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ENGLISH

ASSISTANCE TO CLEMEX FOR

PRODUCT DESIGN

SI/MEX/86/802

MEXICO

(R) Mexico.

Technical report: Computer Aided Design, Training and Education *

Prepared for the Government of Mexico
by the United Nations Industrial Development Organization

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United Nations Industrial Development Organization

Vienna

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ABSTRACT.

The mission has been undertaken under the project "ASSISTANCE TO CLEMEX FOR PRODUCT DESIGN", SI/MEX/86/802.

The immediate objective of the mission was to assist CLEMEX Industrial Plant, producing industrial equipment and machinery in strenthen its current computer aided design activity, to elaborate a short-term (three years) development programme in this field and to recommend necessary hardware and software.

The mission lasted two months (from 22.07.86 to 20.09.86).

ACKNOWLEDGEMENTS.

I would like to return thanks to all staff members for their help in fulfiling my duties and for their realy great hospitality.

I wish them all the best and many achievements in impementing CAD to new designs.

TABLE OF CONTESTS.

ABSTRACT	1
ACKNOWLEDGEMENTS	1
CONCLUSIONS AND RECOMMENDATIONS	3
A. Conclusions	
B. Recommendations	
I. OBJECTIVE OF ACTIVITY AND DUTIES	4
A. Objective	
B. Duties	
II. DESCRIPTION OF THE ACTIVITY	5
A. Lectures	
B. Training	
C. Development programme	
1. Training programme	8
2. Recommended hardware	11
3. Recommended software	12
III. ANNEXES.	
1. Current CAD capabilities at CLEMEX plant	13
2. Recommended literature	14
3. Recommended Institutions	16
4. Programme of lectures	17
5. Programme of training	20

CONCLUSIONS AND RECOMMENDATIONS.

A. Conclusions.

1. The implementation of Computer Aided Design (CAD) in CLEMEX plant is particularly important from the following reasons:

   a. They are designing and manufacturing mechanical products of various types (cranes, pressure vessels, tanks, hidraulic presses, etc...)

   b. They must increase their design capabilities.

   c. Without performing design analyses it is impossible nowdays to design competitive products.

2. The management of the plant realizes how important are computer aided techniques and wants to use them.

3. They have already started some computer aided design activity, but their current hardware and software capabilities as well as personnel skills have to be increased (see Annex 1).

B. Recommendations.

1. The designers should use more extensively existing capabilities.

2. The management should secure continuous education and training for designers (see page 10).

3 It is necessary to buy some books and to subscribe some periodicals on CAD and Finite Element Method (FEM), (see Annex 2).

4. It would be advisable to eter into connections with some foreign Institutions with established reputation in CAD activity (see Annex 3).

5. It is necessary to enhance current hardware and software capabilities (see pages 11 and 12).

6. At the present CLEMEX does not have the budget for new adquisiciones, so it cannot make the required investment. Therefore it is recommended that UNIDO should make an effort to help them acquire the necessary hardware and software by means of a grant of about 30.000 US dollars (see pages 11 and 12). This is considered necessary to complete implementation of CAD at CLEMEX plant. Only this way they will be able to apply the full advantage of this programme.

I. OBJECTIVE OF THE ACTIVITY AND DUTIES.

A.Objective.

The objective of the mission was to assist CLEMEX Industrial Plant, producing industrial equipment and machinery in strengthen its current CAD activity.

B. Duties.

1. Main duties.

a) Training of local staff in the following fields:

a1. Mathematical modelling,

a2. Matrix algebra applications,

a3. Finite element method,

a4. Applications of existing software to some actual designs being undertaken.

2. Secondary duties.

b) Evaluation and estimation of existing capacity in the field of CAD,

c) Conduction of meetings on the targets of CAD,

d) Elaboration of a short-term (three years) development programme in CAD,

d1. Training programme for the staff,

d2. Hardware configuration,

d3. Necessary software,

e) Writing letters to software and hardware dealers asking for offers,

f) Preparation of final report.

II. DESCRIPTION OF THE ACTIVITY.

A.Lectures.

During the mission I delivered lectures on the following subjects:

a) Computer Aided Design in mechanical engineering,

b) Mathematical modelling,

c) Fundamentals of matrix algebra,

d) Finite element method,

e) Software engineering.

(Detailed programmes of the lectures are given in Annex 4).

The lectures were attended by 8 mechanical engineers.

Each of the participants received 200 pages of lecture notes (including the paper on the FEM in CAD).

B.Training.

All the attendants of the lectures were trained in applying the theory to solving some engineering problems.

Using existing application programs they performed simple design analyses of beams, frames, shafts and pressure vessels. They had to define the problem, built a model, prepared the data, run the program, analyzed the results and introduced changes in the designed object. (Detailed programme of the training is given in Annex 5).

I had discussions and consultations on CAD implementations to new designs.

C.Development programme.

Accordingly to the performed CAD works it is possible to distinguish three levels of CAD activity:

1, fundamental,

2, advanced, and

3, developed.

1.Fundamental level.

Tasks.

Simple design analyses, performed using application programs - mainly product oriented.

Means.

a.Hardware configuration.

IBM-PC compatible CPU with 512 kB RAM memory,

keybord,

monochromme or color monitor of medium resolution (640x400),

2 floppy disk drives (2x360kB),

line printer (200 cps),

plotter, format A3, (writing speed 1cm/s, resolution 200lines/cm)

b.Necessary software.

MS DOS operating system, BASIC compiler, Scientific Subroutine Library, Application programs - mainly product oriented, properly choosen to the needs (analysis of gears, shafts etc.).

c.Personnel skills.

Able to define problem, to model analysed designs, to use application programs and to write simple programs using BASIC language.

2.Advanced level.

Tasks.

Complex design analyses, performed using engineering applications systems (finite element analyses, simulation, optimization etc.). Interactive pre and postprocessing of data and results.

Means.

a.Hardware configuration.

IBM-PC/XT or IBM-PC/AT compatible CPU with 640kB RAM memory,

keybord,

hard disk 20MB,

2 floppy disk drives (2x360kB or 1x360kB + 1x1.2MB),

numeric coprocessor 8087 or 80287,

monochrome or color monitor of medium resolution (640x400),

line printer (200cps),

plotter, format A1 (writing speed 5cm/s, resolution 200lines/cm),

digitizer (tablet), format A3 (resolution 200lines/cm).

b.Necessary software.

MS DOS operating system, BASIC and FORTRAN compilers, graphical system, scientific subroutine library, finite element system, graphical pre and postprocessors.

c.Personnel skills.

Able to use interactive graphical pre and postprocessors, to model analysed designs, to use engineering application systems, and to write programs using FORTRAN language.

3.Developed level.

<u>Tasks</u>.

Three dimensional geometry modelling using interactive graphics. Complex design analyses performed using engineering application programs (systems). Automatic drafting. NC-part programming.

<u>Means</u>.

a.Hardware configuration. (Workstation).

32-bit CPU (like VAX or PRIME) with 1MB RAM memory,

disk drive min.64MB,

magnetic tape drive unit,

12" or 14" monochrome or color alphanumeric monitor,

17" monochrome or color graphic display terminal of high resolution (1024x768), keybord,

digitizer(tablet), format A3 (resolution 200lines/cm),

hard copy unit,

line printer (250 cps),

plotter format AO (writing speed 5cm/s, resolution 200lines/cm).

b. Necessary software.

UNIX like operating system, BASIC, FORTRAN 77 and C compilers, Data base management system, CAD system (like MEDUSA, EUCLID etc.), FEM system (like ADINA, MARC etc.) with pre and postprocessors.

c. Personnel skills.

Able to use CAD system for geometry modelling, for preparing data to engineering applications systems for automatic drafting, for NC-part programing, to use engineering applications systems, and to write programs using FORTRAN language.

The above classification is not strict and dependently to the needs there are possible different variants, for example automatic drafting can be implemented without having workstation.

Accordingly to the needs there are possible two versions of CAD activity development at CLEMEX plant.

First one assumes that in the next three years (1987/89) advanced level will be sufficient (in programme necessary actions are planed for 1986/87 and 1987/88 periods).

Second one assumes that at that time it will be necessary to extend activities for reaching development level (in programme this extensions are planed for 1988/89 period).

1. Training programme.

Computer aided design is very rapidly developing and changing discipline and continuous education and training constitute the basis for effective activity in this field.

There are the following main forms of professional education in CAD:

1. Selfteaching.

Having basic knowledge, designers utilize existing capabilities for performing more and more complex tasks.

2. Courses.

Attendants obtain new knowledge (informations about new methods, achievements etc.).

3. Trainings.

During training or workshops engineers do some exercises and actively take part in solving problems.

4. Consultations.

Usually this is very effective form of education because the consultant can act flexibly according to the needs and can collaborate with many designers.

	ACTIVITIES.	NECESSARY SKILLS.	FORM OF EDUCATION.
1986/87	- Simple and more complex design analyses of machine or structure parts (shafts, gears, beams etc.)	- Ability of defining and modelling such a problems and solving them using computer techniques. Fundamental knowledge of MS DOS cperating system (editor, linker and debugger)	- Introductory course on CAD and FEM (30 hours). Introductory training on CAD and FEM (30 hours). Selfteaching. Course or selfteaching on MS DOS O/S (15 hours).
	- Developing computer programs accordingly to the needs.	- Knowledge of BASIC language.	- BASIC language course with exercises (40 hours).
1987/88	- Complex design analyses (linear static and dynamic) of machines and structures.	- Ability of defining and modelling linear static and dynamicproblems as well as solving them using finite element, simulation and optimization computer systems.	- System users course (40 hrs) Training at design office. (2designers 3 months each) Consultation (4-6 weeks). Selfteaching.
	- Interactive pre and postprocessing of data and results.	- Knowledge of computer graphics fundamentals. Ability to utilize the graphical pre and postprocessors.	- Course on computer graphics fundamentals (30 hours). Pre and postprocessor users course (20 hours).
	- Developing computer programs accordingly to the needs.	- Knowledge of FORTRAN language.	- FORTRAN language course with exercises (30 hours).
	- Automatic drafting.	- Ability to utilize the drafting computer system.	- Drafting system users course (20 hours).
1988/89	- Complex design analyses (non linear static and dynamic, thermal) of machines and structures.	- Ability of defining and modelling nonlinear static, dynamic and thermal problems as well as solving them using finite element, simulation and optimization systems. Fundamental knowledge of UNIX like operating system.	- System users course (40hrs). Training at design office (2 designers 3 months each). Consultation (4-6 weeks). Selfteaching. Course on UNIX like O/S (20 hours). Selteaching.
	- Geometry modelling.	- Ability to utilize CAD geometry modelling system.	- CAD system users course (30 hours). Training (1 designer 4-6 weeks).
	- NC part programing.	- Ability to utilize CAD NC part programing system.	- CAD system users course (30 hours). Selfteaching.

2. Recommended hardware.

Period 1986/87.

IBM PC/XT or IBM PC/AT compatible CPU unit with 640kB RAM memory,
hard disk 20MB,
2 floppy disk drives (2x360kB or 1x360kB + 1x1.2MB),
coprocessor 8087 or 80287,
keybord, line printer (200 cps),
12" or 14" color monitor of medium resolution 640x400 lines,
backup tape unit - if possible,
digitizer (tablet), format A3 (resolution 200 lines/cm),
plotter, format A1 (writing speed 5cm/s, resolution 200lines/cm).

Estimated cost 18.000 US dollars.

Period 1988/89 (If it will be necessary - workstation).

32-bit CPU unit (VAX or PRIME like) with 1MB RAM memory,
disk drive unit 100MB,
magnetic tape drive unit,
12" or 14" color alphanumeric monitor,
17" color graphic display terminal of high resolution 1024x1024,
keybord,
digitizer (tablet), format A3 (resolution 200lines/cm),
hard copy unit,
line printer (250 cps),
plotter, format A0 (writing speed 5cm/s, resolution 200lines/cm),

Estimated cost 40.000 US dollars.

3. Recommended software.

Period 1986/87.

MS DOS operating sys tem (the last version),
BASIC and FORTRAN compilers,
scientific subroutine library,
finite element system, for linear static and dynamic analyses (SAP 86 or equivalent),
graphical pre and postprocessor (MICROTAB or equivalent),
CAD graphical sys tem (AutoCAD, ProDesign or equivalent).

Estimated cost 12.000 US dollars.

Period 1988/89.

UNIX like operating system,
BASIC, FORTRAN 77 AND C compilers,
data base management sys tem (relational type),
CAD system (MEDUSA, EUCLID or equivalent) with NC part programing facilities,
finite element system for nonlinear static and dynamic as well as thermal analyses (ADINA, MARC or equivalent),

Estimated cost 30.000 US dollars.

Several letters has been sent to hardware and software dealers asking for detailed informations about their products as well as prices.

Annex 1.

Current CAD capabilities at CLEMEX plant.

<u>Personnel skills</u>.

In the Engineering Department responsible for designing there are 6 mechanical engineers (4 experienced and 2 young), 1 electrical enginer and 6 draftsmen.

They have started to use computer techniques and have terminated the course of BASIC language.

<u>Hardware</u>.

IBM PC compatible microcomputer TeleVideo with 512 kB RAM memory,
keybord,
12" color monitor,
line printer.

<u>Software</u>.

MS DOS like operating system TeleDOS,
BASIC compiler,
scientific subroutine library,
about 30 engineering application programs (problem and product oriented).

Annex 2.

Recommended literature.

a. Books.

1. Encarnacao, Schlechtendahl
Computer Aided Design
Springer-Verlag
2. Shigley, Mischke
Standard Handbook of Machine Design
McGraw Hill
3. Rogers, Adams
Mathematical Elements for Computer Graphics
McGraw Hill
4. Robinson
Understanding the Finite Elements
Robinson & Associates
5. Przemieniecki
Theory of Matrix Structural Analysis
McGraw Hill
6. Huebner
The Finite Element Method for Engineers
J.Wiley
7. Zienkiewicz
The Finite Element Method
McGraw Hill
8. Gallagher
Finite Element Analysis - Fundamentals
Prentice - Hall
9. Bathe
Finite Element Procedures in Engineering Analysis
Prentice-Hall
10. Guidelines to Finite Element Practice
NAFEMS-NEL, Glasgow

b.Periodicals.

1. Finite Element News
   Robinson & Associates, Great Bidlake Manor, Bridestowe, Okehampton, Devon EX20 4NT, England.
2. CAD
   Butterworth Scientific Ltd., 88 Kingsway, London WC2 6AB, England.
3. Finite Elements in Analysis & Design
   North-Holland, POB 1991, 1000 BZ Amsterdam, The Netherlands.
4. Computer Aided Geometric Design
   North-Holland, POB 1991, 1000 BZ Amsterdam, The Netherlands.
5. Computer Methods in Applied Mechanics and Engineering
   North-Holland, POB 1991, 1000 BZ Amsterdam, The netherlands.
6. Computers & Structures
   Pergamon Press, Fairview Park, Elmsford, NY 10523, USA.
7. Numerical Methods in Engineering
   J.Wiley, Baffins Lane, Chichester, Sussex, England.

Annex 3.

Recommended Institutions.

1. Computational Mechanics Centre
   Adhurst Lodge, Ashurst, Southampton S04 2AA, England.
2. Computer Aided Design Centre
   Madingley Road, Cambridge CB3 OHB, England
3. IKO Software Service, GmbH
   Albstadtweg 10, D-7000 Stuttgart 80, West Germany
4. Industrial Institute of Construction Machinery
   Kolejowa 57, 01 210 Warszawa, Poland.
5. National Engineering Laboratory
   East Kilbride, Glasgow G75 OQU, England
6. Structural Dynamic Research Corporation
   300 Techne Center Drive, Milford, Ohio 45150, USA.

Annex 4.

Programme of lectures.

a. <u>CAD in mechanical engineering</u>. (6 hours)

1. Differencies between conventional design and CAD.
2. Product characteristics and design criteria.
3. Objects, problem areas and disciplines.
4. Types of CAD activities.
5. Computational Mechanics.
   5.1 Finite element method.
6. Computer graphics.
7. Integration of analysis methods.
8. Software
   8.1 CAD systems
9. Hardware
   9.1 Evolution of hardware configurations.
   9.2 Workstations.
10. Personnel skills.
11. Know-how.
12. Economical aspects of CAD.

b. <u>Mathematical modelling</u>. (6 hours)

1. Real problems and their simplifications.
2. Physical model.
3. Initial mathematical model.
4. Approximations (numerical methods).
5. Final mathematical model.
6. Variational formulations.
7. Modelling of geometry.
8. Souces of errors.
9. Computer simulation.
10. Verification of the model.

c. Fundamentals of matrix algebra. (4 hours)

1. Definition of matrix.
2. Types of matrices.
3. Matrix algebra
   3.1 Addition
   3.2 Subtraction
   3.3 Multiplication
   3.4 Inversion
4. Applications.

d. Finite element method.

Part I. Linear static analysis. (20 hours)

1. The idea of the method.
2. Definition of a finite element.
   2.1 Shape.
   2.2 Nodes.
   2.3 Nodal values (known and unknown).
   2.4 Approximation functions (shape functions).
3. Shape functions.
4. Nodal values (known) equivalent to distributed values.
5. Relations between known and unknown nodal values for the element.
   5.1 Stiffness matrix.
6. Coordinate systems.
   6.1 Global.
   6.2 Local (connected with element).
   6.3 Boundary.
   6.4 Material.
7. Transformations of values from one to another coordinate system.
8. Relation (in global coordinates) between known and unknown nodal values for the whole system.
   8.1 Global stiffness matrix.
9. Boundary conditions.
10. System of equations and its properties.
11. Solution of the system of equations.
12. Calculation of other derived values.
13. Finite element systems.
14. Examples of applications.

Part II. Linear dynamic analysis. (12 hours)

1. Frames of reference.
2. Types of forces used in dynamic analysis.
   2.1 Loads.
   2.2 Mass forces.
   2.3 Elastic forces.
   2.4 Damping forces.
3. Equation of motion.
4. Eigenvalue problems.
5. Initial value problems.
   5.1 Direct integration.
   5.2 Mode superposition method.
6. Accuracy analysis.

Part III. Nonlinear analysis. (6 hours)

1. Classification of nonlinear analyses.
2. Equations of equilibrium.
3. Solution of nonlinear equations.

e. Software engineering. (6 hours)

1. Languages.
2. Types of software
   2.1 System software.
   2.2 Tool (basic) software.
   2.3 Application software.
      2.3.1 Problem oriented.
      2.3.2 Product oriented.
3. Structure of software.
   3.1 Structural programing.
4. Estimation of software.

Annex 5

Programme of trainig. (FEM applications to CAD)

1. Theory of failures.
   1.1 Fatique strength.
2. Factor of safety.
3. Optimization in design.
4. Steps in design analysis.
   4.1 Defining the problem.
   4.2 Modelling.
   4.3 Preparing the data.
   4.4 Running the program (system).
   4.5 Analysing the results.
5. Training in using existing application programs.
   5.1 BEAM1. (Analysis of beams)
   5.2 PORTFRM. (Analysis of frames)
   5.3 SHAFT3. (Analysis of shafts)
   5.4 MSHELL. (Analysis of shells)
6. Design analyses of some machine parts using the application programs.