COMPUTER VISUALIZATION IN MECHANICS

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Summary

An overview of visualization and animation of data processing outcome has been carried out together with documentation of outcome analyses of mechanics construction software . .Vector and raster screen graphics have been distinguished in data and results display. Almongst modern *FEM* programmes, the following have been described: *COSMOS/M*, *ADINA*, *RPK/NASTRAN*, and *ROBOT*, the most recent outcome of cooperation between Poland and France in this field. Graphical documentation of data processing results in *CAD* systems have been discussed on the basis of *AutoCAD*, *DesignCAD*, *DesignView*, *LOGOCAD*, *SysCAD* and *VersaCAD*. Among universal programmes for graphical documentation analysis of data, the following have been discussed: *Movie.BYU*, *MovieStar.BYU*, *RenderStar*, *TDImage* and *FEMVis*. Sugestions following from the current state of technology in computer data processing were presented with the design of engineering structures and technical appliances in mind.

Foreword

Visualization and animation of the outcome of data processing and graphical documentation of results analyses has a practical, scientific and didactic application. From the point of view of economy the crucial element is decision-making on the basis of results analyses which aim at optimizing products together with their construction and processes of manufacture. Educational benefits of visualization and animation of the outcome of data processing ensue from their instant physical interpretation. The need for visualization and animation of the outcome of data processing stem from the fact that few computer users can construe strings of numerals resulting from processing. Visualization and animation of the outcome of data processing makes the outcome user-friendly especially for decision-makers issuing means for subsequent projects which follow form correct data interpretation. For professionals, visualization and animation has the significance of a physical experiment which validates usefulness of experiments carried out. The foregoing suggests that visualization and animation should be treated as prerequisite for future development of engineering and production technology. Visualization and animation as well as graphical data processing attestation is of vital importance in creating documentation necessary for construction planing of new structures of engineering objects and technical units. Visualization and animation in mechanics is an important intermediary goal in usability, cost and safety optimization.

Visualization and animation of data processing plays an important role in scientific research in: constructing new, especially nonlinear, methods of static and dynamic analysis, 2) examining properties of new structures, and 3) establishing new methods of construction dimensioning and predicting their safety and reliability.

comprehensible form with colour shading (e.g. of different values in the stress or temperature field, etc.). Information requiring separate analyses or documentation can be recorded with a number of peripherals: dot-matrix printers, laser printers (*HP* standard) and plotters capable of interpreting HPGL commands.

ADINA System [1],[8],[9],[10] (*Automatic Dynamic Incremental Nonlinear Analysis*, from *Adina R&D Inc.*) requires the following hardware: PC 386 plus, standard graphics (VGA plus), work stations: *Sun, Silicon, Apollo, DEC*. The system consists of a series of software packages with a variety of applications: *ADINA-IN* - the preprocessor for data preparation; *ADINA* - main software for mechanical analysis; *ADINA-F* - software for analyzing flow of liquids; *ADINA-T* - software for analyzing heat exchange in solid bodies; *ADINA-PLOT*- a postprocessor enabling interpretation and publishing obtained results .

ADINA system has calculation possibilities such as *COSMOS/M* (without electromagnetic problems). Unfortunately, versions of *ADINA* software known to the authors are not compatible with other software applications e.g. of the CAD type. Graphical potential of *ADINA-PLOT*: 2D and 3D graphics (only wireframe models, lack of shading).

Visualization of data and results in *ADINA* system allow the following: close-ups, moving objects, deleting invisible lines, display in several windows at a time, adding captions and comments, colouring separate elements. Selective data and results viewing is also possible. Graphical documentation of data can be done by means of laser printers (*HP LaserJet*), plotters (*HPGL, Calcomp model*) and postscript printers.

ANSYS system [1] (from *Manson Analysis System Inc.*) Has the following hardware specifications: PC computers (depending on software XT or 386 plus [for *ANSYS 386* package]), also workstations, graphics: EGA cards and superior, as for other described above, arithmetic coprocessor is required. In the streamlined version linear static and dynamic analysis and nonlinear analysis of heat flow are possible. In the 386 version calculation abilities are analogous to that of *COSMOS/M* and *ADINA*. The system is compatible with CAD such as: *AutoCAD, Cadkey, Versacad*. 2D and 3D graphics is possible (wireframe models and pseudoreal, i.e. with light modelling, etc.). Visualization of data and results - capabilities same as for software discussed above. Documentation possible with the use of dot-matrix printers, laser printers, postscript printers and plotters (*HPGL, DMPL*).

RPK/NASTRAN system [1] (from *RPK Corp.*) requires PC 386 computers, arithmetic coprocessor, graphics - CGA, EGA, VGA cards, can also be executed on *Apollo* workstations. This system is not conformable with CAD software. In the process of visualization of data and results, the following operations are possible: selective viewing, colouring of planes, deleting invisible lines, alteration of view point and its direction, etc. Its possible to record results with the use of dot-matrix printers, laser printers, and postscript printers.

NOTE: [3] reports on the software (*FEMvis*, for 'big' IBM 5080's) which makes it possible to visualize data and results from FEM software (including *NASTRAN* system).

ROBOT programme, developed in cooperation between Poland and France, also deserves attention (from *RoboBAT v.6*). Designed for construction (and mechanics) engineers, it combines the potential of CAD programme with possibilities of calculation software for engineers. Calculating and dimensioning of constructions with reference to French norms are made possible with its use. It is supplied with libraries containing standard elements present in various engineering constructions (metal, concrete, wooden and aluminium structures). *ROBOT* system can be employed for statistical calculations of bar structures, slab structures and coating structures on the basis of linear and non-linear analysis (static and dynamic) and analysis of stability. PC/386 or PC/486 computers with VGA or SVGA cards are sufficient to exploit this programme. With the use of *ROBOT* programme it is possible to input a structure diagram together with load with the

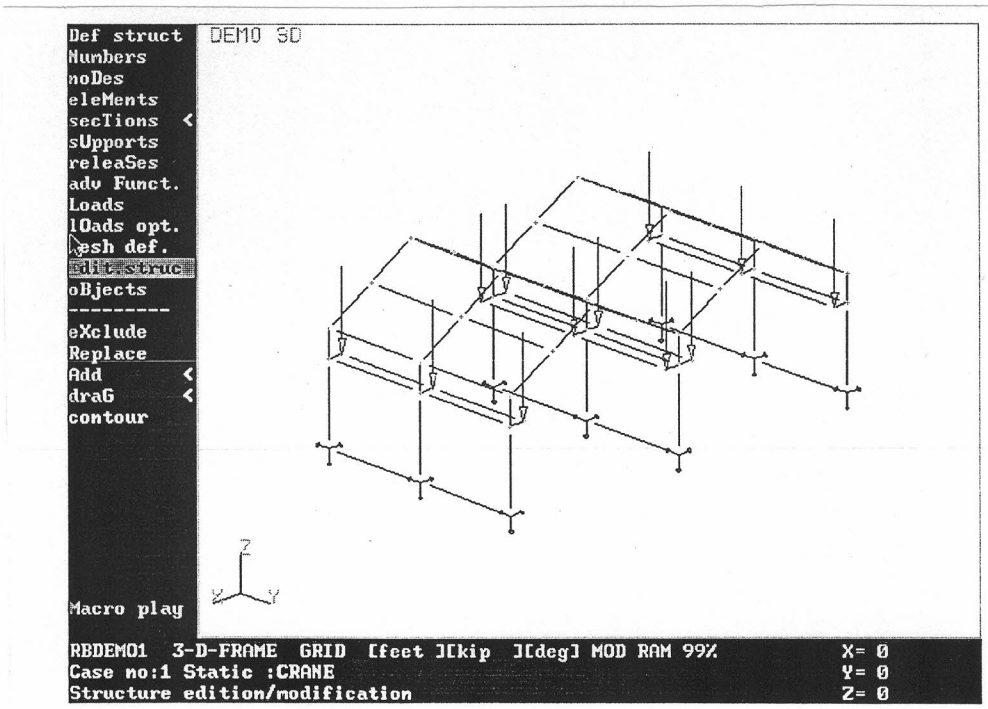

Fig.1 Example of ROBOT's program display

mouse and menu systems, in the same manner as in CAD programmes. Besides it facilitates data input of objects having symmetry parameters or are repetitive (multiplying, rotating, repositioning, mirroring). 3D constructions are easy to input. *ROBOT* system is compatible with *AutoCAD* which makes it possible to input construction diagrams under its supervision and to generate DFX package recognized by *ROBOT*. Visualization of results encompasses amongst others: displaying diagrams of internal forces, stress and their envelopes, shape of object deformation with movable load animation, vibration, construction buckling. Some graphic tools are as follows: magnifying, repositioning, rotating, plane sections, multi-windows display, 3D display with possible pseudo-3D printout.

In addition, there is a wide array of other useful and voluminous systems such as *ADAMS* (until recently under embargo *COCOM*) or *ARTIF*. Other software can be found which are based on programmes on different than FEM e.g. the theory of boundary elements (systems: *BEASY*, *BETSY*, *GP-BEST*, etc.).

It follows from the above that programmes assisting engineering calculations conform more and more with CAD systems and the whole process of design (calculations, drawings, optimizing, publishing) can be done within the scope of one programme.

Graphic documentation of data processing output in CAD systems

AutoCAD programme, from *Autodesk Inc.*, is used for creating 2D and 3D drawings for an object's technical documentation. The characteristic traits are user-friendliness (side, top menus, command line, mouse, or digitizer), low hardware requirements and comparatively low price. *AutoCAD* is equipped with a range of graphical commands (drawing single and multiple lines, circles, arcs, ellipses, polygons) and edit commands (enlarge, move, rotate, flat and dynamic view, copy, delete, round off, cut). Drawings can be done with a variety of lines (single, bold, dashed, etc.), divided into layers, coloured, filled with any saturation pattern. The screen can be divided into several edit screens. *AutoCAD* can be appended with user's own commands by using the built-in programming language - *AutoLisp*. Many publishers have developed overlays or programmes operating in the *AutoCAD* environment e.g.: *ParaCAD* - for *AutoCAD* parameter drawings helpful in working out conceptions, *CAOS* - for optimizing the shape of engineer's structure based on FEM

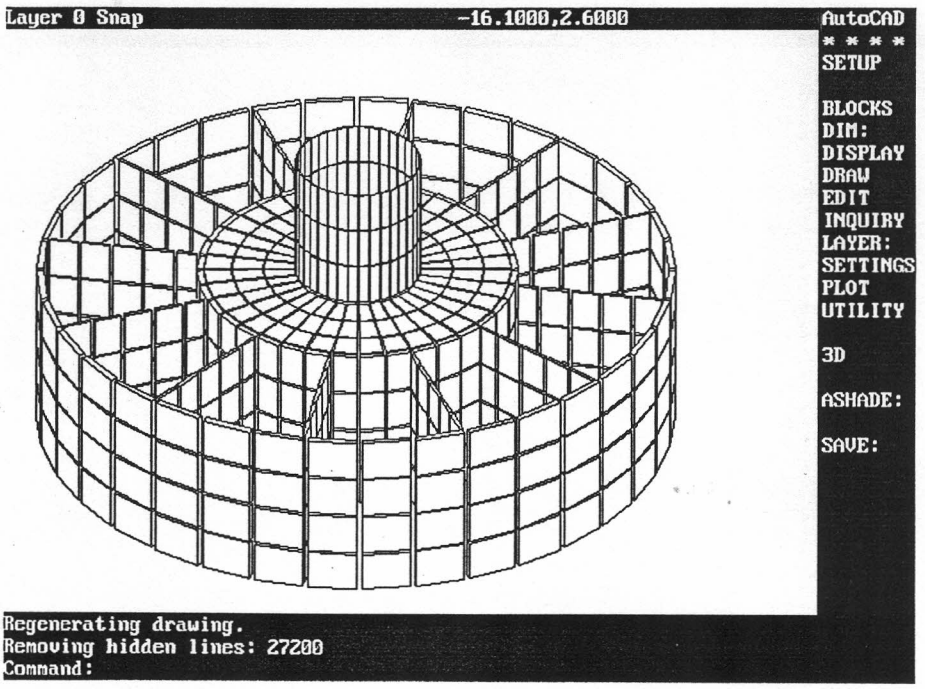

Fig.2 Example of AutoCAD's program display

calculations and estimation of volume, weight, moment of inertia, effort, dislocation. Decisions can be made on the basis of graphs of stress fields, temperature, deformations, etc.

DesignCAD, from *American Small Business Computers* [4], contrived for engineers, architects and graphic artists for making 2D and 3D drawings. Available in 2D and 3D versions. Program is managed with the common or picture menu (user's commands can be created) or digitizer. The programme provides all standard and extended drawing commands (arrows, rectangles, circle segments, perpendicular and parallel lines). Extended edit commands include breaking lines, feature change, phasing, lengthening, shortening, rounding, converting a broken line into a curve, curve smoothing, etc. Bloc operations allow: copying with rotation, dynamic transfer, stratum transfer, linear copying, rotating, scaling. 2D version embraces specialist functions for drawing on the plane (3D does not feature it) and vice versa. 3d system significance is determined by the possibility of creating and maneuvering solids (the system determines if any two solids occupy the same space, demonstrates intersection lines, adds logically, determines product of solids, intersection planes, deletes invisible lines, shades surfaces). *Design CAD* enables calculating surfaces, volume, length, angle of inclination, domain centre of gravity. The substantially developed system editor includes several fonts with the possibility of radial, slanting or perspective letter shapes. To facilitate managing *DesignCAD*, the programme is equipped with user defined macros (strings of commands at a single keystroke) user commands with the use of the attached *BasicCAD* language and the possibility of calling external COM programme. In *MSWindows* environment it is possible to simultaneously work on 6 files. 90 plotters types and 178 printers and other CAD programmes (both ways convertibility is possible with DXF, IGES, PCX, HPGL formats) can be used with *DesignCAD*. Also, the programme is compatible with editors (*WordPerfect, Ventura, Pagemaker*), data bases (*DBase*) and spreadsheets (*Lotus 1-2-3, Excel*).

DesignView, from *Prime Computervision Corporation* [4], supports the conceptual phase in design-making, analysis of solutions and demonstration of results. It is possible thanks to variable geometry and the dynamic environment in which drawings are created. Drawings made with the use of *DesignView* are models delineated by dimensions and formulas. Any change in parameters brings about recalculating their

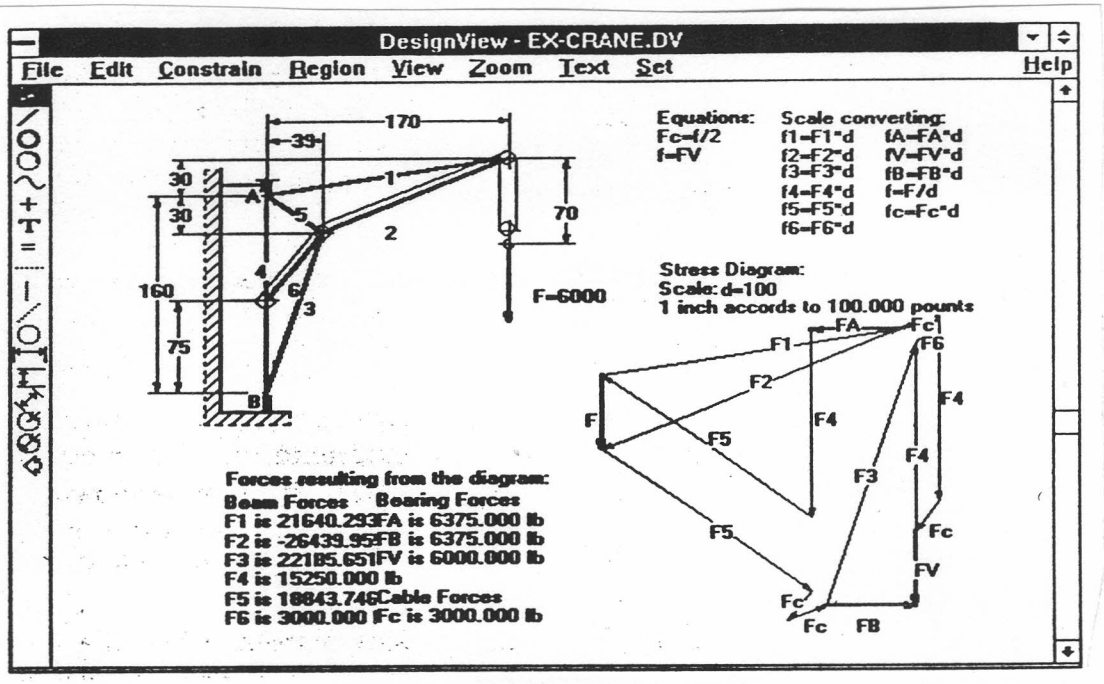

Fig.3 Example of DesignView's program display

geometry so that all equations are satisfied. All basic drawing commands are accessible (line, arch, circle, second- and third-degree curves, rounding, phasing). Each projection and 2D section can be modelled by the programme maintaining its consistence. The system has functions calculating axis, point of gravity, surface area and moment of inertia. It is possible to execute dependence with the IF-THEN-ELSE condition, solving any system of equations determining trigonometric functions, logarithms, and equipotential functions. Phenomena under analysis can also be animated. *MSWindows* environment facilitates processing a number of drawings at a time,data exchange between them and observing current changes on the screen. Excellent effects are offered by dynamic combination of drawing parameters with graphs of unit cost supplied by *MSExcel* spreadsheet which helps in optimizing production costs. *DesignView* works well with CAD programmes by converting DXF and IGES files.

LOGOCAD, from *LOGOTEC* [5], is a professional system capable of supporting all kinds of mechanical constructions. It was created with typical design offices in mind equipped with microcomputers and workstations . User's manual operations were reduced by a half (improved menu). Speed was enhanced - response time is below 1 second irrespective of image size. Indefinite number of windows with possible data exchange can be created. Furthermore, many overlay systems were devised (e.g. *Simula* - kinematic module).

By means of *Simula*, kinematic calculations and movement of flat mechanisms can be performed. The basis for calculations is geometric data from *LOGOCAD* images. Results are obtained as velocity or acceleration diagrams or as curves paths with superimposed velocity and acceleration vectors.

SysCAD, from *SYSGRAPH* [6], supports architectonic design of mechanical electrical and pneumatic structures. It consists of several modules: *SysCAD 2D m*odule for creating structures on the plain (it has a rich set of graphic functions, dimensioning according to Norms in force with potential user definable menu, cooperation with relation data base, character and text generator, dynamic relocation of structures and multiple-window display); *SysCAD 3D* module for spatial design (creating projections and sections, model generation module, perspective views and space-out views); *SysCAD Variant* for parametric design; *SysCAD Engineering* for engineering calculations and analyses (FEM); *SysCAD Library* module - graphic libraries.

VersaCAD, from *Prime Computervision Corporation*, supports construction and mechanical structures design. Allows drawing and dimensioning in 2D, design, visualization and modelling in 3D. It is equipped with a voluminous library of symbols helpful in dimensioning. Dimensioning and geometric calculations are automatic. It is compatible with CAD programmes (IGES and DXF FILES). The programme is available in versions for *PC/386* and *SPARCStation*.

Documentation of Output in CAD and FEM programmes

An important problem of modern technology is visual presentation of objects both at the time of design and later at the stage of graphic publication of results. New improved solutions leading to most advantageous options are aimed at. The significant property is real view of the studied object: its shape, colours, the play of light and animation which requires capacious computation power. The last step is direct manipulation of the technological process which leads to project completion or plotting documentation.

Programmes which concoct their own results or results processed in other programmes linked by common industrial notation of output files are plentiful. The most significant are the following:

MOVIE.BYU, from *Brigham Young Universit*y, is the element o*f MOVIE* system. It was created for presenting and processing data defined by mathematical, architectonic and geometric models which may be determined with known solids or elements with defined contours.

MOVIESTAR.BYU is a processor for the analysis of an object by means of finite element method. It can determine and change graphic parameters: create basic geometry, generate finite element grid, and prepare element for analysis by adding load, geometric and material specifications, estimate boundary conditions. Additionally, forms input data base and presents results of calculations.

RenderStar, from *Modern Medium, Inc.*, translates models created by programmes which generate 3D DFX files (*AutoCAD, Microstation, ...*) into photoreal animation and images. It models external view of objects with their background and colours. Its great advantage is the fact that it takes into account the influence of light on the object: single- or multidirectional shade and reflexion. Self-operated animation combined with the play of light gives an illusion of reality. The programme can be connected to a *VCR*.

TDImage, from *Thomson Digital Image America, Inc.*, creates 3D interactive object images. *TDI* software is used by firms across the world for locating objects in respect of town-planning. It helps to transform the designer's and architect's notion into electronic loop. Design can be done on the computer on the basis of images on display or CAD/CAM files. With TDImage object geometry can be transformed into IGES, VDA/FS, and DXF industrial standard. It is compatible with *CATIA*, *CADAN* and CAEDS. Animation is made possible by generating movement and positioning objects in the plan and change in texture parameters in real time. The programme displays 3D structure allowing for light and colour, presents orthogonal projection on the plane. It can be connected to many external appliances and can manage production.

FEMvis, from *International Business Machines Corporation*, is a tool programme facilitating engineering mechanical analyses including rotation, translatory motion and blow-up. Shapes can be deformed and deformations observed in time with their superposition. Besides, scalable fields can be visualized in plane or space. stress trajectories are displayed in many colours. The deformed object's rendering can be combined with simultaneous exhibition of stress distribution. By displaying 3D phenomena in motion with splitting screen into plane sections deformations and stress trajectories can be observed at the juncture of profiles. Input data for a predetermined object can be changed at will for observing new deformations and scalar fields. *FEMvis* is a device constituting speech and graphic presentation of engineer's concepts and framed in a box ready for use

on a variety of equipment such as workstations and mainframes. It is a tool designed for performing mechanical analyses with direct access to procedures stored (DASD) including loading, stress modelling and deformation study. With its use, prototype testing, predicting mutual influence and reaction in sections and stress distribution is made easy and efficient which to a great extent influences reliability and conditions of implementation.

Best graphical effects are obtained on *IBM AIX*-based workstations or main system drive fitted with IBM 5080 (*Screen Image Conversion and Display Control*). The options provided are: colour control, monochrome conversion with adjusting shade ratio and image scaling.

Conclusion

The analysis of the current state of research and computer data processing technology for the design of structures and technical equipment makes it possible in short-term (10-year) perspective to attain instantaneous visualization and animation of data processing results in the course of analysis of construction statics, stability and dynamics as well as computer managed documentation production. Although, up-to-date computer graphics is capable of visualization and animation of data analysis results and their graphic documentation, separate software systems do not satisfy all requirements.

Compilation of procedures satisfying practical requirements of research and training is possible through specialized supervisory programmes. Nonetheless, combining programmes activating procedures for visualization and animation of results and their graphical arrangement requires in-depth analysis and establishing their construction. The outcome should provide the possibility of managing screen visualization and animation in the expert mode, i.e. at any point in data processing, as required by the expert. Printing of the graphic documentation should be possible at any completed stage of analysis.

Implementing ideas formulated in the postulate in the training of engineers require the following:

1) to compile a handbook or a manual on engineering graphics;
2) to introduce *Computer Engineering Graphics* at technical universities;
3) to create computer graphics sections in technical university libraries;
4) to devise supervisory programmes for creating technical documentation with respect to rules and regulations in force, in accordance with investment processes which require the following documents: localization of the intended object in respect of town-planning, budget and technical estimate, results of static, dynamic and stability analysis, object's technical documentation, execution and use specification.

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