Use Of Personal Computers In The Structural Design And Product Engineering Of Furniture

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ABSTRACT – The analysis of furniture structures is a technically difficult and computationally complex process. Computer programs are presented which are designed to be used on a small inexpensive computer which can be used to solve many of the problems important to the practicing furniture engineer. Included are programs for the analysis of two-dimensional furniture frames; cases constructed of flat panels; bookshelves; case bottoms and tops; and drawer bottoms.

KEYWORDS – furniture structural analysis, product engineering, microcomputer, Commodore 64

The structural analysis and subsequent strength design of furniture is a complex process which requires skilled practitioners to formulate the necessary force and strain equations, and to carry out the detailed solution of equations without error. To a large extent, the introduction of large-scale scientific computers and in particular, the development of accompanying general purpose structural analysis programs have greatly simplified this process and have provided a means whereby quite complex furniture frames can be analyzed in seconds. These programs are powerful analytical tools and have contributed greatly to the discipline of furniture strength design. Their use is limited, however, to those practitioners who have access to large scientific computers. As a result, the Furniture Research Center has attempted over the years to use these "exact" analytical programs to develop simplified programs which can be run on smaller computers. At first this was done with the intent of creating computer programs which could be run on mid-size or mini-computers of the size commonly used in the furniture industry for accounting and inventory purposes. As low cost personal computers became available, however, it became apparent that they might ultimately provide the means whereby the principles of strength design could be routinely applied to furniture design by practicing furniture engineers. Attempts were made, consequently, to develop programs which could be run on relatively inexpensive, yet relatively powerful personal computers. Several of the programs which have been written to date are described briefly in this paper.

PREVIOUS HISTORICAL DEVELOPMENT OF FURNITURE PROGRAMS

As stated above, the rational analysis and design of common furniture construction is both conceptually difficult and computationally complex. There are few statically determinate constructions in use which can be analyzed solely on the basis of simple force summations. The majority of furniture structures are statically indeterminate. Their analysis, therefore, requires the simultaneous solution of several unknowns. In the case of an upholstered furniture frame, for example, an exact analysis of the frame may require the solution of 200 equations. Furthermore, furniture frames are often constructed of curved members of non-uniform cross section, and the joints are semi-rigid rather than rigid in behavior, further complicating their analysis.

Given the difficulties of both formulating and executing analyses of furniture constructions and the relatively low cost of the product, the strength design and product engineering of furniture remained basically an art based on trial and error, and experience, long after rational methods of analysis and design were commonly used in other areas of construction. The introduction and availability of large capacity, high speed, digital computers in the mid-1960's made it feasible, however, for the first time to approach the strength design of furniture on a scientific basis. Computer-based methods of structural analysis, accordingly, were written for the strength design and product engineering of furniture as early as the mid to late 1960's. A method for the analysis of two-dimensional chair side frames based on slope deflection methods written in FORTRAN was developed in 1965 and published in 1968 (Eckelman and Goodrick 1968); an updated version written in both FORTRAN and BASIC was published in 1976 (Eckelman and Fergus 1976). A FORTRAN program for the analysis of three-dimensional furniture frames with semi-rigid joints was published in 1968 (Eckelman 1968). An updated, more useful form of this program also written in FORTRAN was published in 1970 (Eckelman 1970a, 1970b, 1971). This latter program continues to be the most useful tool available for the analysis of frames with semi-rigid joints. These programs have been important tools in the development of furniture mechanics; their availability and use have lead to an understanding of the magnitude and distribution of forces in furniture that otherwise would have not been possible.

In addition, the insights resulting from their use have led to the development of simplified methods of analysis for some types of furniture, and also to the development of methods of analysis for some non-frame type furniture. Historically, however, at the time of their development all of these programs required the use of large digital computers. Their use, therefore, was limited largely to research in large universities or companies. Of particular interest, they could not readily be used by practicing product
engineers and designers. This proved to be a serious limitation in the furniture industry where the number of resident practicing structural engineers is quite limited and where design tools which can be used by trained technicians rather than by licensed professionals are needed.

This situation changed, however, with the introduction of the low cost personal computer. Work carried out at Purdue University indicates that computers such as the Commodore 64 have adequate capacity and computational power for analyzing and designing relatively complex furniture structures. Given the modest costs of these computers, the tools needed for the exact efficient design of furniture are now within the financial capabilities of even the smallest furniture shops.

AVAILABLE PROGRAMS

Several representative programs which have been written for various types of furniture analyses are listed in the appendix. These programs have been written in BASIC and will run on a Commodore 64 computer. Additional programs are currently being prepared. Eventually, all of these programs will be collected together to form a design library for the practicing furniture engineer.

Literature Cited


Appendix—Microcomputer Programs for Furniture Design

CODOC3

The computer program described in this section may be used to analyze certain types of common furniture which contain a two-dimensional quadrangular side frame. Specifically, it may be used to analyze the following furniture frames: a chair side frame with rail and stretcher (Figure 1); a chair side frame with arm and rail but no stretcher; an easy-chair type side frame; table and desk frames; and finally, case and carcass front frames. Any of the members in the frame, except the stretcher, may tilt and the frame may be submitted to any or all of seven different loads. Members may be either rectangular or round in cross section.

Input to the program consists of the width, thickness, and modulus of elasticity of each member; the horizontal and vertical location of key points of the frame; and the loads applied to the frame. Output consists of the deflection of five points on the frame; the bending force acting on the end of each member (and the joints); and the bending stress to which each member is subjected. In addition to the data presented in tabular form, the bending forces acting on the ends of the members is given in graphic form.

This program was one of the first developed by the author for the analysis of furniture frames. It was first written in FORTRAN, then in BASIC for scientific computers, and then was written to run on the Commodore 64. The value of the program in furniture engineering is that it provides information concerning the forces acting on the members and joints in a number of common furniture frames. In addition, the program is relatively short and it executes rapidly. The disadvantage of the program is that it can only analyze frames which contain a quadrangular, that is, a four member, rigid—jointed frame.

Figure 1. Diagram showing a chair side frame which contains a quadrangular (i.e., four—member, rigid frame). Other furniture constructions which include such frames and therefore can be analyzed with CODOC include chair side frames with arm and rail but no stretcher, easy chair type frame, table side or front frame, and case front frame.
COD8G

COD8G is a program which is able to analyze any type of two-dimensional furniture frame. It is based on the stiffness method of matrix analysis. In theory, it is able to treat a rigid-jointed frame with any number of members which are arranged in any configuration. In practice, the number of members which can be treated is limited by the memory capacity of the computer; frames with up to twenty members have been analyzed on the Commodore 64. It is therefore much more versatile in use than is CODOC3 which is described above. It is, however, more complex to use and has higher memory requirements.

Input to the program consists of a) the cross sections of the members along with their material properties; b) the spatial location of the ends of the members; and c) the loads applied to the furniture. Output of the program includes a) the axial, shear, and bending forces acting on the ends of the members; and b) the deflections of the ends of the members and of the joint centers.

Artificial joints may be created in the structure wherever desired so that non-uniform members may be approximated by a series of uniform members. Furthermore, artificial members may also be created; this feature allows the action of semi-rigid joints to be approximated by the action of an inserted member.

The program will treat both determinate and indeterminate frames. Its use, therefore, makes it possible for an analyst, trained in its use, to analyze the distribution of forces and the deflections in essentially any type of two-dimensional furniture frame.

CASE1

CASE1 is a program which is able to analyze case-type furniture which is made up of flat panels (Figure 2). In the model used in this program, it is assumed that panels satisfy the following assumptions: a) the individual panels satisfy the requirements of thin elastic plates; b) the panels do not deflect in their own plane; c) the plates are linked to one another in such a way that shear and axial forces are transmitted, but not bending forces.

Input to the program consists of the length, width, and height of the case; the thickness, length, width, and modulus of elasticity of the individual panels; and the loads applied to the case. Output for the program consists of the deflection of the free corner of the case and the forces acting at each corner of each panel.

This program is particularly useful in determining the deflection of any given case construction, and in determining the effect of changing any panel or any part of the construction on the stiffness of the case as a whole. It is also useful in that it provides the information needed for determining the forces acting on the fasteners used to hold the case together.

References


Eckelman, C.A. and M. Rashid. 1985. The Analysis of Five-Sided Furniture Cases. Purdue University Agricultural Experiment Station.

SHELF1

SHELF1 is a program that was designed to permit the analysis of shelves under either point or uniform loading (Figure 3). Deflection of the shelf is found as

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Figure 2. Diagram showing the configuration and support system for a case to be analyzed by the program CASE1.

Figure 3. Diagram showing the configuration and support system for a case to be analyzed by the program CASE1.
the sum of a series. Use of this model permits the deflection to be found at any point in the shelf, as a function of any number of loads (or a uniform load) applied elsewhere to the shelf.

Input to the program consists of the length, thickness, width, and modulus of elasticity of the shelf along with the loads applied to the shelf. Output consists of the deflection of the shelf at the desired point along its length. Shelves with specified moments of inertia may also be treated by specifying the shelf thickness as "t" and shelf width as equal to $12 \times 1$ where $1$ is the moment of inertia specified for the shelf.

References


DEFLCTN

DEFLCTN was written to permit the calculation of the deflection of shelves, case bottoms and tops, and drawer bottoms when they are supported in various ways (Figure 4). Specifically, the program may be used to calculate:

1. Deflection of a shelf simply supported at each end, and supported at mid-span on the rear, under the action of a uniform load.

2. Deflection of a shelf simply supported at each end and fully supported along its rear edge (i.e., simply supported on three edges), under the action of a uniform load.

3. Deflection of a shelf — or a case top or bottom — simply supported on four edges, under the action of a uniform load.

4. Deflection of a shelf — or case top or bottom or drawer bottom — fixed on four edges.

Input data consists of length, width, thickness, and modulus of elasticity of the shelf material, and the uniform load. Output consists of the deflection of the shelf at the desired point.

References


Figure 3. Diagram showing the configuration and support system for a shelf to be analyzed by the program SHELF1.

Figure 4. Diagram showing three of the several possible support conditions for shelves and case tops and bottoms which can be analyzed by DEFLCTN, including a) shelf simply supported at each end; b) shelf simply supported at each end and at midpoint on back side; and c) shelf simply supported on three edges.
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