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COSMIC/NASTRAN - PATRAN INTERFACE

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ABSTRACT

The capabilities provided by the PATRAN-COSMIC/NASTRAN interface are discussed. While the translator capabilities give some indication of the interface quality between the two programs, certainly there are other attributes to be considered. The ideal interface would be a user-transparent union of the two programs so that the engineer could move from one program to the other fluently and naturally. Hence, a valid assessment of the interface completeness must consider how close the current capabilites are to the idealized case. An example problem is presented to demonstrate how COSMIC/NASTRAN and PATRAN can be used together to meet the requirements of an actual engineering application.

INTRODUCTION

PATRAN [1] is a three-dimensional solid modeling and finite element pre- and postprocessing program developed and marketed by PDA Engineering in Santa Ana, California. Using the latest interactive computer graphics technology, PATRAN provides a visual means to define a finite element model and its environment, and review its resultant model behavior. Although PATRAN offers linear statics and eigenvalue analysis capability as an option, a more detailed analysis is often required. More than 25 translator programs have been developed that move data among PATRAN and external finite element, finite difference, and boundary element analysis programs [2]. It is these interfaces that bring the advanced analysis methods available in general-purpose finite element programs to the PATRAN modeler, and one important interface is to COSMIC/NASTRAN [3].

The COSMIC/NASTRAN interface is comprised of two translators: an analysis translator and a results translator. The analysis translator accepts a PATRAN neutral output file and produces a NASTRAN bulk data file. The forward translator is named PATCOS to indicate the translation from PATRAN to COSMIC/NASTRAN. For postprocessing within the PATRAN system, it is necessary to execute a second program after the analysis. This inverse translator is called COSPAT, because it accepts the COSMIC/NASTRAN results and produces files in a format which PATRAN can read. COSPAT also provides the option of translating an existing analysis input deck into a PATRAN neutral file. Both analysis and results translators are easy to use in that they are menu-driven, execute quickly, and are highly automated. The PATRAN-COSMIC/NASTRAN interface is illustrated in Figure 1.

ANALYSIS MODELING

PATCOS can produce 59 different COSMIC/NASTRAN bulk data card types, including 29 different finite elements. The list of bulk data cards supported is presented in Table 1. The complete analysis model can be defined in PATRAN to include not only the finite element mesh but also element properties, boundary conditions and applied loads. PATRAN also provides visual model verification techniques to check parameters such as element aspect ratio or property assignment.

There are several ways to add the required EXECUTIVE and CASE CONTROL cards to the bulk data deck. The simplest method is to use a text editor and either (1) insert the control cards manually, or (2) copy them in from an existing file.

RESULTS RECOVERY

The results (or inverse) translator, COSPAT, provides the capability to reformat analysis results into PATRAN compatible files. The input file to COSPAT is a binary OUTPUT2 file generated during COSMIC/NASTRAN execution. The output files contain nodal displacements, element centroidal and nodal stress, strain or temperature. To generate an OUTPUT2 file during a COSMIC/NASTRAN execution of a static analysis (SOL 1), the following directives must be added to the COSMIC/NASTRAN input deck. Similiar ALTER sequences can be used for other solution approaches: e.g.

```
ALTER      143 $
OUTPUT2    OUGV1,OES1//C,N,-1/C,N,11/V,N,Z  $
ENDALTER
CEND
DISP   = ALL
STRESS = ALL
```

PATRAN can then be used to combine the results information with the finite element model to evaluate model behavior. Using graphical methods such as animation and color bring unparalleled insight into understanding the voluminous output data often generated from a complex analysis. The engineer can interactively view any piece of the model from any perspective and see color variations of results. Hence one simple exercise for PATRAN might be to crack open an egg and display the variation in circumferential stress on the inside of the shell.

MODEL TRANSLATION

COSPAT also provides the capability to reformat COSMIC/NASTRAN analysis input data into PATRAN neutral format. This method not only brings all PATRAN postprocessing capabilities to bear on existing COSMIC/NASTRAN models (generated by other means or by hand), but also suggests a medium in which to convert a COSMIC/NASTRAN input deck to that of another analysis program format. The COSPAT model translator currently recognizes the 58 different card types as listed in Table 2.

AN APPLICATION

While the translator capabilities give some indication of the interface quality between the two programs, it is clear that there are other attributes to be considered. The ideal interface would be a user-transparent union of the two programs so that the engineer could move from one program to the other fluently and naturally. Hence, a valid assessment of the interface completeness must consider how close the current capabilites are to the idealized case. This can be explored through the use of an example problem.

One common step in the analysis of a part or structure is to determine the structural response to an imposed thermal environment. This involves creating a thermal model subjected to various thermal conditions, solving for a resultant temperature distribution, and then calculating the stresses induced by the applied thermal loads. Both a thermal and a structural analysis must be performed, very often using a structural analytical model of a different mesh density than that of the thermal analysis. The following example demonstrates how PATRAN and COSMIC/NASTRAN can be used together to model, analyze, and evaluate a thermal stress problem.

Problem Definition

The example chosen is a pipe with stepped cooling fins subjected to an internal fluid temperature of 500°F and an outside ambient temperature of 70°F (Figure 2). The structure consists of a 6-inch (0.5 ft) stainless steel pipe with 14.4-inch (1.2 ft) cooling fins. The emphasis here is not on the actual dimensions and properties of the model but rather the technique applied. The objective is to use axisymmetric elements with heat boundary elements to solve for a linear steady-state temperature distribution. Then, determine the stress induced by the resulting temperatures on two different structural models: (1) a finite element mesh matching the thermal mesh, and (2) a non-uniform structural mesh with higher element density.

Thermal Model

The thermal model is represented with axisymmetric trapezoidal ring elements (CTRAPRG). The only material property required for this element is a thermal conductivity equal to 15 Btu/hr-ft- °F. The convection surfaces are defined by heat boundary line elements (CHBDY). The material property for this element is the convective film coefficient equal to 12 Btu/hr-ft-°F on the inside of the pipe and 3 Btu/hr-ft-°F on the outside of the fin. The appropriate PATRAN directives are used to define these data (Table 3), namely element connectivity (CFEG), element geometric properties (PFEG), and material properties (PMAT). The only other value to be defined is the ambient temperatures referenced by the convection surfaces. Because PATRAN originated from structural analysis, there is currently no straightforward way to define this relationship. Hence, a special technique must be used. This technique consists of first constraining scalar points to the appropriate fixed temperatures and then referencing these scalar points in the element associate data field as the convection surface elements are created. The complete list of PATRAN directives required to generate the thermal model is listed in Table 3. The final model is illustrated in Figure 3.

PATCOS is then executed to translate the PATRAN neutral output file into COSMIC/NASTRAN bulk data. A minor coding modification translated the element data associated with the heat boundary elements as the ambient reference points. The EXECUTIVE and CASE CONTROL cards were added and included two important directives: (1) THERMAL(PUNCH) = ALL to write the resultant nodal temperatures to a punch file and (2) OUTPUT2 to save the temperatures for PATRAN postprocessing displays. A sampling of the COSMIC/NASTRAN input file is shown in Table 4.

COSPAT can be executed to read the OUTPUT2 file and generate PATRAN postprocessing files. Figure 4 illustrates the temperature distribution that resulted from the linear steady-state heat transfer analysis.

Structural Model (Mesh 1)

The first structural model is created by slightly modifying the thermal model using PATRAN. The heat boundary elements are deleted, the structural properties for the CTRAPRG elements are defined, and axisymmetric boundary conditions are added. For this case, Young's modulus is given as 194,400 lb/ft, Poisson's ratio is 0.3, and the coefficient of thermal expansion is 0.00009 ft/ft- F.

PATCOS is then used to generate the corresponding COSMIC/NASTRAN bulk data. This time the appropriate EXECUTIVE and CASE CONTROL cards are added, as well as a single point constraint card to eliminate all degrees of freedom except the in-plane axisymmetric motion. Also, because the structural mesh corresponds identically to the preceding thermal mesh, the punch file generated during the thermal analysis can be appended directly to the structural COSMIC/NASTRAN input file. Clearly, this is a most desirable situation and, for this reason, many thermal models are commonly over-modeled such that a structural analysis can be performed easily at a later time.

The OUTPUT2 file generated during the COSMIC/NASTRAN run is processed by COSPAT and PATRAN is used to plot the deformed shape (Figure 5) and stress contours (Figure 6).

Structural Model (Mesh 2)

The next step is perhaps the most difficult, in that a new structural mesh is to be defined but subjected to the temperature distribution calculated in the inital thermal analysis. Many schemes have been devised to interpolate resultant temperature fields onto new structural meshes. The inherent capability to the PATRAN approach of defining a model's environment in terms of the model geometry and not the finite element mesh shows great potential to solving this problem. However, direct methods have not yet been developed.

The approach taken here is to define PATRAN data patches (surfaces) that lie in the thermal distribution field. PATRAN data entities (lines, surfaces, and volumes) can be created to represent a parametric cubic variation of any scalar function [4]. These data surfaces can then be applied to the geometry independent of the finite element mesh density. This is made possible by taking advantage of the axisymmetric nature of the problem. It is noted that the spatial orientation of the model is completly defined by X- and Z-coordinates and that the Y-coordinate is always zero. Hence, a 100-line FORTRAN program, developed in two hours, combines the spatial model coordinates with the nodal temperatures to define PATRAN geometric points (grids) in a PATRAN neutral file. The three coordinates of these grid points are specified as X, TEMP, Z so that they actually lie in the temperature field.

The next step is to delete all finite elements and nodes in the PATRAN axisymmetric model, leaving only the model geometry. The temperature neutral file is then combined th the PATRAN model and these new grid points are used to define PATRAN data patches. The cubic data patches are defined by specifying scalar values that lie in the distribution field. Hence, it is an easy task to have PATRAN extract the Y-coordinates of selected grid points to define the desired data patch (scalar function).

A new structural mesh is defined with a non-uniform element density (Figure 7). Then, each patch is loaded with its corresponding data patch and each finite element node is assigned automatically a temperature depending on its location in the data patch function (Figure 8). Geometric patches were constructed to show the temperature distribution.

PATCOS then translates this new model and loading combination into COSMIC/NASTRAN bulk data. The EXECUTIVE and CASE CONTROL cards are added and the analysis is run. COSPAT is used to generate the postprocessing files that lead to the final Z-X shear stress plots for the critical area shown in Figure 9.

CONCLUDING REMARKS

An overview of the current capabilities provided by the PATRAN-COSMIC/NASTRAN interface is described. While the extent of these capabilites is important in assessing the interface quality, the example problem illustrates the wide range of flexibilty provided. PDA Engineering, in its short history of interface development, has made major strides in linking up the unique analysis tools found in many different programs. Improvements have been made which were primarily due to a close working relationship with the engineering community. We were thus able to define, and meet, the rising needs and expectations of the analysts.

The future holds a great promise for more efficient, complete, and sophisticated methods in software and hardware networks, to solve a growing diversity of engineering problems. PDA's interface developments already are considering new approaches to thermal modeling, substructuring, and composite material modeling. It is clear that PDA is committed to providing the engineering community with the highest quality modeling and analysis software through more efficient, complete, and accurate data definition and transfer -- very often based on user recommendations.

REFERENCES

1. PDA/PATRAN User's Guide Vol. I-II (Rev 1.5), 1984, PDA Engineering, Santa Ana, California.

2. Fong, Henry H., "Interactive Graphics and Commercial Finite Element Codes", Mechanical Engineering, June 1984, pp. 18-25 (published by The American Society of Mechanical Engineers, New York, New York).

3. Field, E. I., D. N. Herting, and M. J. Morgan, NASTRAN User's Guide (Level 17.5), Prepared by Universal Analytics, Inc. (Playa Del Rey, California) for Langley Research Center, NASA CR-3146, June 1979.

4. Casale, Malcolm S. and Edward L. Stanton, "An Overview of Analytic Solid Modeling", IEEE Computer Graphics and Applications, February 1985 (published by The Computer Society of The Institute of Electrical and Electronics Engineers, Los Alamitos, California), pp. 45-56.

Table 1
COSMIC/NASTRAN Card Types Supported By PATCOS (59)

Coordinate Frames

CORD2C
CORD2R
CORD2S

Node Coordinates

GRID

Element Definitions

CBAR
CELAS2
CHBDY
CHEXA1
CHEXA2
CIHEX1
CIHEX2
CIHEX3
CONM2
CQDMEM1
CQDMEM2
CQDPLT
CQUAD1
CQUAD2
CROD
CSHEAR
CTETRA
CTRAPRG
CTRBSC
CTRIA1
CTRIA2
CTRIARG
CTRIM6
CTRMEM
CTRPLT
CTRSHL
CWEDGE

CNGRNT

Element Properties

PBAR
PHBDY
PIHEX
PQDMEM1
PQDMEM2
PQDPLT
PQUAD1
PQUAD2
PSHEAR
PTRBSC
PRTIA1
PTRIA2
PTRIM6
PTRMEM
PTRPLT
PTRSHL

Material Properties

MAT1
MAT2
MAT3
MAT4
MAT5

Pressure Loads

PLOAD
PLOAD2
PLOAD3

Node Forces

FORCE
MOMENT

Specified
Node Displacements

SPC

Constraints

SPC1

Temperatures

TEMP

Bar Deformation

DEFORM

Table 2
COSMIC/NASTRAN Cards Supported By COSPAT (58)

A. Coordinate frames
CORD2C, CORD2R, CORD2S

B. Grid points
GRID ,GRDSET

C. Elements

BAROR , TRIA1, CBAR , CTRIA3, CROD , CQDMEM1
CTRBSC, CTRIARG, CTRIA2, CTRMEM, CQUAD1, CQDMEM2
CSHEAR, CTRAPRG, CQDMEM, CQUAD2, CHEXA2, CWEDGE
CIHEX2, CTRPLT , CTETRA, CQDPLT, CTRIM6,
CTRSHL, CTRPLT1, CHEXA1, CIHEX1,

D. Properties

PBAR , PBEAM , PROD , PTRIA1, PTRMEM
PQUAD1, PQUAD2, PQDMEM, PTRIA2, PHEX
PSOLID, PHBDY , PSHEAR, PSHELL

E. Materials

MAT1 , MAT2 , MAT3 , MAT4 , MAT5 , MAT9

F. Forces and Constraints

SPC , SPC1 , FORCE , MOMENT, TEMP , DEFORM

Table 3

PATRAN Input Directives To Create Thermal Model

```
GO                                ! Initialize PATRAN
1
1
2
VI                                ! Change view to X - Z plane
1
-90
GR,1,,.45                         ! Begin geometry creation
GR,2,,.55
GR,3,,.85
GR,4,,1.75
LI,3#,2G,,1T3,2T4
LI,#,TR,//.3,1
LI,#,TR,//.15,2
LI,#,TR,//.05,3
PA,3#,2L,,1T3,4T6                 ! Finish geometry creation
GF,P1,,4/7                        ! Define thermal mesh
GF,P2,,4/4
GF,P3,,13/2
CF,P1T#,QUAD/4/7                  ! Define axisymmetric quad. elements
LI,4#,2G,,6/8/10/5,7/9/4/1        ! Create geometry for convection boundary
GF,10L,,7                         ! Mesh boundary
GF,4L/7/5,,4
GF,8L,,3
GF,6L,,13
GF,9L,,2
COLOR,BAR,BLUE
GRID,100,,100                     ! Define scalar points
GRID,200,,200
CF,10L,BAR/2/5                    ! Define convection elements
1
G
100                               ! Reference ambient source
4
CF,4LT9,BAR/2/5
1
G
200
4
E                                 ! Use menu sytem to optimize bandwidth
2
3
```

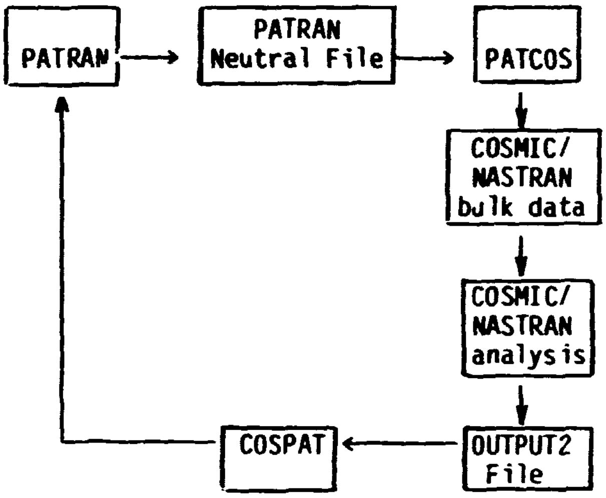
Table 3 (Continued)

```
N
2
1
Y
7
3
3
1
NODE,100,ADD                      ! Define scalar points for ambient temperature
1
1
100.0
5
NODE,200,ADD
1
1
200.0
5
DISP,N100,ADD,1                   ! Specify ambient temperatures
500.0
DISP,N200,ADD,1
70.0
PF,P1T3,QUAD/4/7,,M1              ! Assign material types
PF,10L,BAR/2/5,2,2
PF,4LT9,BAR/2/5,3,3
PMAT,1,TIS,15                     ! Specify material properties
PMAT,2,TIS,12
PMAT,3,TIS,3
E
5                                 ! Create PATRAN neutral file
1
1
AXISYMMETRIC COOLING FIN (THERMAL MODEL)
N
STOP
```

Table 4
Sampling Of NASTRAN Thermal Analysis Input

```
ID DHL,NASTRAN
APP HEAT
SOL 1
TIME 90
DIAG 14
ALTER 109 $
PARAM    //C,N,NOP/V,N,TRUE=-1
EQUIV    HOUGV1,OUGV1,/TRUE  $
OUTPUT2   ,,,,//C,N,-1/C,N,92/V,N,Z  $
OUTPUT2   OUGV1,,,,//C,N,0/C,N,92/V,N,Z $
OUTPUT2   ,,,,//C,N,-9/C,N,92/V,N,Z  $
ENDALTER
CEND
TITLE = LINEAR STEADY STATE CONDITION THROUGH A COOLING FIN
SUBTITLE = AXISYMMETRIC RING ELEMENTS, FILM HEAT TRANSFER
OUTPUT
THERMAL(PRINT,PUNCH) =ALL
OLOAD = ALL
SPC = 1
BEGIN BULK
$AXISYMMETRIC COOLING FIN (THERMAL MODEL)
$--BULK DATA CARDS PRODUCED BY "PATCOS" VERSION 1.6A:   09-JAN-85   15.54:40
SPC            1     100       1 500.000
SPC            1     200       1 70.0000
GRID           1         0.450000.      0.
GRID           2         0.483330.      0.
GRID           3         0.483330.      0.05000
GRID           4         0.450000.      0.05000
GRID         100        100.00000.      0.
GRID         200        200.00000.      0.
CTRAPRG        1       1       2       3       4   0.000       1
CTRAPRG        2       2       5       6       3   0.000       1
CTRAPRG        3       5       7       8       6   0.000       1
CTRAPRG        4       4       3       9      10   0.000       1
CHBDY         40       2REV           26      22                         E    40
+E    40     100     100
CHBDY         41       2REV           22      18                         E    41
+E    41     100     100
CHBDY         42       2REV           18      14                         E    42
+E    42     100     100
CHBDY         43       2REV           14      10                         E    43
+E    43     100     100
CHBDY         69       3REV           64      63                         E    69
+E    69     200     200
PHBDY          2       2
PHBDY          3       3
MAT4           1 15.0000
MAT4           2 12.0000
MAT4           3 3.00000
ENDDATA
```

Figure 1
PATRAN - To - COSMIC/NASTRAN Interface
(August 1984)



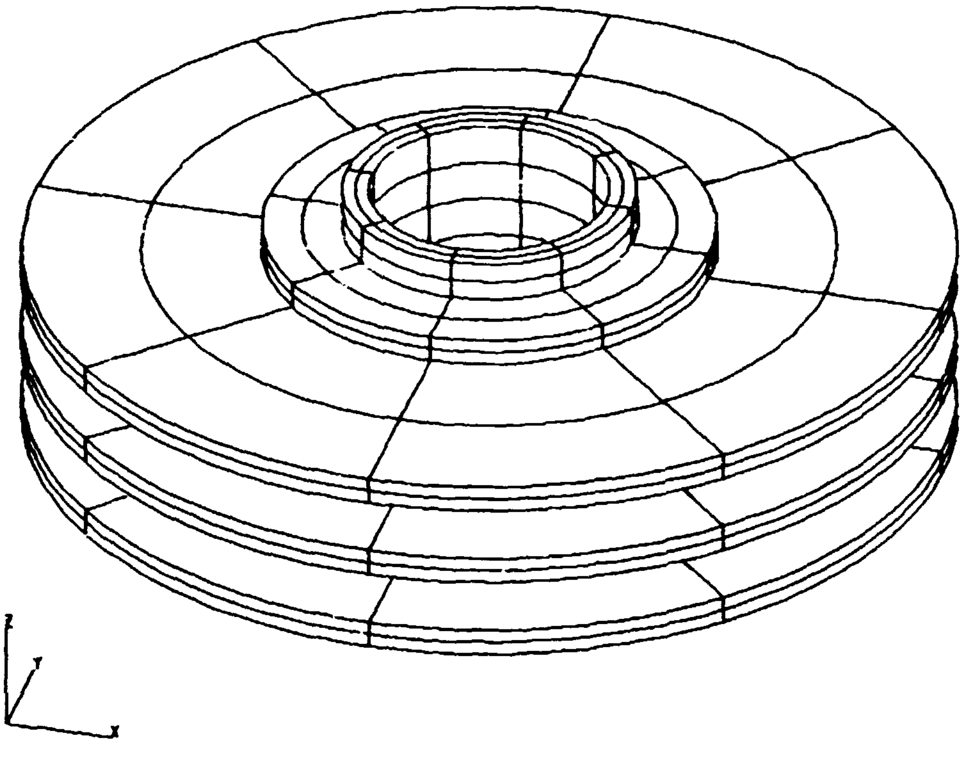


Figure 2 - Pipe With Cooling Fins

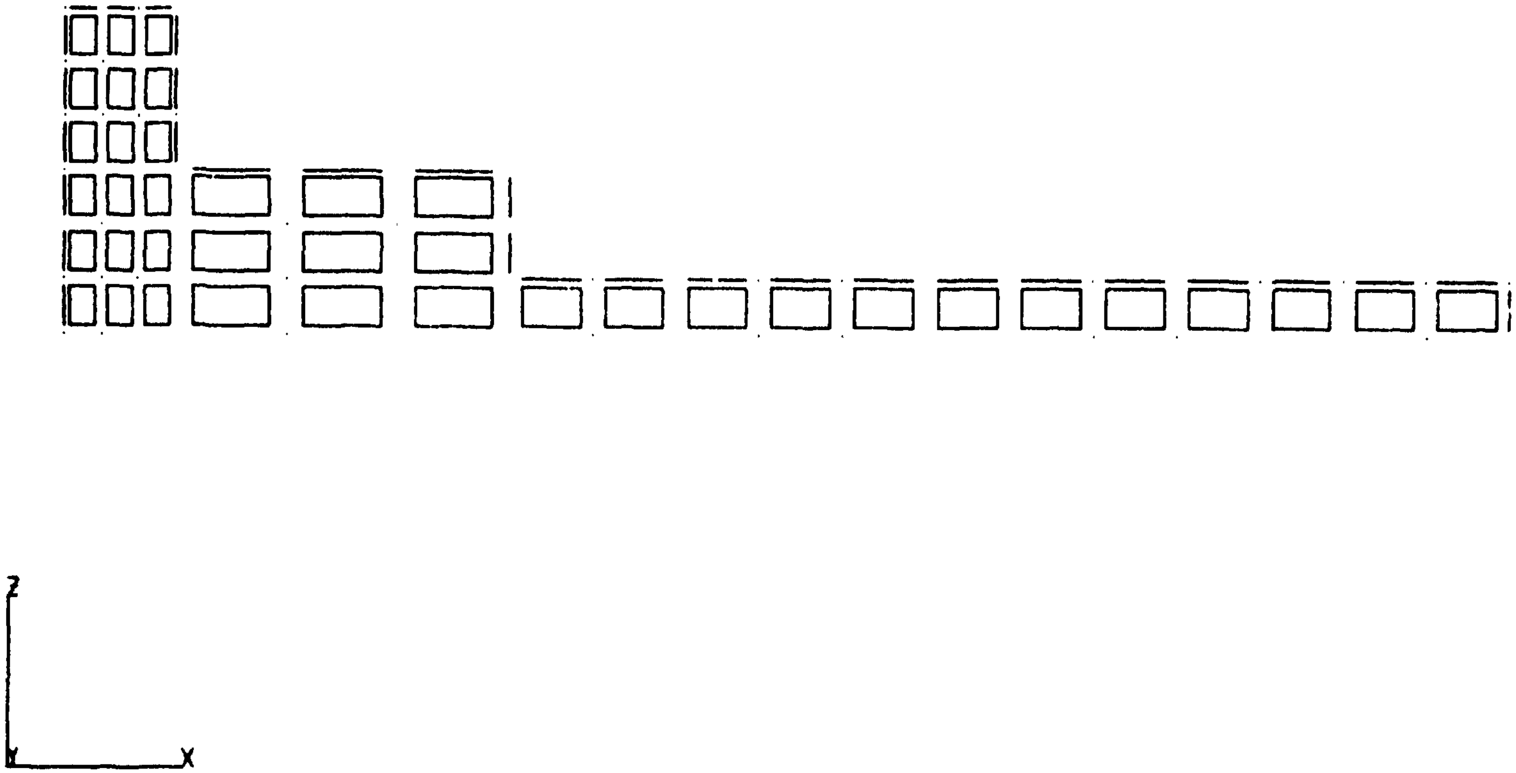


Figure 3 - The Thermal Model (also Structural Mesh 1)

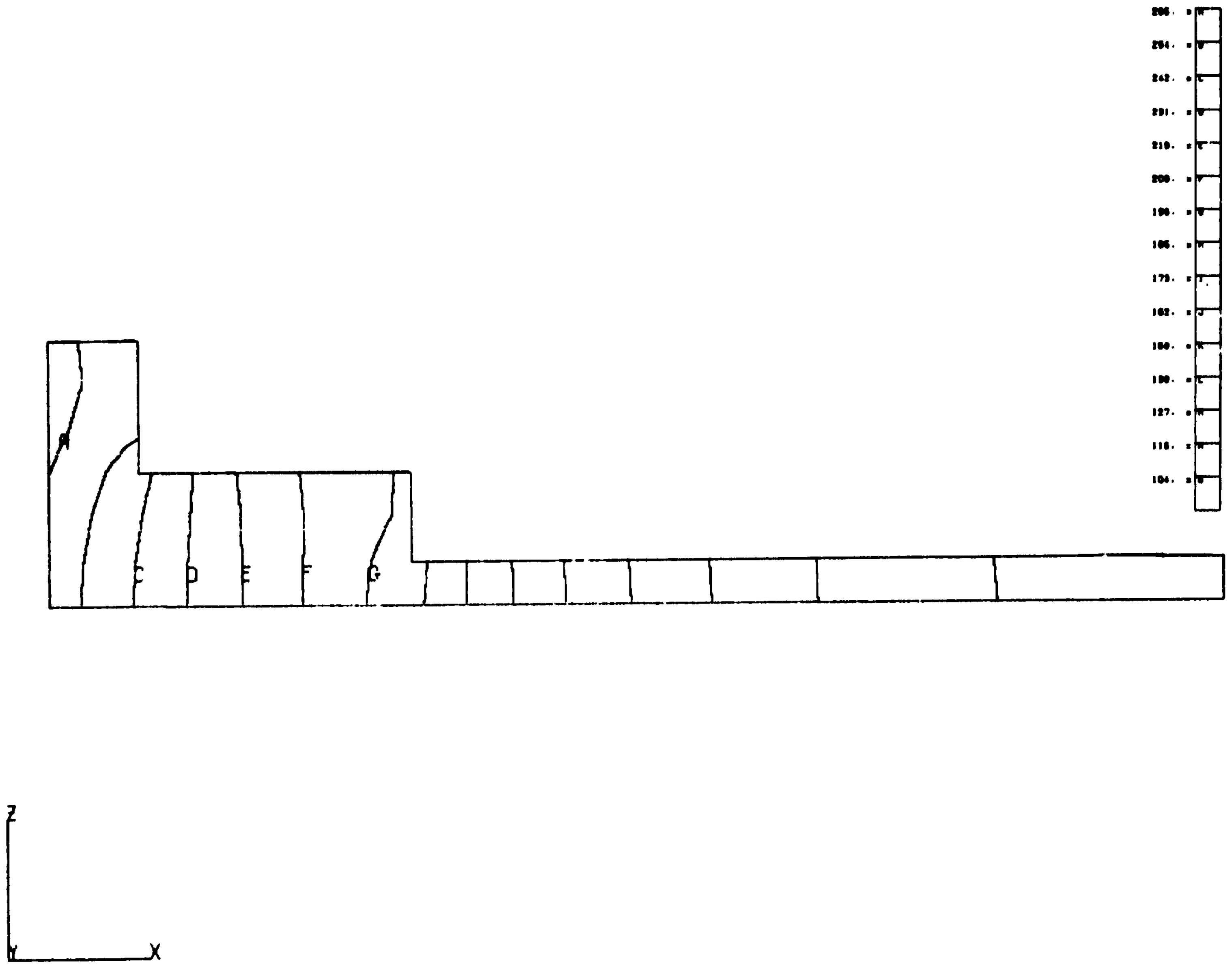


Figure 4 - Resultant Temperature Distribution

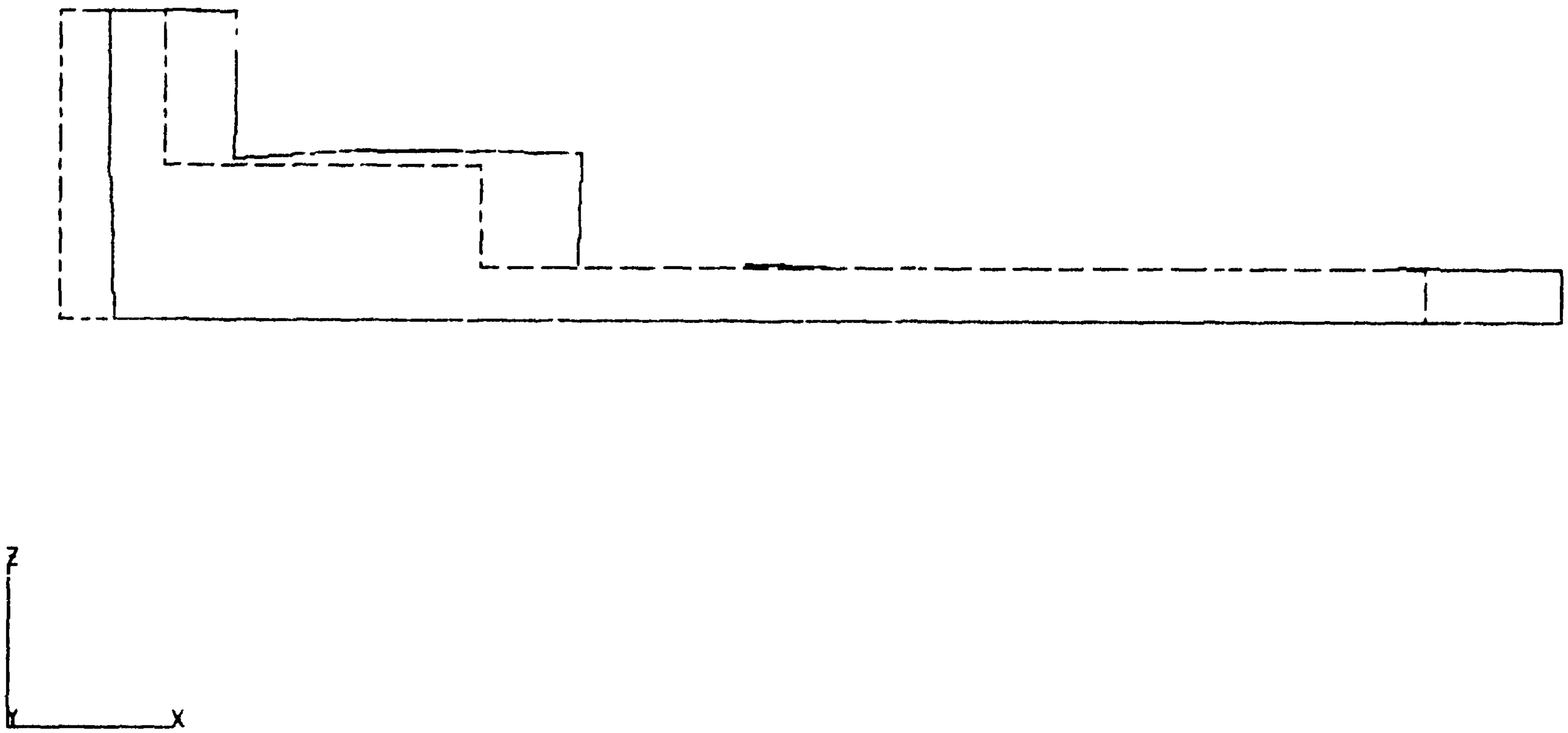


Figure 5 - Deformed Shape (Mesh 1)

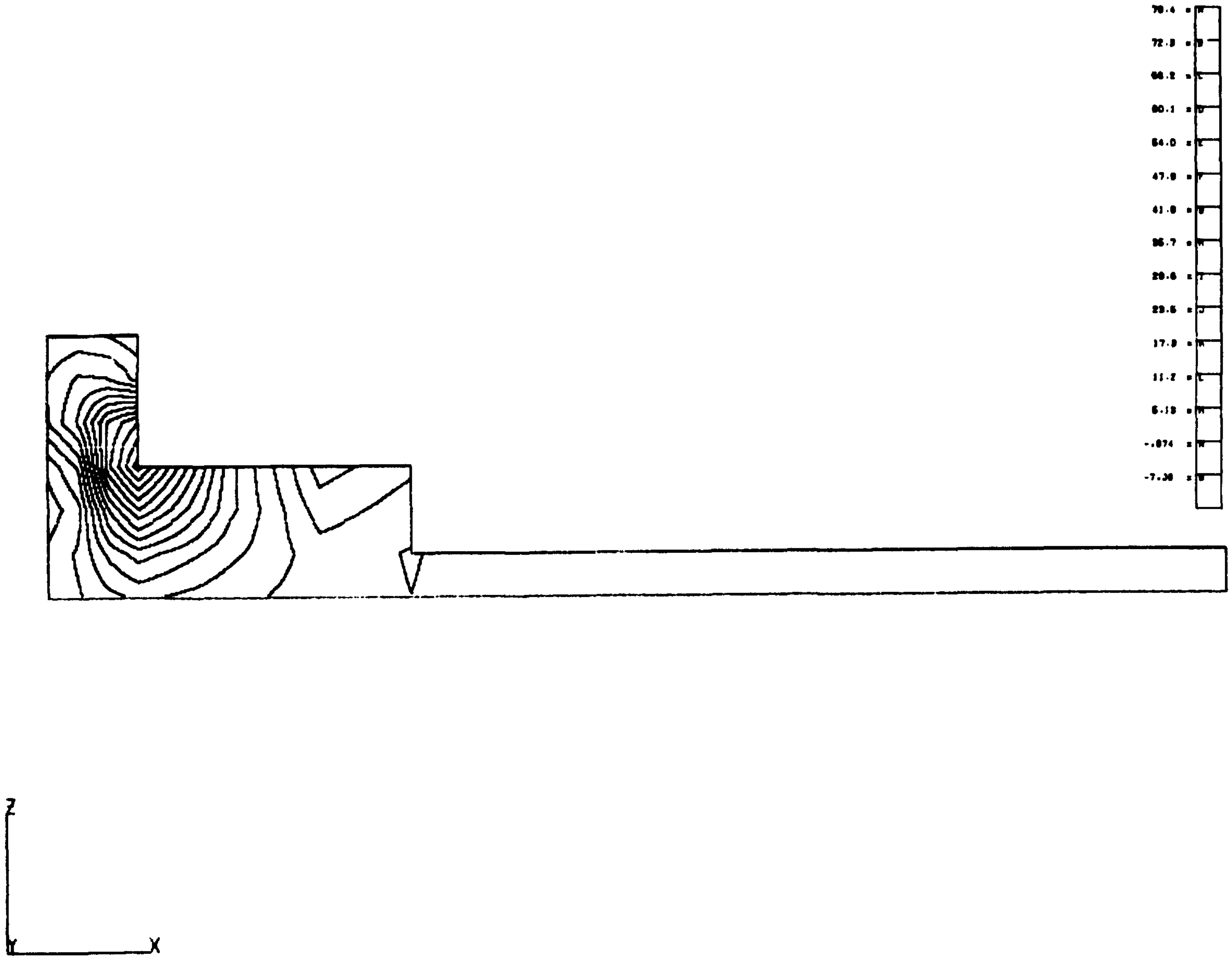


Figure 6 - Z-X Shear Stress (Mesh 1)

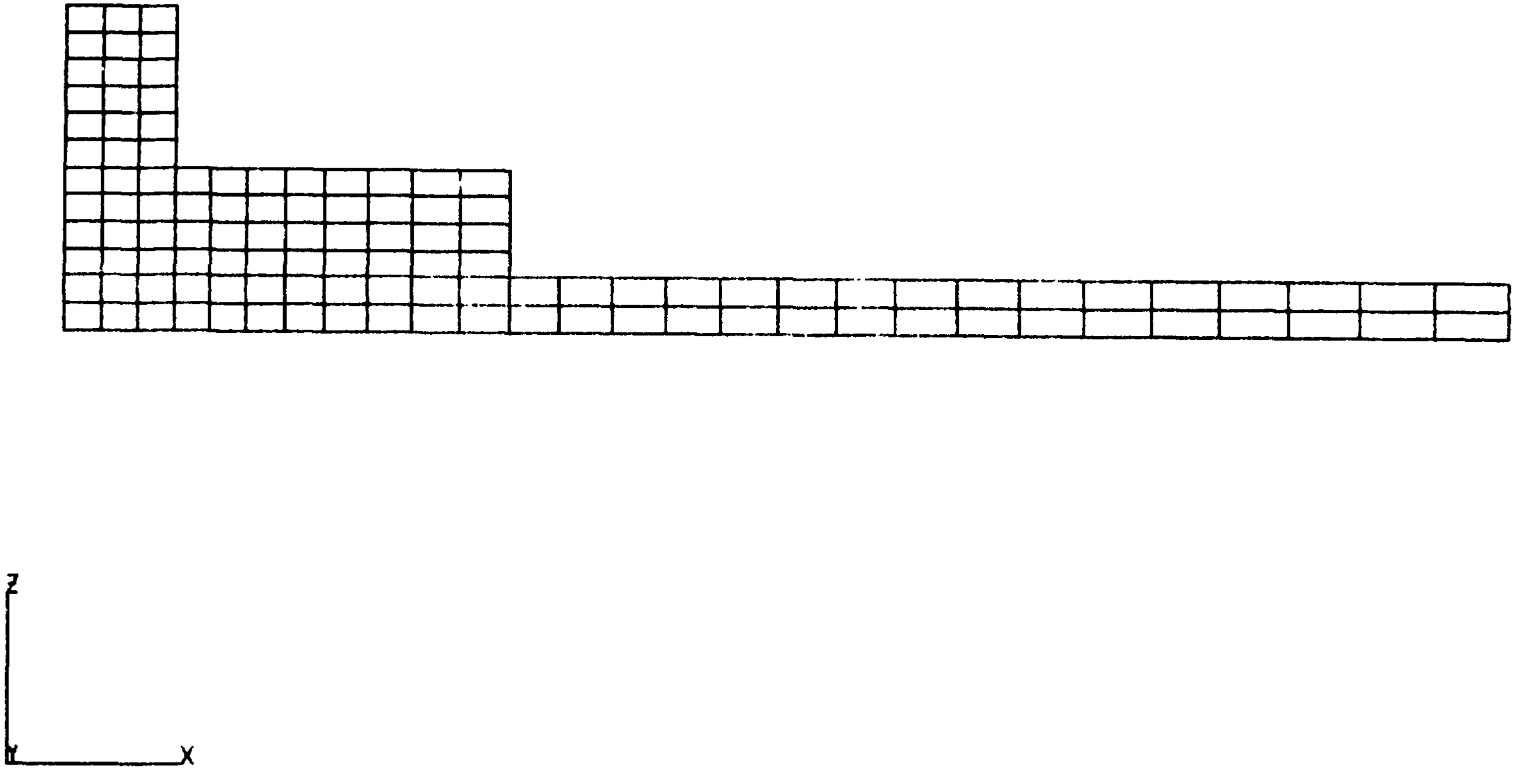


Figure 7 - Structural Model (Mesh 2)

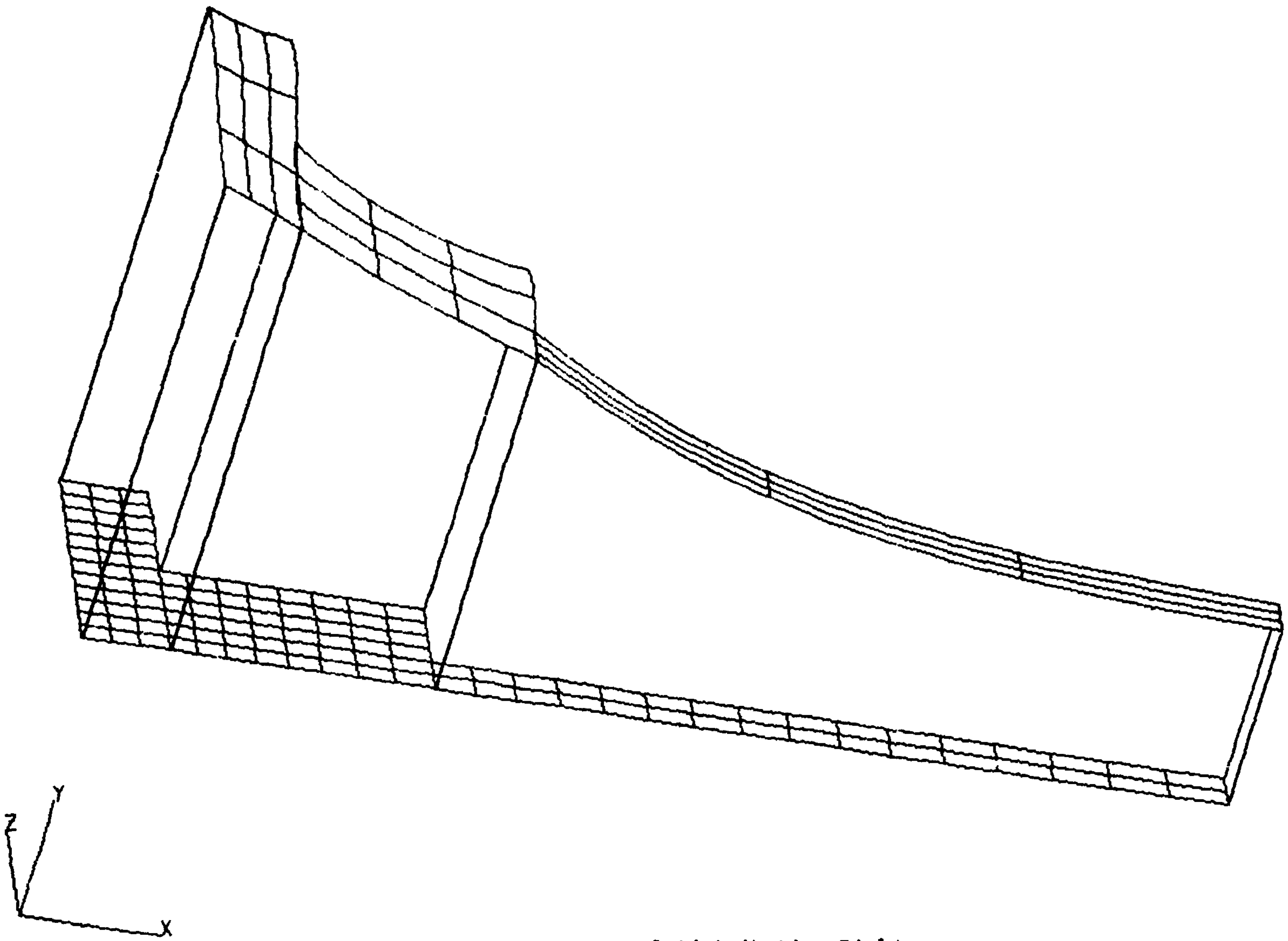


Figure 8 - Thermal Distribution Field

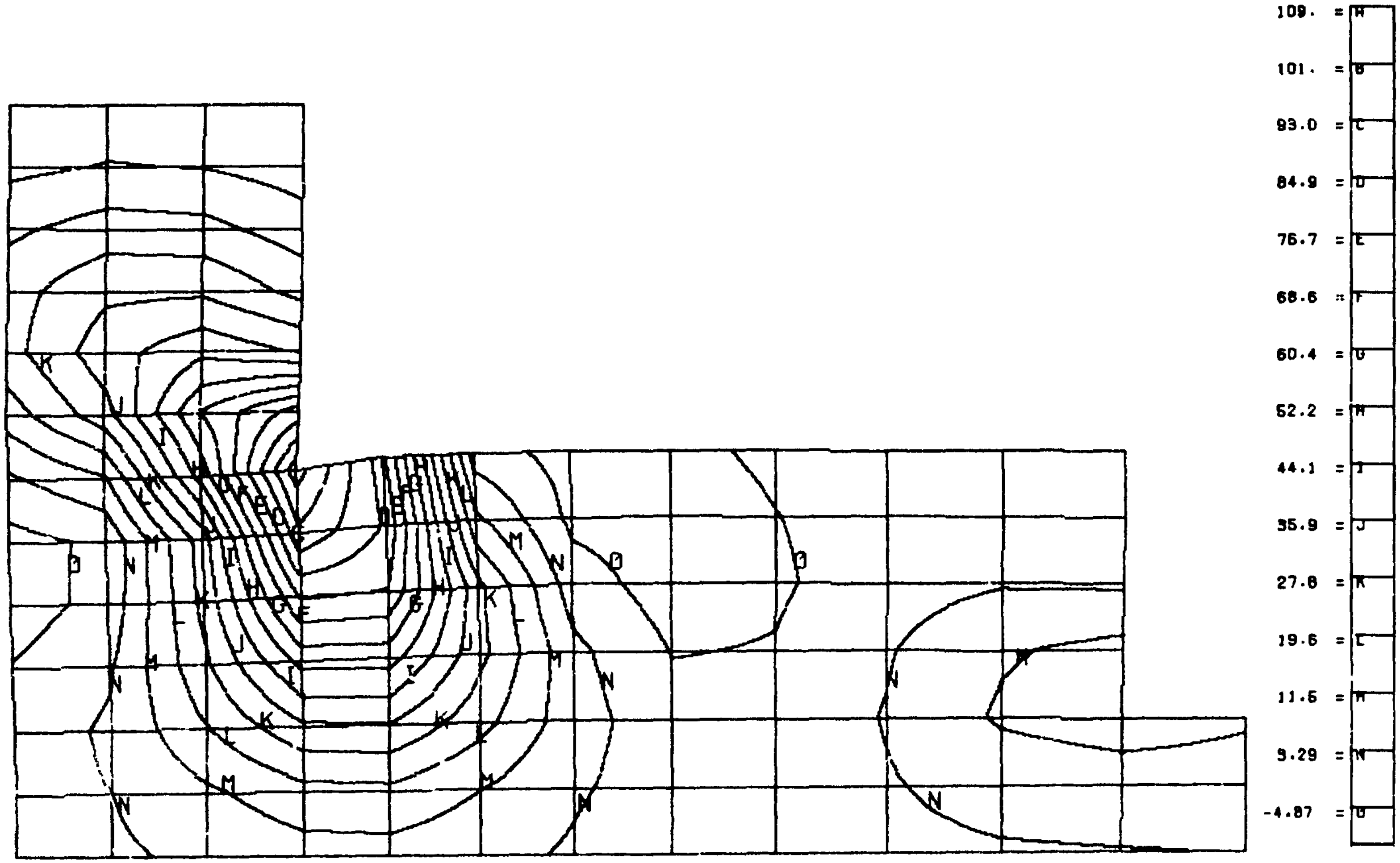


Figure 9 - Z-X Shear Stress On Deformed Shape (Mesh 2)