ABSTRACT

Computer generated graphics has become an important part of finite element analysis. Mesh plots and deflection plots are both accepted as standard tools of the trade, yet over the last ten years, computer speed and memory and the sophistication of programs like NASTRAN have far out distanced the capabilities of the man-machine interface.

The addition of color to computer graphics is now becoming economically practical and has the potentical a spanning this gap between man and machine.

INTRODUCTION

Early finite element analyses were constrainted to simple two-demensional shapes due to computer costs and memory limitations and the elementary formulation of the elements in the programs. Today the problems facing an analyst using finite element methods are entirely different. With the dramatic increase in computer capabilities coupled with the parallel decreases in costs and increased sophistication of finite element techniques, running large three-dimensional finite element problems is becoming quite common. Now construction of the models and understanding the resulting predictions (the pre and post processing function) have replaced computational limitations as pacing items. The task has

become to extend the power of the computer to these pre and post processing functions.

The application of black and white computer graphics to these tasks has been a step in the right direction; however, there are fundmental limits to the amount of data that can be distinguished. For instance, in a two-dimensional slice of a model, it maybe very easy to distinguish between node and element numbers by their relative location on the plot, however, when the third-dimension is added the distinction quickly vanishes. Whether the area of interest is the mesh, as in this example, or stress levels, temperature, deflections or whatever, only a limited amount of data may be presented at any one time.

The addition of computer generated color overcomes many of the limitations. Instead of each point of the plot being restricted to black or white only, each point can take on many discernible colors and thus can code many additional parameters. The large increase in visual discrimination can then go a long way to closing the gap between the mountains of data produced by the computer and the limits of the human trying to assimilate it.

COST

Experimentation with color computer graphics has been going on for at least a decade; however, hardware costs have been so

high as to preclude its use as a routine engineering tool despite its tremedous potential. It is only in the last two years that the computer hardware market has been flooded with reasonably priced medium resolution color terminals that make color graphics viable for general engineering applications (Table 1). With continued competition and improving technology, the capabilities of color terminals should become even more well suited to engineering uses with constant or decreasing price tags.

CAPABILITIES

There are three distinct engineering uses for color computer graphics (see Table 2). First of all color graphics can be used for presentations. It can attract and hold the attention of an audience; it puts a non-technical audience in a familiar environment; it can quickly give the overall picture tying the predictions to the geometry, and it can emphazie areas of importance. A second use is for documentation. Color has the ability to compact large amounts of data into an easily understood form. Finally, and perhaps most importantly to an engineer, color can be used for analysis. Color can put large amounts of data into a form that gives not only point magnitudes but relationships through out the entire geometry. It allows the analyst to detect subtle effects in the analysis while at the same time visualizing the whole of the analysis. The computer calculates it all; its a waste not to understand it all.

As an example, Figures 1 and 2 show two different ways to view a three-dimensional NASTRAN thermal analysis. The printed output is over an inch and an half has thick yet both figures condense the geometry and the results of the analysis into a single page. Figure 1 shows temperatures plotted at each location in the model. It does not, however, provide any immediately recognizable relations between different locations in the model, temperature values are hard to read in areas of refined mesh, and locations of solid material verse cooling channels are not clear. Figure 2 is the same plot as in Figure 1 with the addition of color (published in black and white). In this plot the high temperatures in each cross section immediately stand out, as do the temperature relationships throughout the model. The internal cooling channels (dark areas inside the model) are easily distinguishable, and temperatures are easily discernible in both coarse mesh and fine mesh areas.

Figure 2 could also be used for any of the three engineering uses of color graphics. It provides an attractive presentation aid that can transfer the results of the entire analysis to the viewer emphasizing areas of maximum temperature by the proper selection of color. Smoothing of the colors and mirroring the model about lines of symmetry would further enhance the picture for presentation. The conciseness of the display also makes it valuable for documentation. Instead of volumes of unintelligible numbers, the plot presents all of the predictions in relation to

the geometry in a single page. Finally the color plot also gives the analyst a direct method of viewing his predictions relative to the geometry and the model mesh. Large color gradients between adjacent elements may point out a need for further mesh refinement or a relatively hot color at the cooling channel could indicate a misplaced boundary condition.

Simply put, color computer graphics can cram a tremendous amount of data into an attractive and funtional form.

DRAWBACKS

Despite the attractiveness or the potential of color computer graphics, there remain some significant drawbacks to it general acceptance as an engineering tool.

One of the major problems associated with color graphics is illustracted by this article (Figure 2). Despite the amount of data that can be present with color graphics or the ease of assimuliation, most engineering publications refuse to publish in color. Time, Omni and even comic books are printed in color strictly for asthetic reasons; yet, engineering articles are devoid of color even in the face of compelling technical justification.

Another problem with color is the association of color graphics with electronic toys and games by management. Color computer graphics for engineering is not a plaything, nor is it just for asthetic purposes. It can free a highly paid and highly skilled engineer from months of difficult busy work preparing and trying to understand complex finite element analysis. It frees the engineer to think rather than to endlessly punch and scan.

Engineers too have trouble overcoming their affinity for black and white. They have been trained to summarize large amounts of data into margins of safety, maximum temperatures, etc., but now with the power of modern computers these point values effectively waste the understanding that can be had by looking at the whole problem.

Cost and standardization of hardware and software provide additional drawbacks. The cost are coming down, but in such a rapidly advancing field great care must be excerised to insure continuity and productivity.

Finally reasonably priced hard copies are another problems. Great strides have been made, but a low initial investment, low cost per copy, high quality, rapid turn around color hard copy unit is still not available. There are, however, many devices that provide three of these four desirable features in various combinations.

The great healer of all of these problems is time and experience. As experience with computer generated color graphics demonstrates its power, publications will be forced by popular demand to include color, managers will see the cost effectiveness of color, engineers will become adapted to a new tool, cost will continue to drop, and competition and technology advances will provide quality low cost hard copies to document its successes.

CONCLUSIONS

Using computers to automate input and output of complex finite element analyses in color has come of age. It can, today, be a useful, cost effective tool to concentrate engineering resourses on solving problems. With a little graceful aging and experience, color computer graphics can be the next great improvement in finite element methods.

TABLE 1

COLOR COMPUTER GRAPHICS ENGINEERING USES

	PURPOSE	CHARACTERISTICS
Technical Presentations	To Inform	Simplicity Directness Color for Emphasis Reduced Data
Documentation	To Remember	Completeness Conciseness
Analysis Interpretation	To Understand	Raw Data Rapid, Complete Review

TABLE 2

COLOR GRAPHICS TERMINALS

RESOLUTION	COLORS	COST(K$)
Low 256 x 256		1 - 10
Medium 512 x 512	8 - Up	8 - 25
High 1024 x 1024	8 - 1024	20 - 120

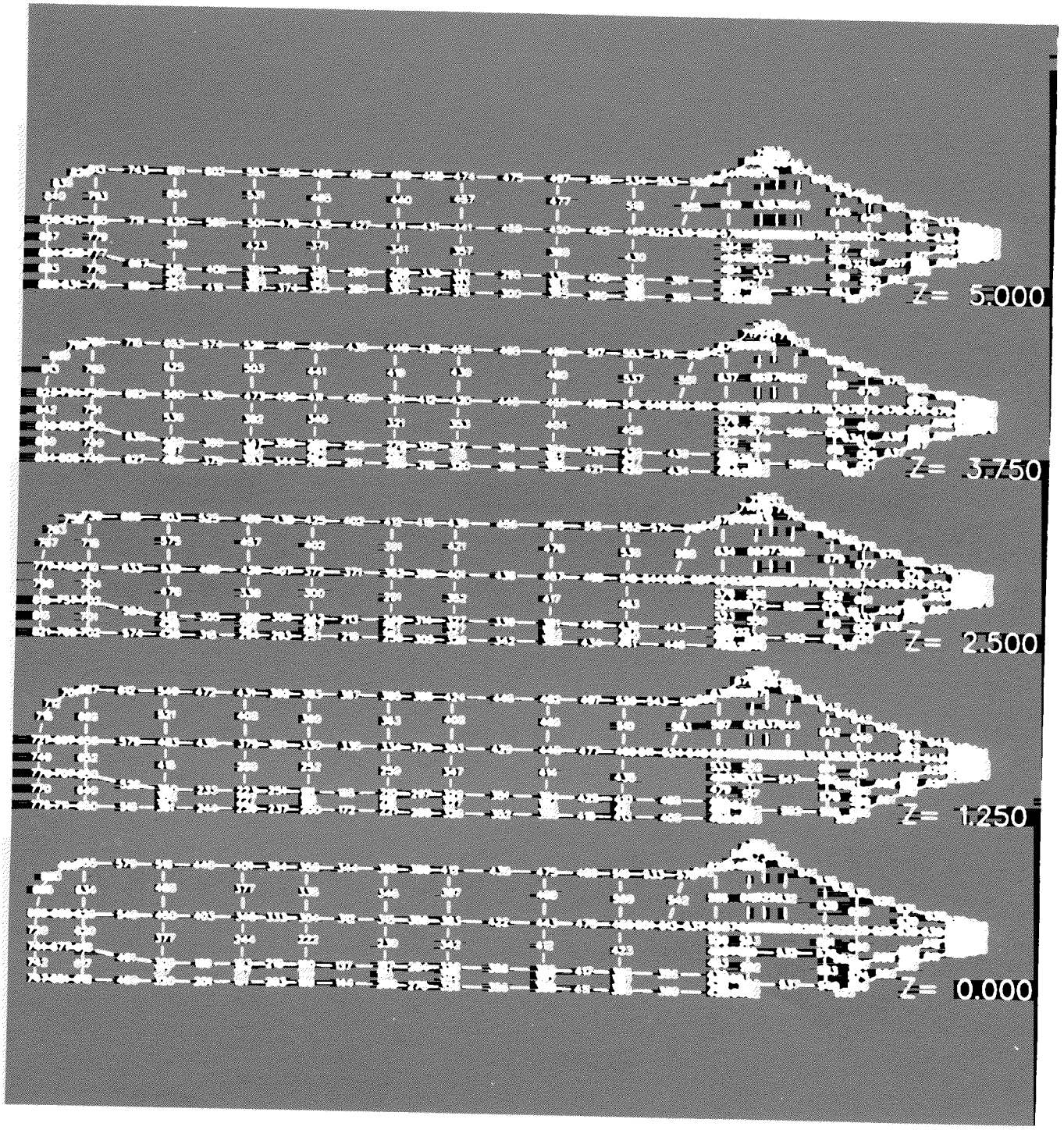

FIGURE 1. BLACK AND WHITE PLOT OF TEMPERATURES.

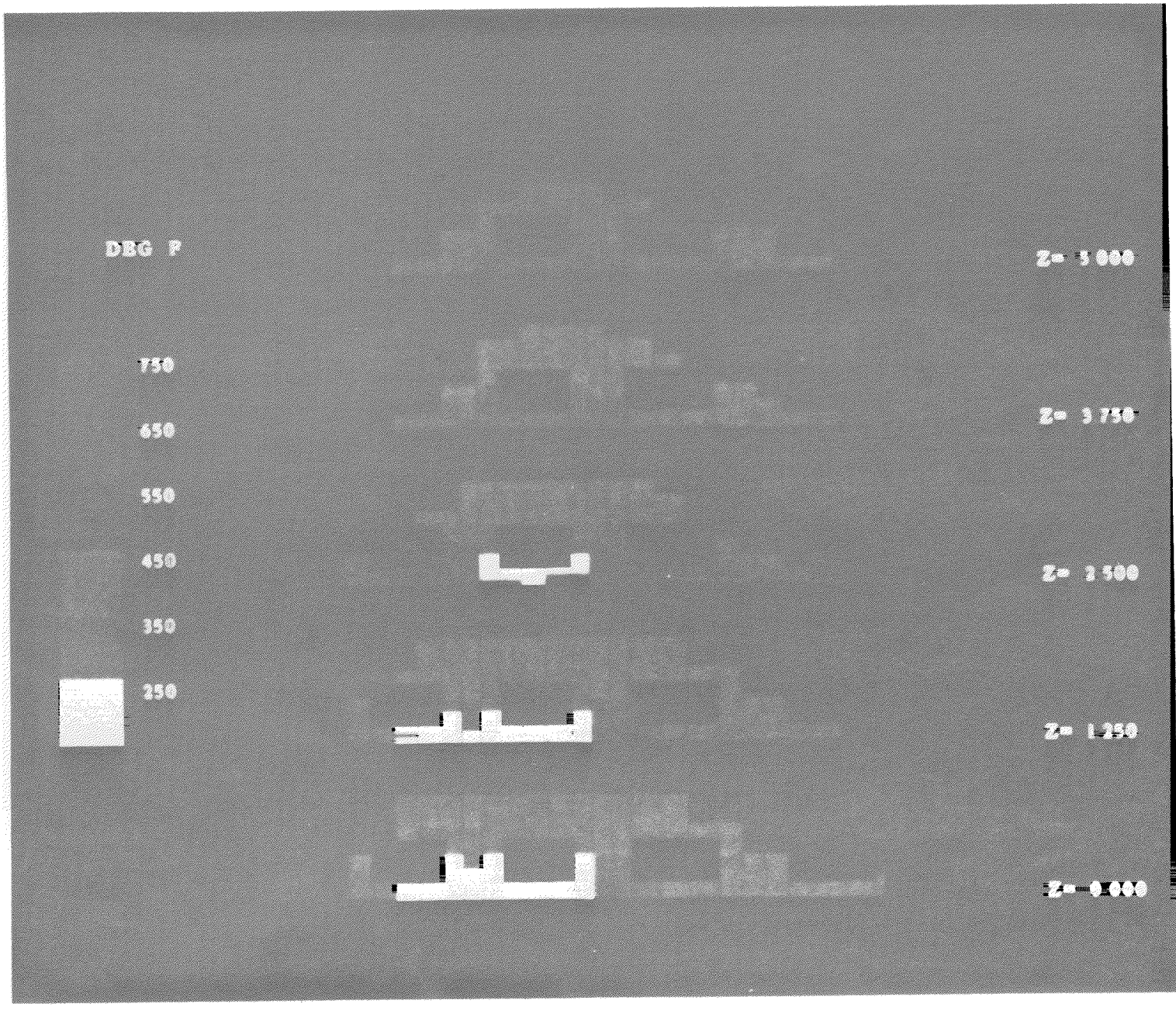

FIGURE 2. COLOR PLOT OF TEMPERATURES