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Visualization of Scroll Compressor Dynamics via Computer Graphics

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VISUALIZATION OF SCROLL COMPRESSOR DYNAMICS VIA COMPUTER GRAPHICS

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ABSTRACT

Computer simulation of compressor dynamic loading has become a fundamental exercise in the design process. Several papers have been presented at past conferences that describe such models for scroll compressors.

Due, however, to the complicated geometry and interplay of the scroll pump components, computer simulation output tables and plots do not, in general, allow "visualization" of their dynamic nature. With the advent and proliferation of engineering workstations, much more powerful simulation and analysis becomes possible. This paper gives an overview of Carrier's integration of computer aided design tools with the development process. The potential benefits are explored. The video that will accompany the presentation of this paper will highlight the capability of these design tools.

INTRODUCTION

"Seeing is Believing."

"One Picture is Worth More Than a Thousand Words."

These may be time-worn proverbs, yet they aptly describe the advantages of what we call "visualization" to the design/development process.

How many times have you caught yourself attempting to envision in your mind's eye the motion, loading, or interaction of a set of components as you pored over a computer printout tabulating simulation results? Who hasn't imagined the heft and feel of an object as they stared at its 2-D representation on a drawing?

Visualization, as a human attribute, is both intuitive and experience based; it complements the "hard" data we gain from texts and testing and actually "doing". It is an important part of our creative nature. Yet complex mechanisms and their interactions can tax the visualization skills of the best of us. The authors place the scroll compressor in this category. We have chosen to supplement and enhance those skills as we develop our scroll design with computer aided tools that are rapidly becoming "daily use" components of the development process.

Over the last several years, the size and cost of engineering computer workstations have shrunk dramatically, yet their power has risen to rival small mainframes. The engineering profession is taking advantage of this opportunity in many ways. 3-D modeling, 2-D drawing/detailing packages, kinematic and dynamic analysis software, and sophisticated structural analysis routines are widely available. These can be linked with additional computer aided packages for the manufacturing process. Powerful graphics and animation features enhance the value of these tools. Their use can ultimately lead to better products introduced in a compressed time frame. The use of computer aided design tools can allow fewer "hard" prototyped iterations, and yet also more detailed and exact analyses at the same time.

An overview of Carrier's integration of computer aided design tools with the scroll compressor development process in the areas of design, analysis, and testing is presented in this paper. The potential benefits are explored. The videotape that will accompany the presentation of this paper will serve to highlight our view that not only do these tools represent "hard" capability, they effectively enhance an engineer's visualization skills in a decidedly positive manner.

DESIGN

The United Technologies Carrier Scroll Team employs PXCL Engineering Workstations by PRIME Computer, equipped with an interactive 3-D modeler called PrimeDESIGN. The modeler is highly "user friendly", allowing for rapid assimilation of the mechanics of using the software. It is our objective to design up front in 3-D. This approach, coupled with other features of the package, offers many benefits.

The short learning curve and ease of use puts the modeler directly in the hands of the engineers - from concept through final design. The 3-D capability allows proper visualization. A part is easily and quickly viewed from any perspective (see Figure 1A).

Material assignments are stored with the geometric model. Physical property calculations are made instantaneously. Derived dimensions are easily determined.

The geometric database of PrimeDESIGN and other similar packages allow for assembly of components (again offering powerful visualization of 3-D and/or section representations), and calculation of physical properties and clearances/interferences for entire scroll compressor assemblies.

Beyond the self-contained value of the package, it offers a stepping-off point for other development related activity. 2-D "slices" of a component are electronically sent to compatible packages for detailing with no compromise of design intent. The package contains an interface for the PATRAN pre/post processor; the geometric database is compatible with generation of PATRAN finite element analysis models. The modeler also has GNC and IGES interfaces. We have transferred component data to similarly equipped prototype and production vendors. Our manufacturing teammates step through their processes from casting to final machined part in solid modeled steps. Material removal calculations for each process are readily available.

PrimeDESIGN has another interface to a relatively new capability, stereo lithography. This "3-D Printing" process can quickly produce plastic parts from a PrimeDESIGN model. The stereo lithography device builds an object by means of a computer controlled laser. The laser draws the object, one cross-section at a time, on the surface of a vat of liquid photosensitive resin. Only the resin touched by the laser is hardened. Once one cross-section is finished it is lowered into the vat, and the process repeats until the object is complete. Intricate parts with complex internal shapes can be produced. Carrier has used stereo lithography to produce an orbiting scroll model. The process has potential not only for initial conceptual models, but for uses such as casting or mold patterns as well.

ANALYSIS

Finite element packages are used throughout the profession. It is not our intent to extol any one FEA package over another. Rather, it is that the cost (and thus availability) and power of most allow more extensive and exact analyses of components and/or processes upstream in the design process. Additionally, the graphics capability of many pre/post-processors exemplify the value of visualization. Stress and thermal contour plots, displacement plots, and loading diagrams shown on actual representations of the components are more readily assimilated and understood than tabulated output. United Technologies Research Center has done extensive analysis for Carrier on the scroll elements (see sample output, Figure 2). It isn't hard to imagine further improvements. For example, it is a reasonable stretch to compile snapshots of an FEA output plot at discrete moments in time (e.g. crank angle) into animated scenes of the behavior of a part for an entire cycle.

Another, and perhaps more powerful, benefit of computer aided visualization is simulation of dynamic systems. Carrier and UTRC have developed and use a complex scroll simulation package. The tabular output from, for instance, the dynamic load calculation module is manipulated in a graphics routine to show scroll components and/or subassemblies in animated 3-D. Arrows are superimposed showing the magnitude and direction of applied and reaction forces (see Figures 3A and 3B). This ability has impacted our fundamental understanding of a scroll compressor.

The use of graphics to view the simulation of complex, multi-degree-of-freedom interaction is also demonstrated with a rotary compressor. A means of determining the dynamic clearance between the rolling piston outer diameter and the cylinder inner diameter was described by Kassouf, Tomayko, and Vaccaro [1]. Resultant polar plots of journal orbit and clearance trajectory are readily transformed to 3-D animated views. Using proportionally exaggerated displacement, the interplay of the shaft, bearings, rolling piston, and cylinder is visualized.

TESTING

Instrumented testing is typically applied in the prototype hardware stage of the development process. The engineer instruments to determine pressures, motions, temperatures, etc., with output historically to oscilloscopes or to tape or chart recorders. Some forms of computer manipulation of acquired data are well known - P-V diagrams, for instance. While valuable and insightful, the authors suggest that carrying these efforts another step can add benefit. Analog or digital test data is transformed with graphics routines to view the actual event that the data represents. As an example, we were interested in the axial movement of the orbiting scroll during operation. We mounted proximity probes pointed at the orbiting scroll thrust surface in the fixed scroll. Output from two probes was stored in a digital oscilloscope (see Figure 4A). We transferred that output to our workstation, converted the voltages to displacements, and calculated the displacement of the orbiting scroll thrust surface based on the known probe locations. We proportionally exaggerated the displacements for visual impact. The result is the capability to view an animated representation of the orbiting scroll with those displacements superimposed (see snapshot, Figures 4B and 4C).

SUMMARY

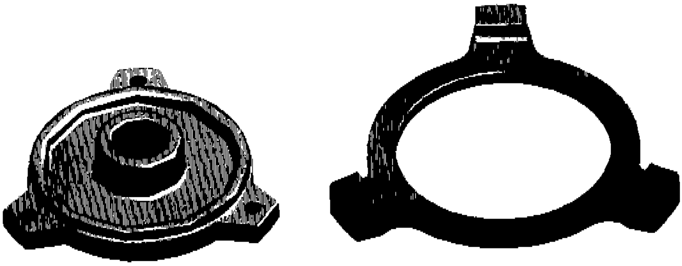
We have presented our contention that visualization is important to the design and development processes. We have suggested that computer tools available today enhance the ability to visualize complex mechanisms such as the scroll compressor, and have discussed other areas in which these tools can be used for overall improved design practice with increased productivity. We hope that the examples from our experience might inspire other ways to take advantage of the power of computer tools in our profession.

REFERENCES

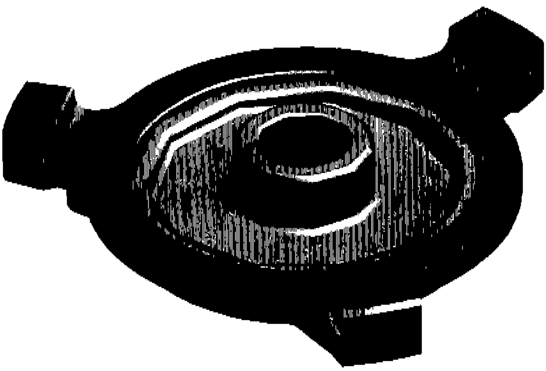
1. T. Kassouf, E. Tomayko, J. Vaccaro, "Selection Considerations for Rotary Compressor Shaft Geometries", proceedings of the 1988 International Compressor Conference.

2. PrimeDESIGN Documentation; PRIME Computer, Inc.; 1989

3. PATRAN Plus User Manual; PATRAN, A Division of PDA Engineering; 1988.



BEARING COMPONENTS (a)



BEARING ASSEMBLY (b)

Figure 1. COMPUTER-AIDED DESIGN: (a) Scroll Bearing Components, (b) Bearing Assembly

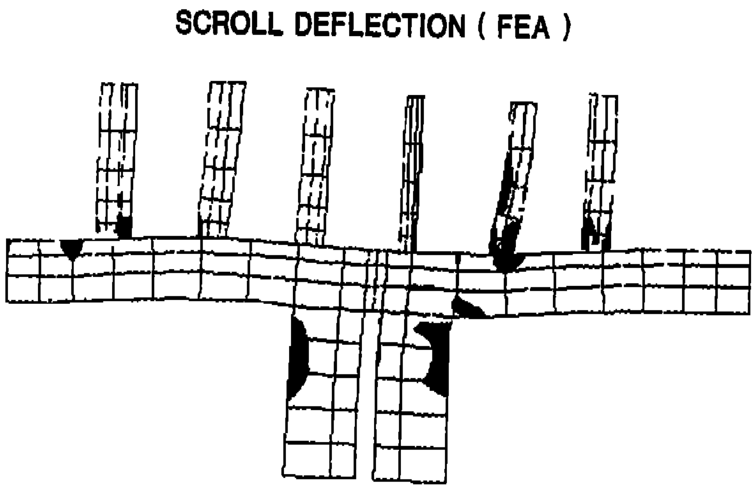
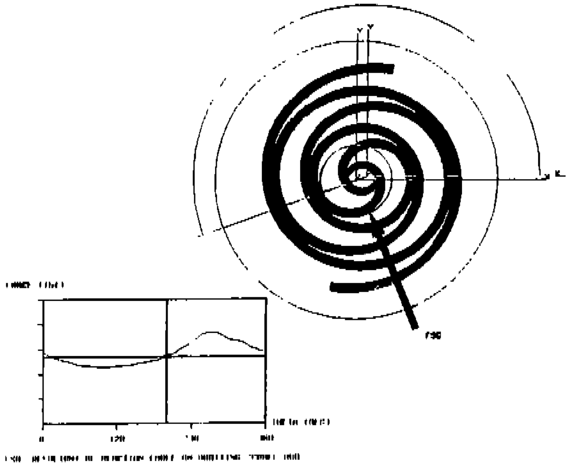
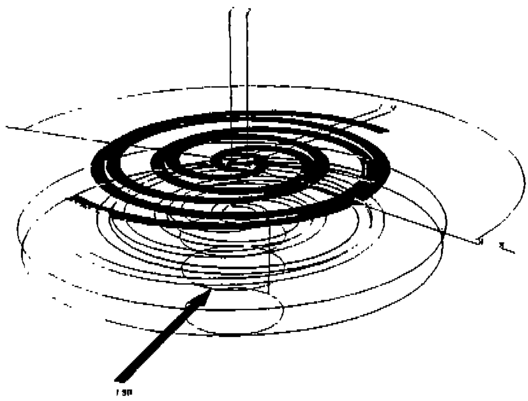


Figure 2. FINITE ELEMENT ANALYSIS: Deflection Analysis of Scroll Component



FORCE DISPLAY (a)



FORCE DISPLAY (b)

Figure 3. GRAPHICS SIMULATION: Scroll Motion and Reaction Force Display, (a) 2-D View, (b) 3-D View

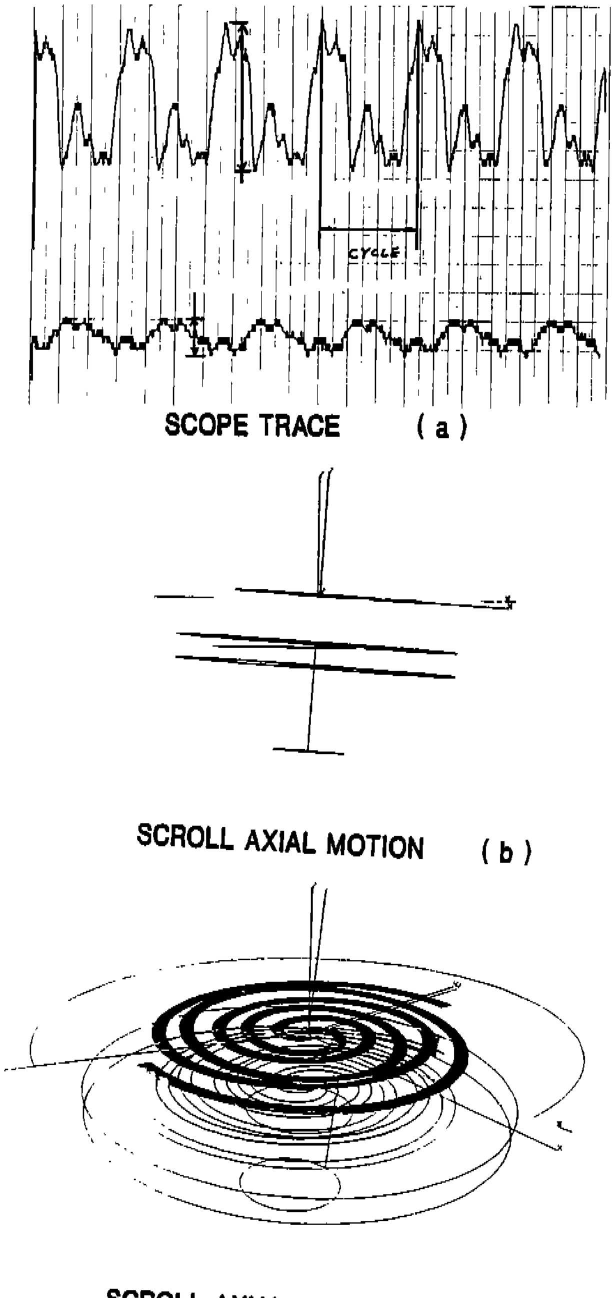


Figure 4. EXPERIMENTAL TEST ANALYSIS: Scroll Axial Motion, (a) Scope Trace Output, (b) 2-D View, (c) 3-D View