Centimeters.
M	Meters.

3.15 New Polynomial Fitting/Polynomial Disturbance/Polynomial Actuator Features

When fitting Zernikes to a disturbance over an optical surface, the geometry is normalized to a unit circle by dividing each node's radial position by a normalizing radius ($\rho_j = r_j/RNORM$). In previous versions of SigFit, RNORM was determined by the SURAPER entry. If there was no SURAPER defined by the user, then RNORM was determined from the maximum radial node position of all the nodes on a given optical surface. While this process is still implemented in V2009R1, the user

can now override the determination of RNORM by specifying the value on the FITPOLY entry through two new fields, FNORM1 and FNORM2. This override applies to all polynomial types in SigFit. For details, see the FITPOLY entry in the SigFit dictionary. There are similar new normalization options on the specification of polynomial disturbances and actuators on entries DPPRM and APPRM, respectively.

In addition to RNORM, the polynomials may be normalized to unit amplitude at $r=RNORM$ or to unit RMS over the area of the circle of $r=RNORM$. An integer “1” is tagged to the polynomial name to indicate normalization to unit RMS. The surface polynomial prescription types are now compatible with all fitted types. The complete list of polynomial fitting types supported in v2009R1 are as follows:

ZRN	Standard Zernike polynomials. Each term’s amplitude is normalized to 1.0 at a radius of FNORM1.
ZRN1	Same as ZRN except each term’s RMS is normalized to 1.0 within a radius of FNORM1.
ZFR	Fringe Zernike polynomials. Each term’s amplitude is normalized to 1.0 at a radius of FNORM1.
ZFR1	Same as ZFR except each term’s RMS is normalized to 1.0 within a radius of FNORM1.
AZRN	Annular Zernike polynomials. Each term’s amplitude is normalized to 1.0 at a radius of FNORM1.
AZRN1	Same as AZRN except each term’s RMS is normalized to 1.0 within a radius of FNORM1.
ASPH	Aspheric polynomials including even and odd powered terms. Each term’s amplitude is normalized to 1.0 at a radius of FNORM1.
ASPH1	Same as ASPH except each term’s RMS is normalized to 1.0 within a radius of FNORM1.
ASPHE	Aspheric polynomials including only even powered terms. Each term’s amplitude is normalized to 1.0 at a radius of FNORM1.
ASPHE1	Same as ASPHE except each term’s RMS is normalized to 1.0 within a radius of FNORM1.
XY	XY polynomials. Each term’s amplitude is normalized to 1.0 at $X = FNORM1$ and $Y = FNORM1$.
XY1	Same as XY except each term’s RMS is normalized to 1.0 within the boundary $X = \pm FNORM1, Y = \pm FNORM1$.
LEG	Legendre polynomials. Each term’s amplitude is normalized to 1.0 at $X = FNORM1$ and $Y = FNORM2$.
LEG1	Same as LEG except each term’s RMS is normalized to 1.0 within the boundary $X = \pm FNORM1, Y = \pm FNORM2$.
FLG	Fourier-Legendre polynomials. Each term’s amplitude is normalized to 1.0 at $Z = FNORM1$.
FLG1	Same as FLG except each term’s RMS is normalized to 1.0 within the boundary $Z = \pm FNORM1, \theta = \pm\pi$.

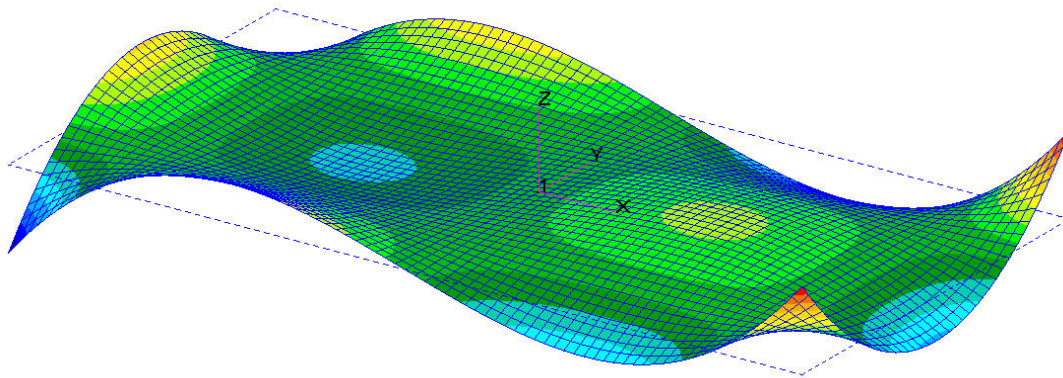
This new feature allows the user to select ZRN for CodeV standard Zernikes or ZRN1 for Zemax standard Zernikes. In previous versions, SigFit would only fit ZRN, but convert to ZRN1 on output to Zemax files. If ZRN1 is selected, all SigFit listings of Zernikes (fit file tables, CSV files, etc) will be RMS normalized. Note that most optics programs do not have AZRN, LEG or FLG polynomial types.

For a discussion of LEG and FLG see the following sections.

3.16 Polynomial Fitting of Legendre XY Polynomials

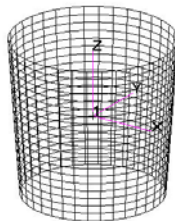
Legendre polynomials in X and Y are now available for polynomial fitting and polynomial input as disturbance or actuator influence function. For rectangular geometries the normalization in X and Y are based on the extent in each direction independently. Equations are given in the SigFit Reference Manual. Applications for Legendre polynomials are usually

rectangular optics. An example plot of a Legendre polynomial of order $N=3$, $M=2$ where $N=X$ order, $M=Y$ order. Note that most optical programs (CodeV, Zemax, Oslo) do NOT support Legendre polynomials.



3.17 Polynomial Fitting of Fourier-Legendre Polynomials

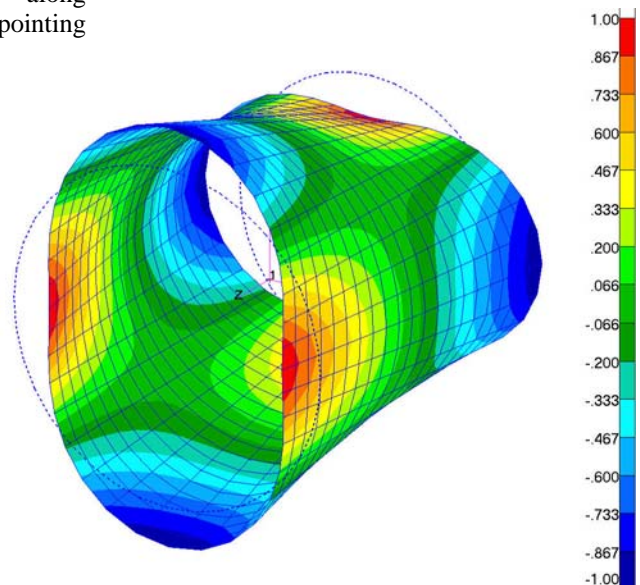
Optics used in grazing incidence telescopes are often called near-cylindrical optics. The NASA Chandra X-Ray Observatory is an example of a system using grazing incidence optics. Fourier-Legendre polynomials are generally the most convenient set of polynomials for fitting surface deformations of such optics.



Polynomial displacements along surface normal, positive pointing towards axis

FCID = fitting coordinate system centered on optic segment, offset from VCID along Z axis

VCID = vertex coordinate system at vertex of conic surface



Fourier-Legendre wave numbers: Axial $N = 1$ Circumferential $M = 2$

Currently, the surface deformation direction must be normal (ASAG=NORM on the SOL entry). Fitting of sag deformations is not yet supported. In addition, the optical prescription of the surface must be conic as defined in the vertex coordinate system.

The current release limits GRCONIC grazing incidence optics to surface fitting with Fourier-Legendre (FLG) polynomials. GRCONIC optics are NOT supported for adaptive analysis, dynamic analysis, thermo-optic analysis, or stress-optic analysis.

Also HitMaps are NOT supported for input/output to GRCONIC surfaces. However, there are many planned improvements to the grazing surface analysis capability. Interested users should contact Sigmadyne to express their needs.

3.18 Conic Constant Disturbance and Actuator

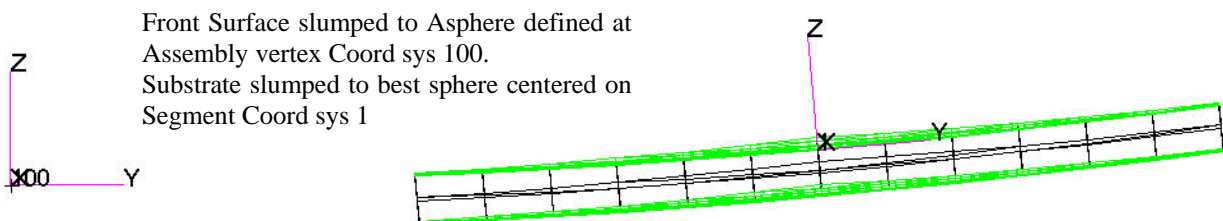
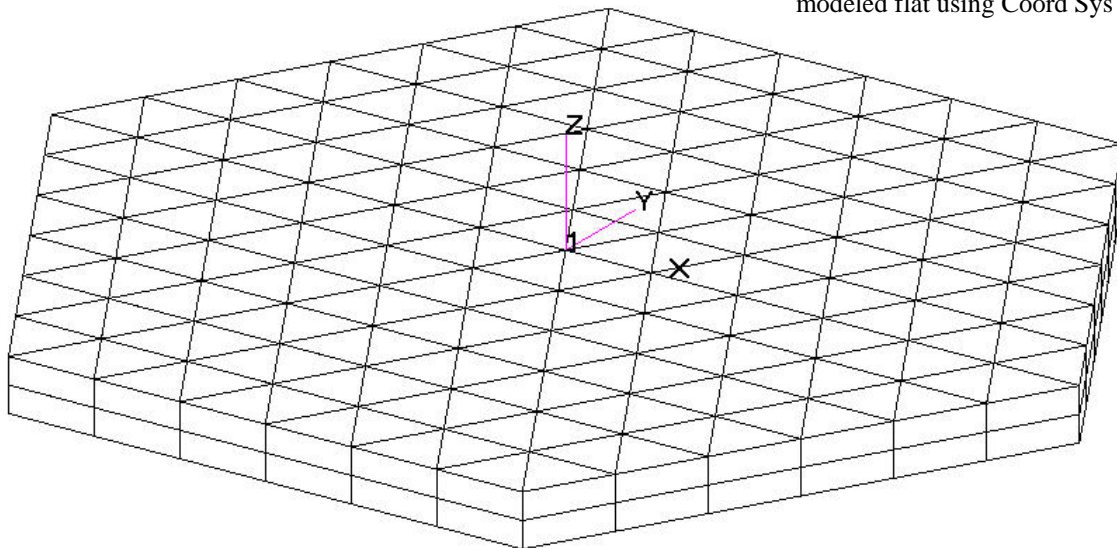
The change in conic constant has been added as both a disturbance (DPCC) and actuator (APCC) influence function type. These combine with the change in radius-of-curvature functions (DPROC) and (APROC) to complete the re-definition of the base conic surface.

3.19 Model Slumping to Prescribed Optical Surface Shape

Creating FE models of many optical components such as light-weight mirrors in curved geometry is very time consuming. This new feature allows models to be created flat and then slumped to a desired curved geometry. Another use for this feature is to overcome the limitation that many CAD systems are unable to accurately represent common optical surface shapes. The SigFit slumping feature can modify an approximate FE model to locate nodes on the exact optical prescription.

As an example, an off-axis segment as shown below may be slumped in the Z direction of a local segment coordinate system, yet the prescription is defined in the assembly parent vertex system. SigFit will perform the required coordinate transformation and node relocation while maintaining the core strut alignment in the local system.

Example: Hex mirror segment modeled flat using Coord Sys 1



Front Surface slumped to Asphere defined at Assembly vertex Coord sys 100.
Substrate slumped to best sphere centered on Segment Coord sys 1

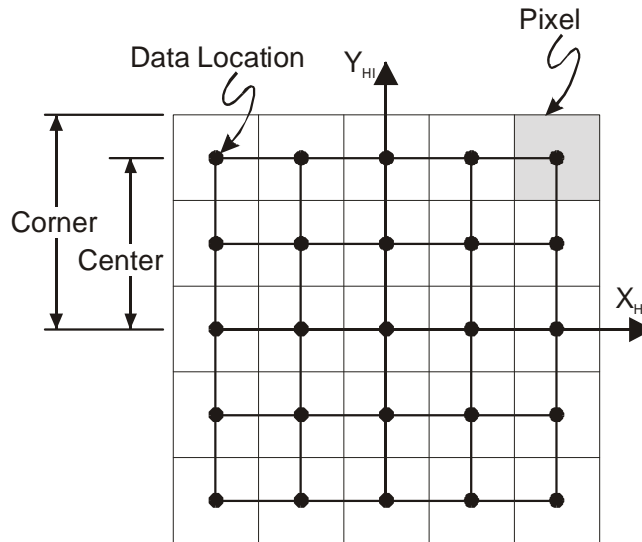
The slumping feature SLUMP is an analysis type pick on the SOL entry. The details of the coordinate systems used are given on the SLUMP entry. Currently, slumping is only available for NASTRAN models.

3.20 CSV Input/Output format for Grid Arrays (Hit Maps)

An additional I/O option (CSV) has been added to HITOUT, DHINP and AHINP. The CSV is a free-format, comma separated variable file. Input data may be comma separated or blank separated. Output data will be comma separated.

3.21 Center or Pixel Corner Grid Array Dimension Specification

In an attempt to allow full generality of I/O, the grid array overall dimensions may be specified as distances to pixel centers or pixel corners as shown in the figure below. The default is to interpret array dimensions to the pixel centers. This is a change from the interpretation of previous versions which would assume dimensions are to pixel corners. For arrays of at least 100 by 100 data points, this will result in very small changes to interpolated results. Significant changes in results due to this correction are likely indicators that the array fidelity chosen is too coarse. See HITOUT, DHINP, and AHINP entries for details.



3.22 Nodal Rotation Tolerance for ZEMAX Grid Sag Slope Data

When SigFit writes grid sag data for Zemax (both DAT & GARR Format) the slope terms are computed from the nodal rotation data. If the nodal rotation data for a surface is perfectly zero over the entire grid sag surface, then ZEMAX will compute its own slope data from the sag data using finite difference means. However, if any point contains non-zero data, this automatic calculation of slope data will not occur and the slope data will be used as written. This causes a problem for finite element results whose nodal rotations are numerically zero but not exactly zero as the use of such data will significantly alter the surface representation within ZEMAX.

Therefore, Sigfit now has a new parameter allowing users to specify a maximum value below which nodal rotations are assumed to be zero. This new parameter is PARAM,ROTZERO and its default value is 10^{-18} .

3.23 Improved Warning for FE Geometry vs. Prescription Deviation Errors

SigFit has always reported an 'Error' term in the surface geometry summary table where Error is the optical prescription Z position minus the node Z position. If this quantity is larger than $0.001 \times R_{\max}$ for any node, a warning message is issued at the bottom of the fit file. The value of Error for every node is given as the last result quantity in the nod file so that it may be plotted by the user. This value is also printed in the fit file if DIAGPRT is set to MED or HIGH. The Zerr label has been replaced with Error to accommodate cylindrical optics, whose prescription error is defined in the radial direction.

It is highly recommended that the node position Error be plotted for every model. It is a good check of input data, coordinate systems, units, etc. If Error is large, then the SigFit results may be incorrect. The SLUMP feature may be used to reduce the Error term. Example output is as follows.

```

Surface# = 1 SID = 1 #Node = 312 FEA Ar= 2.0320E+03
Vertex Coord: VCID = 1 R-B Ar= 1.9954E+03
Node R (VCID): Rmax = 2.5882E+01 Rmin = 5.2336E+00 Ravg = 1.7841E+01
Node T (VCID): Tmax = 3.4500E+02 Tmin = 0.0000E+00 Tavg = 1.7250E+02
Node X (VCID): Xmax = 2.5882E+01 Xmin = -2.5882E+01 Xavg = -1.0547E-15
Node Y (VCID): Ymax = 2.5882E+01 Ymin = -2.5882E+01 Yavg = 2.1406E-15
Node Z (VCID): Zmax = 3.4074E+00 Zmin = 1.3705E-01 Zavg = 1.7657E+00
Error (VCID): Emax = -9.3909E-05 Emin = -5.8052E-02 Eavg = -2.0134E-02

```

```

Fitting Coord: FCID = 1 # Fit = 300 Fit Ar= 1.9954E+03
Node R (FCID): Rmax = 2.5882E+01 Rmin = 5.2336E+00 Ravg = 1.7841E+01
Node T (FCID): Tmax = 3.4500E+02 Tmin = 0.0000E+00 Tavg = 1.7250E+02
Node Z (FCID): Zmax = 3.4074E+00 Zmin = 1.3705E-01 Zavg = 1.7657E+00
Poly Fitting : Norm = 2.5882E+01 Based on Max Node Position
Best Sphere : SRoC = 1.0176E+02 Based on FE model footprint

```

```

**Warning: Possible geometry Error for Surface SID= 1
Error = SurGeom - Node Location
Error (VCID): Emax = -9.3909E-05 Emin = -5.8052E-02 Eavg = -2.0134E-02

```

3.24 Best-Fit Sphere Calculation on Undisturbed Optical Prescription

SigFit now calculates the best-fit spherical surface to the undisturbed optical prescription given on SURGEOM and SURPOLY entries. The result of this fit is reported in the node summary table where SRoC = best-fit spherical radius-of-curvature and is expressed in FE units. Note that SRoC is based on the optical prescription only. The finite element node locations and displacements have no impact on this calculation. In addition, SRoC is only calculated for conic surfaces.

```

Surface# = 1 SID = 1 #Node = 312 FEA Ar= 2.0320E+03
Vertex Coord: VCID = 1 R-B Ar= 1.9954E+03
Node R (VCID): Rmax = 2.5882E+01 Rmin = 5.2336E+00 Ravg = 1.7841E+01
Node T (VCID): Tmax = 3.4500E+02 Tmin = 0.0000E+00 Tavg = 1.7250E+02
Node X (VCID): Xmax = 2.5882E+01 Xmin = -2.5882E+01 Xavg = -1.0547E-15
Node Y (VCID): Ymax = 2.5882E+01 Ymin = -2.5882E+01 Yavg = 2.1406E-15
Node Z (VCID): Zmax = 3.4074E+00 Zmin = 1.3705E-01 Zavg = 1.7657E+00
Error (VCID): Emax = -9.3909E-05 Emin = -5.8052E-02 Eavg = -2.0134E-02

```

```

Fitting Coord: FCID = 1 # Fit = 300 Fit Ar= 1.9954E+03
Node R (FCID): Rmax = 2.5882E+01 Rmin = 5.2336E+00 Ravg = 1.7841E+01
Node T (FCID): Tmax = 3.4500E+02 Tmin = 0.0000E+00 Tavg = 1.7250E+02
Node Z (FCID): Zmax = 3.4074E+00 Zmin = 1.3705E-01 Zavg = 1.7657E+00
Poly Fitting : Norm = 2.5882E+01 Based on Max Node Position
Best Sphere : SRoC = 1.0176E+02 Based on FE model footprint

```

```

**Warning: Possible geometry Error for Surface SID= 1
Error = SurGeom - Node Location
Error (VCID): Emax = -9.3909E-05 Emin = -5.8052E-02 Eavg = -2.0134E-02

```

3.25 Increased FE Node Summary Output

The FE node summary has been expanded to include a separate summary of only those nodes which remain after aperturing/obstructing. This can be a useful debugging tool when unexpected results are obtained due to incorrect aperturing or unit errors.

```

Surface# = 1 SID = 1 #Node = 312 FEA Ar= 2.0320E+03
Vertex Coord: VCID = 1 R-B Ar= 1.9954E+03
Node R (VCID): Rmax = 2.5882E+01 Rmin = 5.2336E+00 Ravg = 1.7841E+01

```

```

Node T (VCID): Tmax = 3.4500E+02   Tmin  = 0.0000E+00   Tavg  = 1.7250E+02
Node X (VCID): Xmax = 2.5882E+01   Xmin  =-2.5882E+01   Xavg  =-1.0547E-15
Node Y (VCID): Ymax = 2.5882E+01   Ymin  =-2.5882E+01   Yavg  = 2.1406E-15
Node Z (VCID): Zmax = 3.4074E+00   Zmin  = 1.3705E-01   Zavg  = 1.7657E+00
Error  (VCID): Emax =-9.3909E-05   Emin  =-5.8052E-02   Eavg  =-2.0134E-02

```

```

Fitting Coord: FCID =      1      # Fit =      300      Fit Ar= 1.9954E+03
Node R (FCID): Rmax = 2.5882E+01   Rmin  = 5.2336E+00   Ravg  = 1.7841E+01
Node T (FCID): Tmax = 3.4500E+02   Tmin  = 0.0000E+00   Tavg  = 1.7250E+02
Node Z (FCID): Zmax = 3.4074E+00   Zmin  = 1.3705E-01   Zavg  = 1.7657E+00
Poly Fitting : Norm = 2.5882E+01   Based on Max Node Position
Best Sphere  : SROc = 1.0176E+02   Based on FE model footprint

```

```

**Warning: Possible geometry Error for Surface SID=      1
Error = SurGeom - Node Location
Error  (VCID): Emax =-9.3909E-05   Emin  =-5.8052E-02   Eavg  =-2.0134E-02

```

3.26 Changes to ANSYS Format Nodal Files

Two issues regarding color contour plotting of SigFit results in ANSYS have mandated a change to the ANSYS format of the nodal files written by SigFit. The first problem relates to the fact that the ANSYS degrees-of-freedom (DOFs) allowable in ANSYS are limited by the features allowed by the user's ANSYS license. For example, DOFs such as VOLT and MAG are not allowable if electromagnetic field analysis is not allowed. The second issue is that the definition of DOFs requires consistency with the element type definitions of the elements attached to the nodes for which DOFs are being defined. If there is inconsistency between the DOFs and the element types then an attempt to plot results of inconsistent DOF results may crash ANSYS. User's of ANSYS versions prior to V11 may not experience these issues.

Several changes have been made to SigFit to accommodate these issues. A new entry, APLTDOF, has been added to allow the user to define the ANSYS DOFs to which SigFit results are to be sent. The default ANSYS DOFs have been changed to TE2 through TE26 allowing up to 25 values to be sent to the nodal file. The standard nodal results file uses 13 values while an interpolation visualization nodal file uses only one value. The number of result values per node in an extra nodal file is dictated by the number of polynomial terms fit. If more than 25 result values are generated by SigFit, then only 25 will be written and a warning will be issued to the .fit file.

In addition to the new APLTDOF entry, if the default values of the APLTDOF entry are used (TE2 through TE26) then commands will be written to the beginning of each nodal file to change all element types in the model to thermal element types so that TE DOFs may be plotted without an ANSYS crash. This change in element type definition will destroy prior element type definitions. Therefore, the user is advised to perform plotting on a "dummy" copy of the ANSYS model.

If the APLTDOF entry is used to define the SigFit results to ANSYS DOFs definitions different from the default values, then the commands to change element types will not be written. It is the user's burden in this case to be sure that the element types are consistent with the DOFs being used or the user may experience ANSYS crashes while attempting to plot.

Since the default values on the APLTDOF entry are thermal degrees of freedom, use of the default APLTDOF values requires ANSYS Thermal to be licensed. If ANSYS Thermal is not available then the user is forced to define alternative degrees of freedom and be sure that element types are consistent.

3.27 Change in Default DFREQ Parameter

The default value for PARAM DFREQ has been changed from 1.0×10^{-3} to 1.0×10^{-5} . PARAM DFREQ is used to eliminate duplicate forcing frequencies for which harmonic results are evaluated to avoid integration over an extremely small or a zero frequency step during random response analysis. The default was changed to better accommodate large ranges in frequencies leading to an unsuitably large tolerance value. User's of random response should always set PARAM DFREQ to a value consistent with their requested range of forcing frequencies. This value is set in VSigFit in the Parameters module. See the documentation on PARAM DFREQ in the Parameters section of the Dictionary.