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UNIDO PROJECT NO.:

DP/ROK/82/026/11

Job Description: 69/31.9.B

CONSULTANT IN CAD RESEARCH

Report of training

~~Provision of services relating~~ in ~~the~~

Computer Aided Design Techniques

in the Republic of Korea.

Technical

REPORT

Covering the complete work performed by the consultant in the project area from 16.-29. August 1986

Based on the work of Dr. M. Sörensen, expert in CAD Research

10

United Nations Industrial Development Organization

Vienna

Synopsis

This report describes the work performed by the consultant at KAIST in August 1986.

The primary task was to performe training in the use of the acquired software package ASKA. In addition to this, up-to-date presentation on the following topics were presented: Expert Systems, Feature Technology, Modeling Techniques, a CAD/CAM Case Study. (All topics are described in some details in section 3).

Furthermore, a presentation on the Finding and Conclusions experienced in the project area is given in section 4.

Finally, the Recommendations (section 5) for further work suggest KAIST to start R+D activities in Expert Systems and Feature Technology, as well as continue their research in the non-linear problem area.

Table of Contents

Appendices

1. Introduction

The subject of this report is to give a presentation of the work performed and the recommendations made under this contract in South Korea (UNDP Project Number: DP/ROK/82/026/11-69/31.9.B. Project title: Mechanical Engineering Computer Application-MECA).

The work took place at the Korean Advanced Institute of Science and Technology - KAIST. This institute is located at Seoul.

The work described herein is based on the knowledge and experience accumulated by the consultant during a previous four-week assignement under the current MECA-project. This assignement took place in May 1984 and has been documented in Ref. 1. Those readers who would like a detailed description of KAIST, its CAD-equipment and application area are kindly referred to Ref. 1.

The activities of the work cover the field of Computer Aided Design (CAD), with particular emphasis on the application of the computer package ASKA-acquired by KAIST under the MECA-project. A definition of what the consultant understands CAD to be was defined in Ref. 1, of which the vital parts are repeated here for consistency:

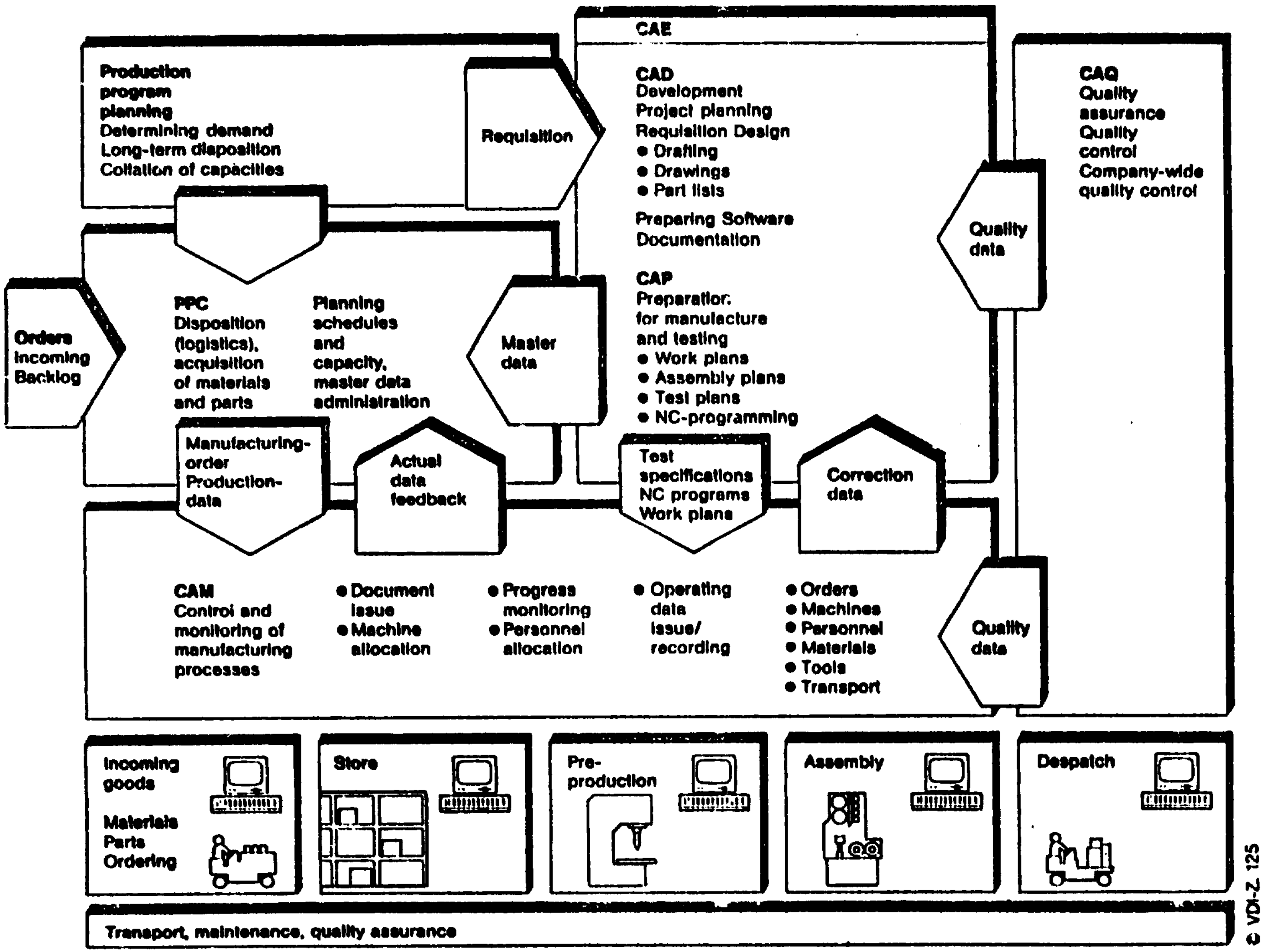
* Conceptual Design
* Detail Design Analysis
* Complete Design
* Drafting
* Data Processing (in Engineering Design)

In addition to these partial CAD subjects, an overall view of

Computer Integrated Manufacturing (CIM)

was presented and discussed in order to stress the importance of of an integrated view on CAD and Computer Aided Manufacturing (CAM). Separate solutions to CAD and CAM makes a later integration of both tasks into a general CIM concept almost impossible. You are kindly referred to fig. 1, where it is evident that CAD and CAM are only two ilands in the total concept. A third very important topic is, of course, Computer Assured Quality (CAQ).

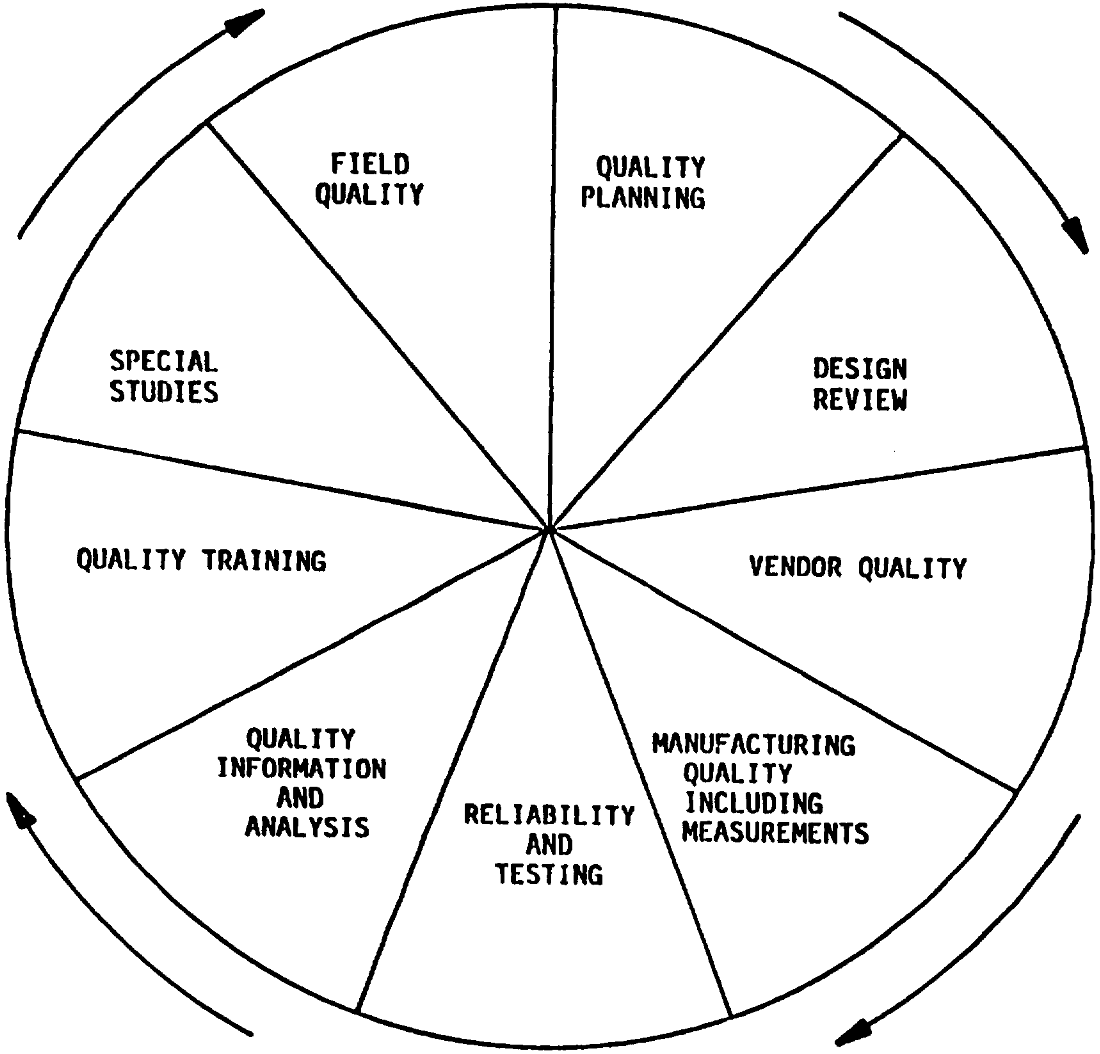
Fig. 1 **CIM - computer integrated manufacturing functions**



The topic of Quality Control and Assurance has been the "number one" topic for most of the industries that compete on the world market. (See also fig. 2).

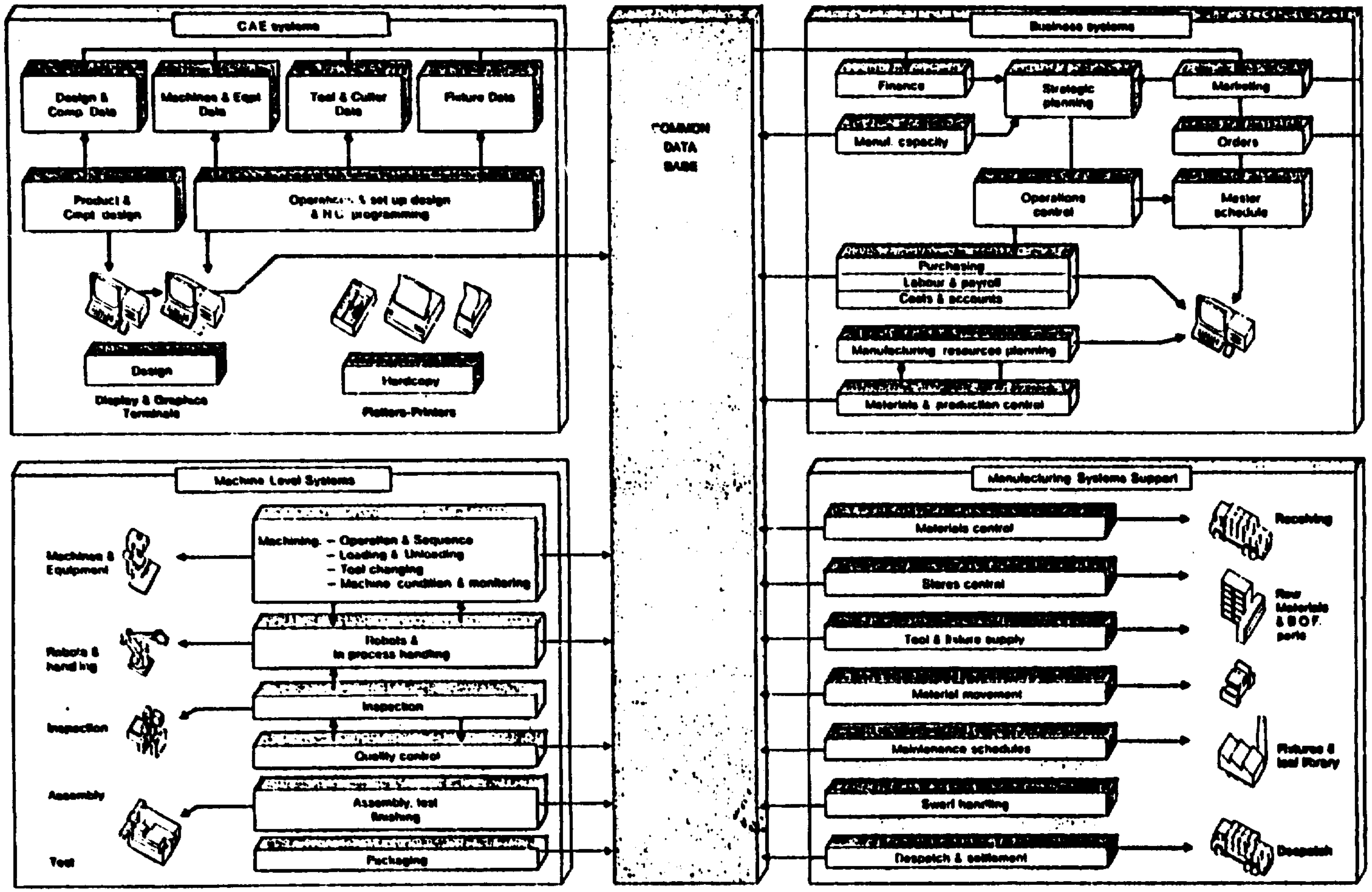
Fig. 2

TOTAL QUALITY SYSTEM



To put the particular field of CAD in its proper perspective you are referred to fig. 3. As can be seen, CAD (called Design & Comp. Data) is just one tiny step in the total picture. Important is, however, to integrate the CAD Database into the Common Data Base as early as possible in order to facilitate a proper integration between CAD and the other, equally important tasks.

Fig. 3 **THE MAIN ELEMENTS OF SYSTEMS IN MANUFACTURING**



2. Scope of Work

According to the Job Description (DP/ROK/82/026/11 - 69/31.9.B) the Consultant in CAD Research should:

a) Assess the facilities, knowledge, computer hardware and software for CAD available for MECA programme and make recommendations for better utilization.

b) Make recommendations for designing and developing CAD software systems using a variety of computer hardware in an organization responsible for major CAD Research.

c) Help perform the on-going R+D projects related to finite element method. He is expected to bring over all informations relevant to present research trends of pre and post processor of finite element method.

d) Visit representative manufacturers to observe the present level of utilization of computer technology in Korean Industry.

Suggest specific CAD applications that would be most useful to industry.

e) Hold seminars for KAIST staff presenting the main features of FEM softwares including ASKA and their application cases.

Comparing these tasks with those of the first assignement in 1984 (see Appendix 1), they are seen to be identical to a large extent.

Upon arrival in the project area, discussions with the National Project Director of the MECA project, Professor Kwak at the Department of Mechanical Engineering at KAIST, took place, as well as a briefing at UNDP with the Project Manager Mr. A.S. Nasir.

During the discussions with Professor Kwak, it became evident that he wanted the consultant to emphasize point 5 in the job description. The main reason for this being the acquisition of the ASKA program. So he stressed the urgent need of

"Presenting the main features of
ASKA and its application cases",

more or less ignoring the other specified tasks.

The consultant took this drastic change of assignement up with Mr. NASIR during the briefing. It ..as agreed upon to try to follow the wish of the MECA project director as far as possible, but at least some attention should be given to the other topics. However, it was mutually decided not to visit any representative manufacturers in order to give more time to the ASKA training. This was found acceptable since another UNDP-expert in CAD, Professor Kinzel from the Ohio State University was due in a forthnight and his planned schedule included visits to relevant manufacturers. Based upon these discussions, the consultant presented a schedule of work to the national project director, see Appendix 2. This schedule was accepted by the project director.

The schedule and topics for the agreed upon lectures and training is shown in Appendix 3. The topics covered ty the lectures on Computer-Integrated Manufacturing can be found in Appendix 4. The reader is also referred to Fig. 1. Furthermore, a list of CIM-functions and CIM-benefits are listed for the reader's convenience in Appendix 6 and 7 respectively. These two appendices show the importance of CIM. Finally, the ASKA presentation and training performed is shown in Appendix 5. The contents of the ASKA presentation is listed in Appendix 6.

This report does not include a detailed description of the complete organization of KAIST. This was described in Ref. 1 to which the reader is kindly referred.

3. Lectures and Training

3.1 Introduction

As mentioned in the immediate section above, the agreed upon lectures and training are shown in Appendices 3 to 6 inclusive. In this section some of the topics covered in the lectures are presented in "short hand" below. Readers not interested in these details should pass on to section 4 directly.

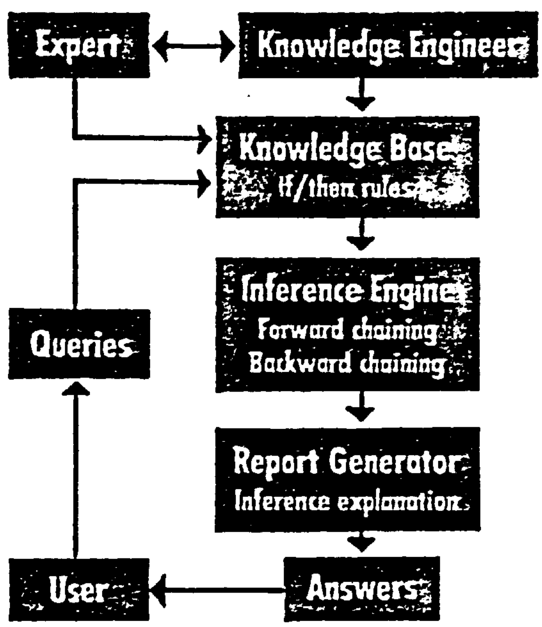
3.2 A technology update on Expert Systems (ES)

The design and use of expert systems is increasing very fast throughout the developed countries. Furthermore, since one of the recommendations given in this report (see section 4) is to do research and development in this field, it is felt necessary to give a short description of what is ment by an expert system.

There are quite a few ways to build expert systems, but they all can be thought of as having two principal components: a knowledge base and an inference "engine" (see fig. 4). These components are designed to allow us to represent what we know about some portion of the real world - usually quite a small portion - and then to give the computer a method for "reasoning" within this body of knowledge so it can solve problems. The knowledge base in the most common form of expert system, which is known as a rule-based system, consists of a series of if/then rules concerning pertinent objects and events. The "if" part of a rule presents the situation. The "then" part is the response. For example, an if/then statement might read: "if you want to fill a car with gas, then go to a gas station". These rules, which are known as the system's heuristics, can be added to or subtracted from as the program is used. This is one of the advantages of expert systems - from the moment you have encoded more than a few rules, you have set up a working system that can be constantly refined as more rules are added. True expert system typically needs at least 20 rules to be a valid mirror of the subject it covers, while some may have more than 1,000. Most systems have well over 100 rules.

Fig. 4

The Inner Workings Of Expert Systems



Research into artificial intelligence (AI) has resulted in several classes of applications, including systems that attempt to duplicate learned skills and expertise. These applications, often referred to as expert systems (ESs), have been touted as one of the technologies most likely to revolutionize the acquisition and processing of information. Having heard such claims, manufacturing managers are asking what the excitement is all about. What is an ES? Can these systems be applied practically to solve industrial problems? What benefits does this technology offer that existing computer science methods do not? What are their limitations and what is involved in applying ESs?

In short, an ES application is a program that renders judgments based on questionable input and heuristic reasoning and usually obtains the right answwer (i.e., the system acts as a human expert would act). Thus, an ES application accepts and works with incomplete or inexact input, reasoning about facts instead of performing only computations on data.

ES applications differ from the traditional automation applications of management information systems (MISs), operations research, group technology, and decision support in both their application domain and their design. These type of applications are usually defined as well structured or semistructured problems. They have all been tackled by normal programming techniques.

ES on the other hand are used to solve unstructured problems. Unstructured problems arise when the process or task involved is so poorly understood that the appropriate objectives as well as initial alternatives must be determined. Often, these alternatives are vaguely defined and thus escape traditional modeling analysis. ES technology addresses these unstructured problems.

In spite of the fact that ESs are becoming very popular, there are some limitations.

Current reasoning approaches and control strategies are capable of logical deduction, simple forms of induction, and a technique called generate and test, which is a reasoning approach that generates possible solutions and then evaluates them. A technique called property inheritance can be used to determine properties of an object based on the methods of mathematics of set and subset functions. Capabilities for plausibility-based reasoning, procedural invocation, and heuristics are also available.

ESs cannot perform model-based reasoning in which they would construct arbitrary models of a particular problem and create new insights based on those models. Nor can current ESs perform reasoning based on beliefs or on modalities, such as few, many, or most. Abstractions and approximations are also beyond the scope of available technology. In general, current ESs are good at mathematical and deductive logic but poor at creative problem solving.

The primary considerations in determining whether an ES is suitable for solving a particular problem include the following:

* Characteristics of tasks associated with the problem
* Organizational goals
* Development constraints
* Use environment

The most important of these considerations is the first: the characteristics of the manufacturing tasks associated with the problem. Table 1 lists the characteristics typical of a task well suited to an ES appplication. Of these, the existence of both a bounded knowledge domain and a human expert is the most crucial.

Table 1 Manufacturing Task Characteristics that Indicate ES Applicability

* Requires human expert
* Involves transferable knowledge
* Involves short thought processes
* Is neither too hard nor too easy
* Involves cognitive process
* Performed better by expert than by novice
* Is bounded
* Is performed frequently
* Has high value to organization
* Has simple and difficult versions
* Falls into one of the general categories been addressed by existing ESs

A recent study performed for the U.S. Air Force Materials Libray examined potential manufacturing applications for ES technology (Ref. 2).

Figure 5 illustrates the major functional groupings examined during the study.

The study found the most potential for high-payoff ES applications in technical and management planning and control areas. The subareas in Figure 5 illustrate the major functional categories in which these high-payoff applications are clustered.

Table 2 lists the 10 most promising areas for ES applications identified in this study. For example, ES concepts could be applied in the first two areas to create a hierarchical rule-based planning system that could interpret engineering assembly drawings to determine the sequence of assembly steps required to produce the assembly. In the third area, natural language interfaces and intelligent help systems could be appended to existing manufacturing information systems. In the eighth area, ESs that integrate manufacturing engineering knowledge and computer-aided design system data bases would allow for automated analysis of product manufacturability during the earlv design-definition process.

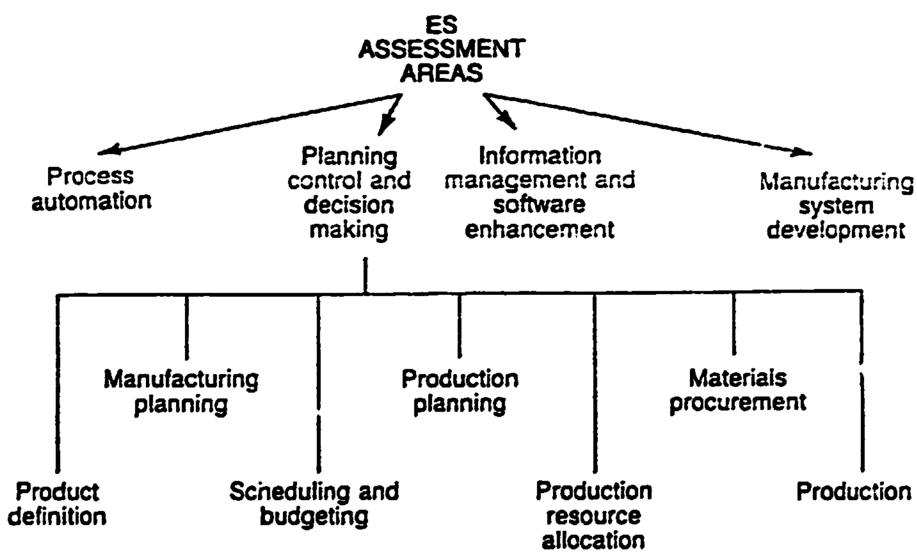


Fig. 5 Major Functional Groupings Assessed for ES Solutions

Table 2 Top 10 Areas for ES Applications

1. Assembly methods planning
2. Assembly methods and assembly instruction training
3. End-user computing tutoring and improved operator-machine interfaces
4. Engineering change order preparation and management
5. Scheduling bottleneck resources or high-cost items
6. Program or project cost estimating and budget preparing
7. On-the-floor generating of contingency plans
8. Designing for manufacturability
9. Fabrication process planning
10. Quality assurance and quality control methods planning

A warning though, is felt necessary, the most important part of an expert system is not actually encoded in the program; it's the analysis of how experts come to conclusions and the determination of which kinds and sets of facts are the most useful in the process.

Finally, a quotation from the Financial Times (August 5th, 1986) does support the importance of this interesting application area:

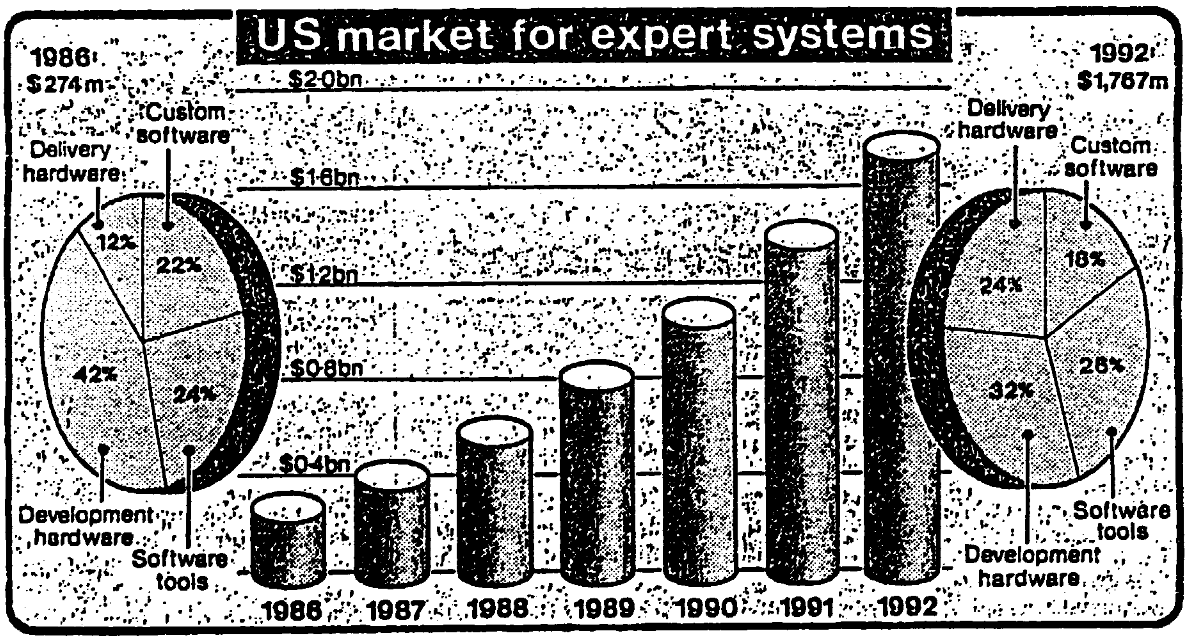
"By the end of this decade the researchers expect annual ES sales to total over US $ 800 bn.

With over 300 of the largest companies in the US already looking into the potential of artificial intelligence, and at least 100 actively working in the field, expert systems are poised to make an important transition from the laboratory into the workplace."

Another quotation of equal importance is from the Herald Tribune (August 15th, 1986):

"People recognize that this is the next wave in automation", said Bernard A. Weinstein, vice president in charge or programming, systems and communication at E.F. Hutton & Co.

Financial Times Thursday April 24 1986



3.3 Feature Technology (FT)

The presentation of this very new concept was felt to be of importance, since FT could be a key to CAD/CAM integration. This integration is receiving lot of attention throughout industry, however, so far very few companies have succeeded in performing this integration. Without this integration, the CIM concept will never work.

FT is a method of identifying, based on part features, the unique manufacturing requirements for each part. Part features - standard descriptions of a part's geometric characteristics (e.g., holes, cutouts, notches, bends, ribs, pockets, welds, and solder joints) - should be independent of company or function and readily transformable into manufacturing operations and sequences of manufacturing operations.

There is a need for FT because, although many of the technologies employed in computer-aided design and computer-aided manufacturing (CAD/CAM) systems are highly advanced and well proven in production environments, certain fundamental technologies that would enable CAD/CAM systems to be electronically linked have not yet been developed. In particular, the format and structure of the data to be shared between the geometric modeling (i.e., computer-aided design) systems and manufacturing systems have yet to be defined.

Group Technology (GT) alone cannot provide all of the information needed by automated process planning and production systems, because GT serves primarily to identify simlilarities in parts and processes rather than unique differences that must be known to produce the part. At the other extreme, passing all the detailed design geometry unneccessarily burdens manufacturing with too much information. Attempts to resolve this dilemma have resulted in the development of feature technology (FT), which provides an intermediate level of detail between the GT code and the part geometry.

Feature technology research has been driven by leadingedge companies' efforts to link CAD an CAM systems and by recent developments in solids modeling. The relationship of FT to solids modeling and previous developments in computer-based geometric modeling is shown in Fig. 6.

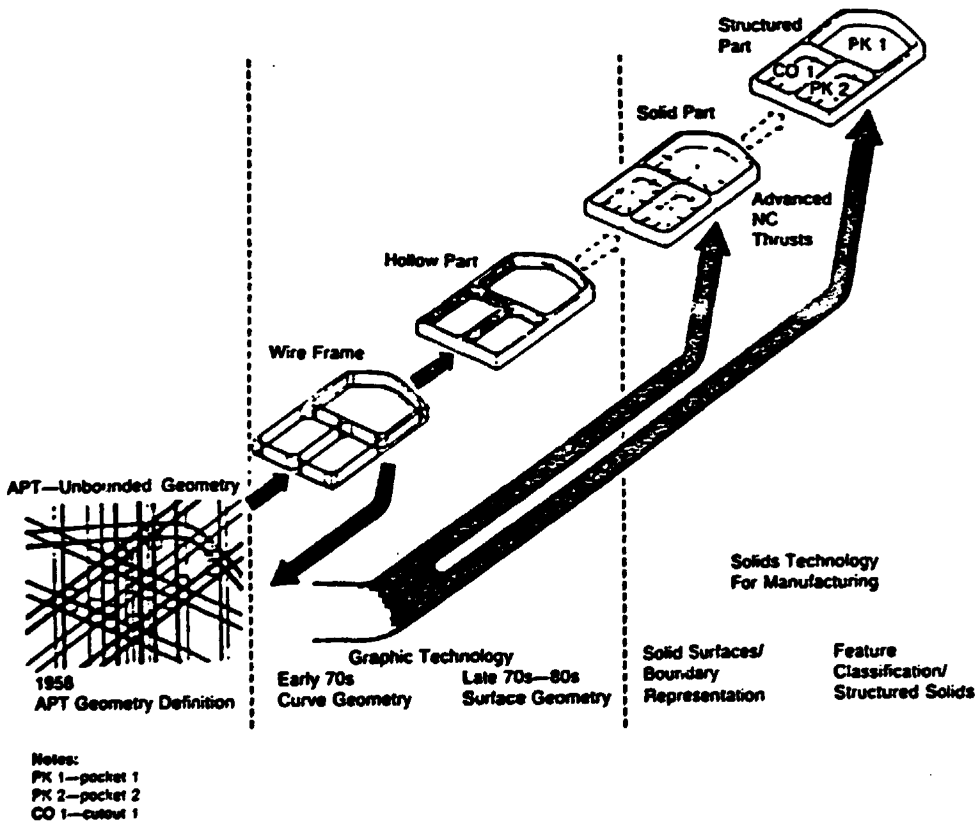


Fig. 6 The Evolution of Computer-Based Geometric Models

GT and FT are closely related technologies with different purposes. GT has also figured prominently in the systems integration efforts of many companies. GT is a method of classifying parts into families by assigning standard codes to each major part characteristics (e.g., shape, high-level features, material, size, or common manufacturing process).

Thus GT descriptions are, by design, high-level summaries that serve to group parts by similarities, but present ambiguities in detailing the individual characteristics of each part.

As a result, GT is generally an excellent basis for variant systems that support such applications as minimizing product and process variations, forecasting uncertain situations (e.g., master scheduling by product families), and analyzing aggregates rather than individual items. In contrast, FT provides a detailed description of a part's distinguishing features that provides a basis for generative systems.

The manufacturing process involves either volume decomposition of raw material stock into intermediate and final geometries or the mating of components. In volume decomposition, intermediate and final geometries are obtained from machining, casting, or forging operations. Before these operations can be performed, process planners must define the portion of the total material to be removed in a machining operation. The components of material to be removed in the machining operation are called delta volumes.

The process of machining can be thought of as a series of removals of the material. Each distinct step is represented by a delta volume until the final product is completed. Features can be correlated to each distinct manufacturing operation and thus to each delta volume. Fig. 7 shows the removal of the first delta volume in a typical machining operation. The volume decomposition depicted in fig. 7 entails drilling a hole within a notch. In this example, the first operation is the cutting of a notch in the raw stock. The next operation would be drilling the hole. By associating specific machining techniques for removing material with these features (the notch and the hole), the combination of features, delta volumes, and sequences provides a complete representation of the manufacturing process.

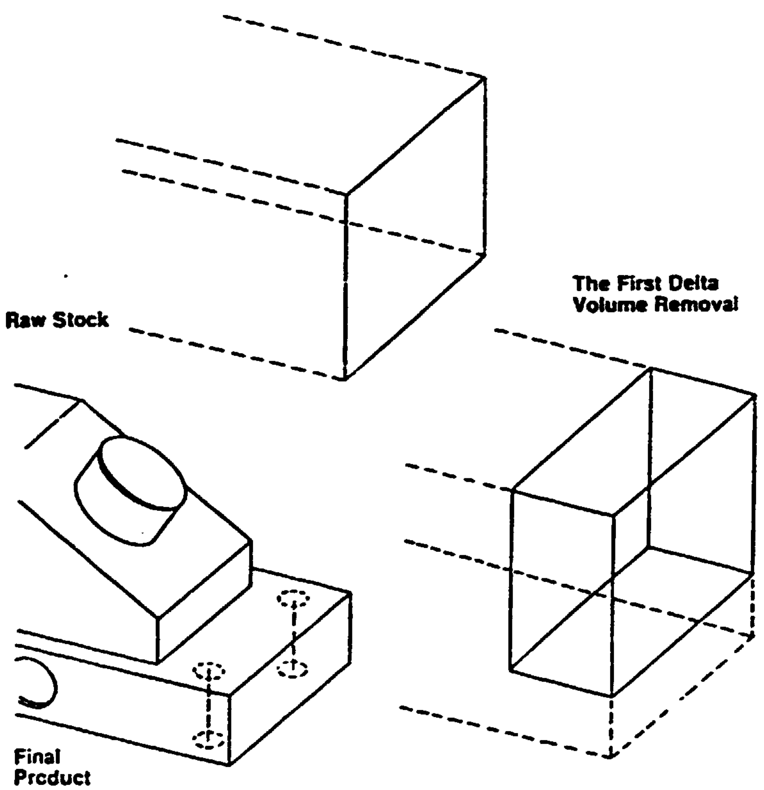


Fig. 7 From Raw Stock to Final Product

Fig. 8 shows the relationship between the product model as stored in the CAD system and the manufacturing process. Product buildup involves mating components through assembly, welding, fastening or composite buildup. Feature descriptions in a product buildup environment include mate-with locations and mate-with conditions that identify the type of connection between components.

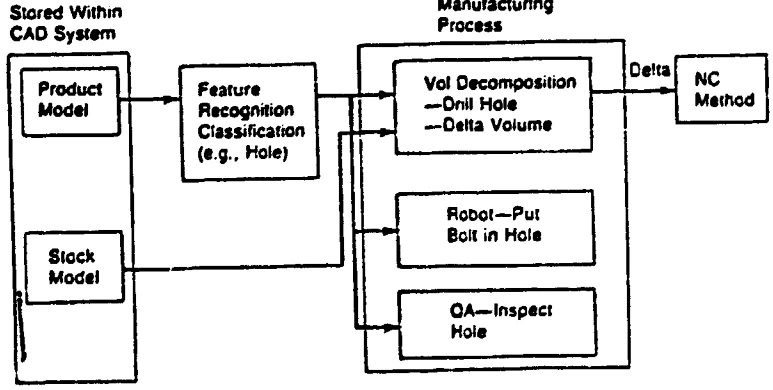


Fig. 8 Relationship Between Features and Volume Decomposition

Bill of material and FT information is complementary yet mutually exclusive. Bills of material represent the material (component) entering each manufacturing process and the output (subassembly or intermediate machined part). FT identifies what is to be done within each process, in terms of specific machining or assembly operations.

FT can also be valuable to the quality engineer. Because each feature has a standard definition with associated detailed attributes, a generic list of feature measurements and measurement techniques can also be associated with each feature. An example of features-based quality inspection is a vision system that matches the actual features with those in the geometric model through the vision/sensory system. Inspection reports and quality information systems can also track data by feature and feature class.

FT is also a R+D field recognized and recommended by the consultant as an area where KAIST research team should become involved (see section 5 Recommendations, 5.3).

3.4 IGES Assessment: Present and Future

This topic was not recommended as a R+D area for KAIST, however, it was felt important to mention this important development taking place in the U.S., since this will most probably by the world standard for exchanging information between graphic computers from different vendors.

Until recently, users typically have installed computer-aided design/-computer-aided manufacturing (CAD/CAM) systems to automate specific and often isolated design or manufacturing activities. As a result, many companies use several CAD/CAM systems for a variety of design and manufacturing activities. It is therefore becoming increasingly important that users who have or plan to acquire dissimilar CAD/CAM systems have a means of exchanging product data among the various systems. Without the capability for systems to exchange data, data output from one system usually is reinput to another system. A data exchange capability eliminates the need to enter product data in several systems; product data can be captured once and shared with other systems as needed in the various phases of the product life cycle.

The obvious and best method of translation is to provide software that translates data from the internal format of the sending system into a neutral (system-independent) data format and then translates the data from the neutral format into the internal format of the receiving system (see fig. 9).

Because an extra processing step is needed for translation to the neutral format, exchanging data generally takes longer than when direct translators are used. In addition, each system requires two translators - one to translate data from the system's internal format into the neutral format and the other to translate data from the neutral format into the system's internal format.

Using neutral-format translators, however, has significant long-term advantages. A neutral data format can be used to translate data from any CAD/CAM system format into any other CAD/CAM system format. Although modifications may be required to keep point-to-point translators up to date with system upgrades, a neutral data format does not have to be entirely rewritten.

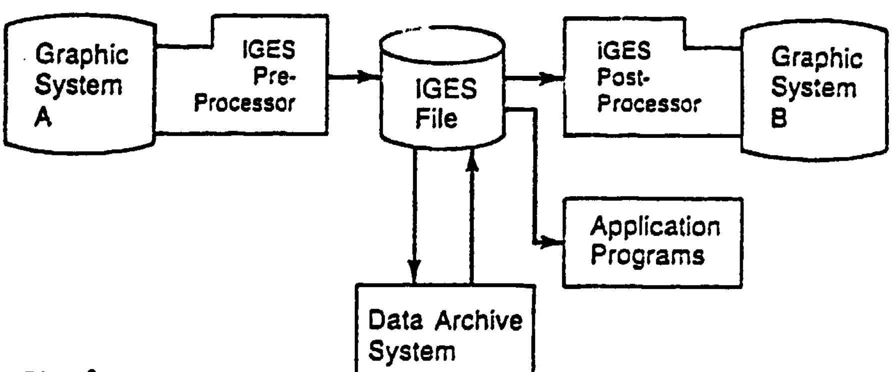


Fig. 9

Two-way communication requires that both systems A and B be equipped with IGES pre- and postprocessors.

The concept of data transfer using a neutral data format has gained strong support among CAD/CAM users and vendors. The Initial Graphics Exchange Specification (IGES), a neutral data format that has received widespread support, was specifically developed to be the industry standard for exchanging graphic data. This section provides background information on the organization of the IGES data structure. The capabilities and limitations of IGES and the results of a U.S. Air Force project for evaluating the IGES format are also discussed.

The IGES format was developed under the auspices of the Air Force Integrated Computer-Aided Manufacturing (ICAM) program, and project coordination has been provided by the National Bureau of Standards (NBS). Led by the NBS, a task team was formed late in 1979 to address graphic data standards to support data exchange among dissimilar CAD/CAM systems. The task team members were representatives from the NBS, Boeing Company, and General Electric Company. The committee's efforts resulted in the IGES Version 1.0 data format, published in January 1980 and approved in September 1981 as part of American National Standards Institute (ANSI) specification Y14.26M for communication of product definition data. Table 3 illustrates the IGES data transfer concept. By May 1983, 20 vendors of graphics systems were offering some IGES compatibility. By the end of 1983, 15 different CAD/CAM system vendors had participated in public demonstrations of graphic data exchange using IGES.

Below a timetable of IGES is given.

Table 3 IGES Graphic Data Support Timetable

Data Type	IGES Approval	ANSI Approval	Test Case Available	Vendor Translators Available
Basic Wireframe Mechanical Part Data	1980	1981	1981	1981–1982
Drawing Attributes (dimensions, text)	1980	1981	1983	1981–1982
Advanced Wireframe Geometry (rational B-spline curves and surfaces, geometric arrays, surfaces of revolution)	1982	1984–1985*	1983	1984
Finite-Element Modeling	1982	1984–1985*	1983	1984
Electrical Geometry	1982	1984–1985*	1983	1984
Piping Diagrams, Architecture, Mapping	1980	1981	1983–1984	1981–1984
Electrical and Piping Connectivity	1984*	1984–1986*	1984	1985*
Solid Modeling Data for Mechanical Products	1984*	1985–1986*	1984	1985–1987*

*Estimated date

As is evident, the IGES standard is becoming more and more accepted and it is therefore important to take this into account when performing R+D work at KAIST.

3.5 A study of CAD/CAM modeling techniques

Due to the heavy committment of KAIST to the research and development of pre- and postprocessors (a topic highly recommended in Ref. 1), it was important to give the development team an update on what has happened in the last two years. (This topic was also part of the presentation already in May 1984).

This presentation was a typical state-of-the-art representation, showing the present research trends, with particular concentration on pre- and postprocessors for finite element application (see section 2, scope of work, task 3).

A model is a representation of an object or a physical system. Models can be symbolic (e.g., a set of mathematical or logical equations), iconic (e.g., a map), logical (e.g., a flow chart), or geometric (e.g., part drawings). Designers, engineers, and analysts use models to simulate, test, or predict the behavior of an object or system and to assist in its design and construction. Computer-aided design/computer-aided manufacturing (CAD/CAM) systems, because of their interactive graphics capabilities, have proved to be valuable tools for creating and manipulating geometric models. Modeling techniques and capabilities vary considerably, however, from system to system. User modeling requirements differ as well, depending on what is to be modeled and how the model will be used.

In the first usage of modeling techniques, wire-frame models were used. Thereafter surface modeling was developed. Today the state-of-the-art is represented by solid modeling.

A solid model is a mathematically complete (i.e., unambiguous) representation of a part. A solid model thus describes a single unique part completely. A first generation of experimental solid modeling systems appeared in the mid-1970s. These early systems elicited great interest because they held the promise of permitting many traditionally manual tasks, such as detail drafting, finite-element mesh generation, and NC program verification, to be fully automated. By the late 1970s, a second generation of systems intended for industrial use had evolved. In the past two years, there has been a proliferation of commercial systems. There are a variety of schemes for representing a solid in a mathematically complete form. Most of the commercial solid modeling systems currently use either the constructive solid geometry (CSG) or boundary representation technique.

CSG represents an object as a combination of solid primitives, such as blocks, cylinders, cones, spheres, wedges, and tori. Primitives are combined through use of the Boolean operations of union, intersection, and difference.

The boundary representation techniques are a collection of faces (surfaces), edges (curves), and vertices (points). Sculptured surfaces can theoretically be described with boundary representation techniques, and hence, boundary representation is applicable to more object shapes than is CSG. In actuality, current boundary representation-based systems' capabilities for modeling sculptured surfaces are still limited. The development of solid modeling systems that can accurately describe solid objects, including sculptured surfaces, is, however, an important and active research area. Current experimental systems typically use Bezier, B-spline, or rational B-spline surface representation.

Current System Capabilities.

The data base and the algorithms used to construct and manipulate the data base constitute the core of a solid modeling system. Much of the research of the past 15 years has been directed to this area, and as a result, the core is relatively well developed. User interfaces, response time, and applications for solid modeling, however, still require considerable research and development.

Current solid modeling systems are, in general, difficult to use. The construction tools provided do not facilitate easy model construction. For example, building a fairly complicated model through combination of solid primitives is quite difficult and requires a thought process that is unnatural to most designers. Claims made in the past that constructing a model by combining solid primitives is easy and natural are not generally supportable. Relatively little experience with a solid modeling system will often disprove such claims.

Contemporary solid modeling systems are also relatively slow. The computational requirements are quite heavy, especially to generate a color-shaded picture. A realistic picture often requires hours to compute and the use of raycasting techniques. Faster algorithms are available, but the resulting pictures are not as realistic. Display manufacturers are addressing this problem with special-purpose hardware that performs hidden surface removal and color shading in the display controller. Many solid modeling applications have yet to be implemented and made commercially available.

In the future, the CAD/CAM data base will be integrated with other company data bases so that design release, production tracking, material requirements planning, and a myriad of other functions will all access a common data base. This concept, often referred to as systems integration (CIM), is the process of unifying diverse systems into a cohesive network for rapid communication of engineering and manufacturing data. The next generation CAD/CAM systems for mechanical design will incorporate solid modeling. In addition, improved user interfaces and additional applications will result in more engineers (as opposed to designers/drafters) using these systems. These improvements will better equip CAD/CAM systems to meet the model and data requirements of numerous and diverse design, engineering, and manufacturing functions.

3.6 CAD/CAM Justificational Case Study

As the reader states this presentation was working through a case study on how and why an American company (Simmonds Precision) decided to introduce CAD-techniques. (This was part of topic 2 in the scope of work, see section 2). This case study should need no further comment in this report.

3.7 Training

The training performed was to show the engineers how to use ASKA to solve actual engineering problems. A description of the topics covered by this training is given in the appendices 5 and 6, to which the reader is kindly referred.

3.8 Concluding Remarks

Two additional subjects were also suggested,
- Managing Software Development
- A microcomputer based CAD/CAM-system

but unfortunately there was not enough time available due to the fact that the largest part of the work should cover topic 5 of the job description (see section 2).

4. Findings and Conclusions

As should be evident from the above elucidations, that the total work period of the consultant took place at KAIST. No visits to other institutions and/or manufacturers took place. This was mutually agreed to at the first meetings between UNDP in Seoul, the National Project Director of MECA and the consultant. (See also section 2, scope of work). Furthermore, it was agreed to concentrate on the training of KAIST-engineers in the use of the ASKA program. This program had been acquired by KAIST just before the arrival of the consultant.

Due to this mutually agreed upon change of the job description, it is really not possible to give a presentation of any findings and recommendations, but for the topics listed in the next section, recommendations.

A conclusion that can be drawn upon the experience accumulated in the two weeks' stay in the project area is that

There is a need of further training
of engineers in the use of ASKA.

Usually a 6-8 week training course is recommended by the vendor to any buyer of the ASKA system (see also recommendations below).

The consultant found it worth-while to discuss with relevant researchers and engineers at KAIST what actions had been taken on the recommendations that were presented in the report in June 1984 (i.e. after the first MECA-assignement of the consultant).

The main topics of recommendations to enhance the MECA project were (see ref. 1 for a detailed description)
- Special Purpose Design Packages (SPDP)
- Development of Problemoriented Pre- and Postprocessors
- Development of Teachware
- Structural Synthesis Techniques (SST)
- Research into Composite Materials
- Design and Use of Data Bases (DB)
- Standardisation of CAD/CAM Tasks.

Furthermore, the consultant stated that (quotation from ref. 1)

"there is a need for a more
powerful and flexible FEM-program
(e.g. ASKA)"

Based upon these discussions it can be stated that all recommended topics have been given attention by KAIST engineers, but for the topic of Teachware. This topic is still just as important, however, the lack of personnel made it impossible to tackle this problem up to now.

Especially in the field of SST, much valuable work has been performed. Actual problems from industries have been tackled and solved. The reader is kindly referred to figs.10, 11 and 12 that show the optimization of a car-chassis which had developed dangerous cracks due to very high peak stresses. The optimization was able to reduce these peak stresses and no crack developed after the redesign.

KAIST has developed a sw-program called STROD (structural optimum design) to tackle such problems. They recently gave a seminar (18th. to 22nd. of August 86) on this to 37 participants from industry.

Furthermore, in the field of Pre- and Postprocessors, they have developed processors for a quadratic brick element (PREQB and POSTQB), whereby the modeling of the element mesh (pre) and the presentation of the stresses (post) can be easily performed. These two packages are nearly completed and will be installed at selected industries, universities and research institution for testing purposes. (This also concurs with the consultants previous recommendation). They will also organize a user group in FEM and optimization in order to exchange information and educate the participating members.

In 1985, the research and development team associated with the MECA project performed R+D tasks for approximately US $ 200.000,- of which a large amount was spent on the topics reommended in 1984.

To complete the presentation of the findings, in the appendix 7, a list of publications etc. of Prof. Kwak, the National Project Director of the MECA project is listed for consistency. The list containes only material published after the consultant's visit to KAIST in May 1984. (Previous publications were presented in ref. 1). As is evident from the above presentations, the MECA-project has been a very fruitfull endeavour and should receive high marks in any comparasion.

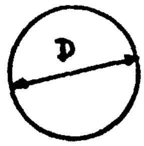
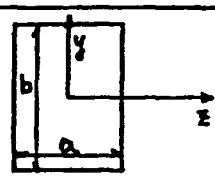
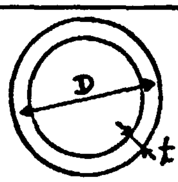
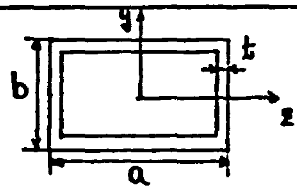
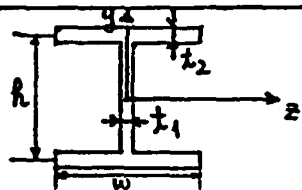
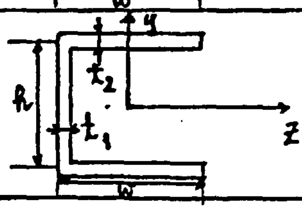
	첫 번 째 치수변수	두 번 째 치수변수	세 번 째 치수변수	네 번 째 치수변수
	D			
	a	b		
	D	t		
	a	b	t	
	w	h	t_2	t_1
	w	h	t_2	t_1

Fig. 10 Beamsection that are included in the optimization package

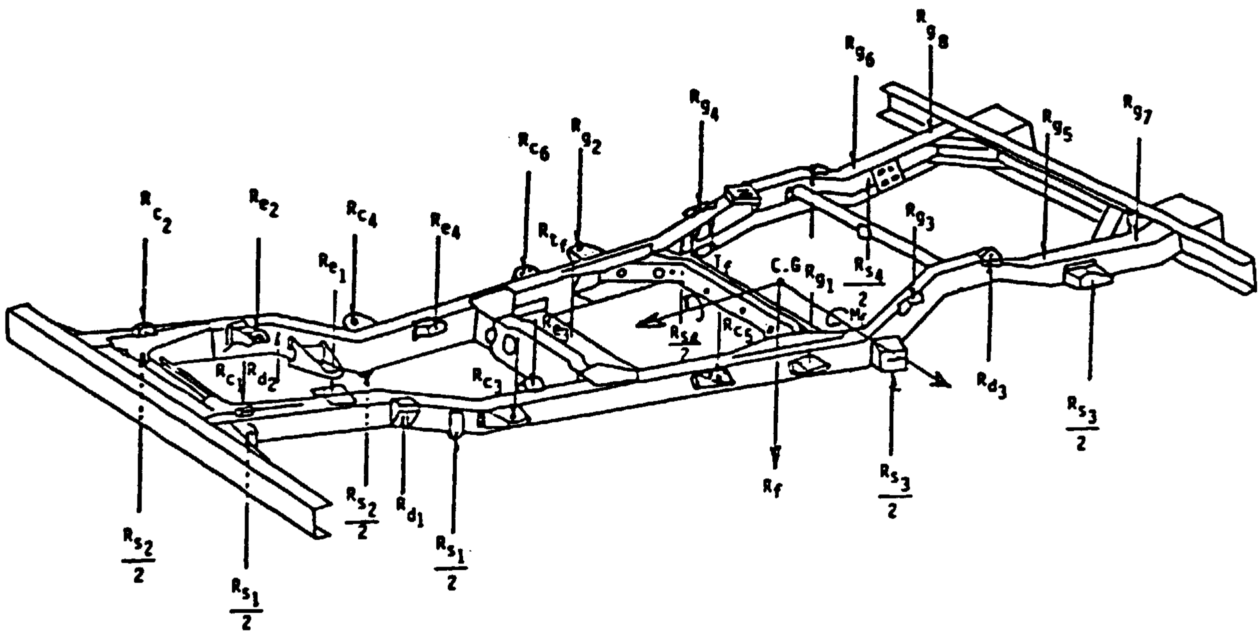


그림3-1 프레임의 동하중 점

Fig. 11
Geometry of a Chassis

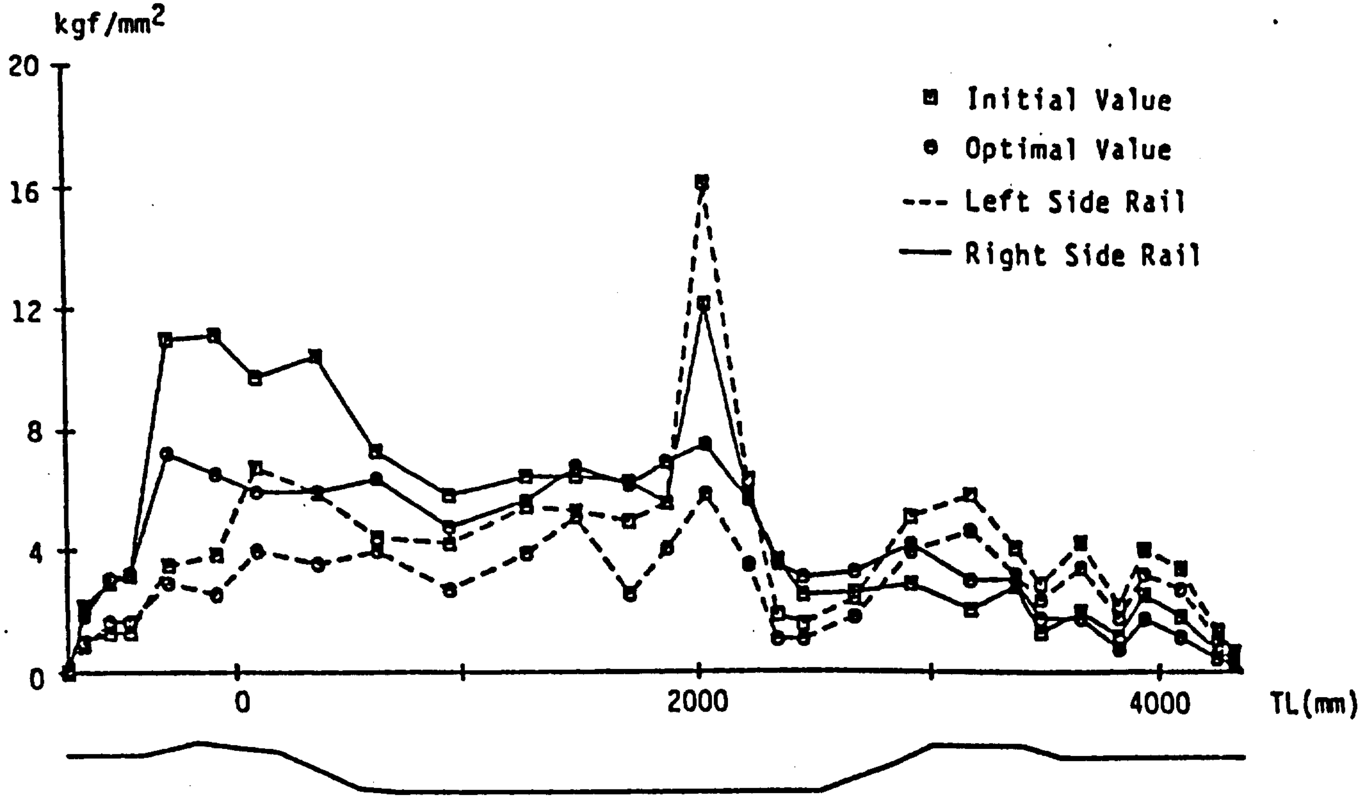


Fig. 12
Stressdistribuiion in
Chassis

5. Recommendations

5.1 Introduction

Referring to the above section - Findings and Conclusion, it is evident that the previous recommendations presented two years ago have found acceptance by KAIST management and engineers. They also plan to continue with all these topics. In addition to this, the consultant recommends new R+D activities in the following fields.

5.2 Expert Systems (ES)

Above under section 3.2 the ES has been presented, its importance in the coming years was also stressed. It is therefore to be expected that the Korean industry and other institutions will be forced to become active in this field.

The reader is kindly referred to page 18 for an estimate of the US market for ESs. One very important aspect in the application of ESs is the need for "knowledge-engineers", the earlier KAIST starts educating these, the better it will be.

Unfortunately, only a handful of ESs currently are operating in manufacturing, partly because the tools for building ESs include languages and programming constructs that are both revolutionary and nonstandardized. Furthermore, manufacturing personnel are only now becoming aware of the potential of this new technology. Furthermore, the development process for ESs differs from that of traditional applications in that it is much more a trial-and-error process, requiring extensive user involvement. The success of an application depends on the characteristics of the problem to be solved.

Further, determining whether a problem is amenable to an ES solution is not a straightforward task; it necessitates the involvement of an experienced AI company, and these companies are in short supply. Finally, the maintenance of ES applications constructed with the tools and methods available today appears to pose a major problem. However, research is in progress in the area of advanced development tools (e.g., high-level languages) that allow the original system users to be trained to update and maintain the systems. Although significant advances in the science of AI have been made in the past 20 years, the technology is still in its infancy. Thus, companies considering the establishment of an AI group must recognize the early state of the technology and its limitations. They should also understand the importance of picking the right problem for an AI/ES solution. Many of the techniques used by human beings to solve both simple and complex problems are still very poorly understood, even in the laboratory. Unfortunately, the intense research under way in universities, government laboratories, and private companies seems to be focused on applying the concepts that are already understood, rather than filling the technological voids. A qualified consulting firm or university research group can provide valuable assistance in problem selection, employee training and system development. Further, most companies will have to make a significant investment in the training of knowledge engineers in order to support in-house ES technology.

Based upon the above comments, the consultant highly recommends activities in this important field.

It must be mentioned though, that should the MECA-project become involved in ES design, they would need a

Developing computer with a
suitable compiler (e.g. LISP)
and an ES-language
Appr. cost: US $ 40.000,-

5.3 Feature Technology (FT)

This topic has also been presented in detail above, see section 3.3. The state-of-the-art of FT could be characterized as follows.

Although FT has been introduced in such business organizations as Deere & Company, General Dynamics Corporation, McDonnell Douglas Corporation, and United Technologies, much additional R+D is needed before it becomes widely used in industry. Specifically, manufacturing and engineering personnel must formalize terminology and definitions of features that today are arbitrary. Such organizations as CAM-I, the Initial Graphics Exchange Specifications (IGES) committees, see section 3.4, (headed by the US National Bureau of Standards), and the US Air Force are conducting research in this area. Table 4 lists other organizations currently involved in various aspects of FT research.

Solid modeling systems (see section 3.5) that allow design by feature also must be developed. Using a methodology common in many of today's solid geometry systems, an engineer designs a hole by defining a cylinder, assuring that the cylinder extends beyond the part, and subtracting the cylinder from the part. However, solid modeling systems do not recognize the final hole as a feature.

Future solids systems should recognize the term hole, allow the user to define hole attributes, and automatically model the final hole in the part.

These capabilities should soon begin to emerge in commercial systems.

Because of its potential to remove a significant obstacle to CAD/CAM systems integration, manufacturers are encouraged to follow FT developments closely, consider participation in joint industrial research and standards activity, and begin to assess the strategic impact of this technology on their internal operations.

Based upon the above elucidations, the consultant recommend the MECA-project to initiate FT-research.

To facilitate this, they will have to invest in a

Engineering Workstation with a
Color Monitor (e.g. SUN or Apollo)
Appr. cost: US $ 30.000,-

Table 4
Organizations Involved in FT Research

- University of Aachen, West Germany—FT for process planning
- University of CRIF, Belgium—FT for process planning
- Institute Nationale Polytechnique de Grenoble, France—FT for artificial intelligence/expert systems process planning. Key issues being addressed include:
  - — Methods of feature data representation (e.g., classification, attributes, relationships, and integration with geometric modeling systems).
  - — Methods of automatic feature recognition, classification, and extraction from solid modeling-based geometry.
  - — Industrywide approaches providing anticipatory guidelines and potential standards as the technology develops.
  - — Prototype applications for features.
- University of Cranfield, United Kingdom—FT for geometric modeling
- Arizona State University—FT definition
- Brigham Young University, Utah—FT definition
- University of Michigan—FT definition
- National Bureau of Standards, Maryland—Product Data Definition Interface (PDDI)
- CAM-I, Texas—FT definition for geometric modeling, numerical control, quality, and process planning

5.4 Non-linear Problems

During the training of the MECA-engineers in the application of ASKA, it became evident that their primary interest is in the non-linear field (e.g. elasto-plastic analysis, buckling behaviours). It was not possible to give enough training in the short time available to the consultant. He therefore recommends

- A two-week training in non-linear applications of ASKA to be performed by an UNDP-expert. -

Furthermore, it is recommendable to introduce an additional research tool, especially designed to tackle highly complex non-lineareties at MECA, since this topic will be of immense importance in the future. One solution to this would be to buy the

LARSTRAN package from the
company IKOSS in Stuttgart,
West Germany
Actual costs: DM 30.000,-
(This price does not include the cost of training. An additional UNDP-expert could perform this).

5.5 Concluding Remarks

The three new topics above (section 5.2, to 5.4) are of particular importance and should and must receive some attention shortly. The consultant therefore hopes that UNDP will be willing and able to initiate these before the fade-out of the MECA-project at the end of this year. Maybe a possible continuation of this project could be contemplated. In the opinion of the consultant, the achievements so far are far above average and should therefore continue, especially more so due to its importance for the Korean industry in the future.

6. Implementation and Follow-up

As for the previous report (ref. 1), it is difficult at this stage to give actual dates for the start up of the activities of the different recommendations and suggestions given above. Obviously, one first of all has to perform a selection and agree on a priority list before any actual planning activities can start. Since the UNDP-project MECA already has a plan for project activities, it is not felt necessary to give actual suggestions for planning and implementation of the recommendations presented in this report.

Concerning follow-up procedures, it is recommendable that one or two experts should come to the project area to performe the training in non-linear applications before the end of 1986.

7. Acknowledgement

The consultant would like to express his gratitude for all the kind and expert help he got from the secretariat at the Department of Mechanical Engineers and the National Project Director Professor Byuon Man Kwak.

Appendix 1

2. Scope of Work (Ref. 1)

According to the job description, the scope of work for the consultant in CAD research was to be

a. Assess the facilities, knowledge, computer hardware and software for CAD available within various departments of KAIST and other organizations in the country.

b. Make recommendation for staff development, and direction and areas of research aimed at making the centre (MECA) capable of doing CAD research and developing software for industrial applications.

c. Visit representative manufacturers to observe the present level of utilization of computer technology in Korean industry. Suggest specific CAD applications that would be most useful to industry at this time and could be developed and assisted by the MECA centre.

d. Hold seminars for KAIST staff and industrial eingineers, presenting the current state of CAD research and development and the extent and trends of industrial application in advanced countries.

Appendix 2

Schedule of travel and Work performed in the Project Area

1986, August

13. Departure Mönsheim 13:00 (local time)

14. Arrival Seoul 19:00 (local time)

15. Recuperation

16. Discussions with the national project director

17. Sunday, prepared lectures

18. Briefing at UNDP, Seoul
    Technical Discussions at KAIST
    Installation of ASKA on PRIME at KAIST

19. Discussion on work schedule for lectures and training programme

20. Preparing lectures and training programme
    Test runs of ASKA Demonstration proplems on PRIME

21. Start of lecturing and training

22. to 27. Lecturing and training

28. Final discussions with the national project director
    Preparation of draft of project report

29. Debriefing at UNDP, Seoul
    Departure from Seoul 17:55

30. Arrival Mönsheim 10:00

31. Recuperation

September

1. Preparing final report

2. End of Assignement

Time Schedule for Lectures and Training

August 21, Thursday

11:00 - 12:00	Computer Integrated Maunfacturing, Part 1
14:00 - 15:00	Presentation of ASKA, General Overview
15:00 - 17:00	Training in the use of ASKA, Part 1

August 22, Friday

11:00 - 12:00	CIM, Part 2
14:00 - 15:00	ASKA problem description and analysis procedurs, Part 1
15:00 - 17:00	Training in the use of ASKA, Part 2

August 25, Monday

11:00 - 12:00	A technology update on Expert Systems IGES Assesment : Present and future Feature technology : A key to CAD/CAM integration
14:00 - 15:00	ASKA problem description and analysis procedure, Part 2
15:00 - 17:00	Training in the use of ASKa, Part 3

August 26, Tuesday

11:00 - 12:00	CAD/CAM justification : A case study
14:00 - 15:00	ASKA problem description and analysis procedure, Part 3
15:00 - 17:00	Training in the use of ASKA, Part 4

August 27, Wednesday

11:00 - 12:00	A survery of CAD/CAM modelling technique
14:00 - 15:00	ASKA problem description and analysis procedure, Part 4
15:00 - 17:00	Training in the use of ASKA, Part 5

Presentation on CIM-Computer Integrated Munufacturing (2hrs)

Part 1

- State-of-the Art
- Application growth and installations world-wide
- Microprocessor market
- Main frames, Micros, PC's, future trends
- Automation development in the US
- Robot applications
- Industrial development, company development
- Western philosophy v. Japanese philosophy
- Computer costs, HW and SW
- Changing of the work force
- Expert systems, trends
- A production system
- Systems in Manufacturing
- CIM functions and benefits
- Comp.-aided technologies in manufacturing
- Improvement of flexibilities of techn. organizations
- Process flow in a factory of the future
- Product design and manufact. Inform. flow

Part 2

- Mainframe Computer Based CAD/CAM System
- Present levels of Standards

- Strategic implementation of CIM
    - Management role
    - Industry's risk
- CAD/CAM Justification and Implementation methodology
- Feasibility study, planning route and project contr.
- Training of personnal
- CAD/CAM investigation-planning, A Check-list approach
- Technical system specifications document
- RFP contents
- Questions to ask service organisations
- Technology inform. sources
- Use of Critical Path Method (CPM)
- Flexible Manufucturing Systems (FMS)
- Mechanical CAD/CAM Systems, Major capabilitics
- Quality Circles

ASKA - Presentation

1. Origin and Future
2. Basic Features
3. Available Element types
4. ASKA I - Linear Static Analysis
5. ASKA II - Dyr.amic Analysis
6. ASKA III/1 - Elastoplasticity and Creep
7. ASKA III/2 - Linear Buckling

Problem description and analysis procedures

Part 1	1.	Summary of input steps
Part 2	2.	Topological Description
Part 3	3.	Numerical data, general aspects
Part 4	4.	Processors
	5.	Books
	6.	Features and capabilities
Training	7.	Problem Solution
		- Linear Static
		- Linear Dynamics
		- Material Non-linearihics
		- Linear Buckling

Contents of ASKA Presentation

5. ASKA-II - DYNAMIC ANALYSIS

5.1 General

5.2 Natural Modes and Natural Frequencies

5.3 Time-History Response

5.4 Random Response

5.5 Spectral Response

5.6 Frequency Response

5.7 Viscous Damping

5.8 Direct Integration

6. ASKA-III/1 - ELASTOPLASTICITY AND CREEP

6.1 General

6.2 Metal Type Material

6.3 Creep

6.4 Mohr-Coulomb Type Material

6.5 Element Library

7. ASKA-III/2 – LINEAR BUCKLING

7.1 General

7.2 Linear Buckling Analysis

8. ASKA-III/3

8.1 Contact Analysis in Linear Materials

8.2 Fracture Mechanics

CIM FUNCTIONS

BUSINESS PLANNING AND SUPPORT

Economic Simulation
Long-term Forecasting
Customer Order Servicing
Finished Goods Inventory Mgmt.

ENGINEERING DESIGN

Computer-Aided Drafting
Computer-Aided Tool Design
Group Technology
CAD

MANUFACTURING PLANNING

Process Planning Systems
Parts Programming
NC Graphics
Tool & Materials Catalog
Material Requirements Planning
Production Line Planning Simulation
Bill of Materials Processors
Machinability Data Systems
Computerized Cutter, Die Selection
Materials/Parts Inventory Mgmt.

MANUFACTURING CONTROL

Purchasing/Receiving
Shop Routing
Methods & Standards
In-process Inventory Mgmt.
Short-term Scheduling
Shop Order Follow System

SHOP FLOOR MONITORING

Machine Load Monitoring
Machine Performance Monitoring
Man-time Monitoring
Material Stores Monitoring
Preventive Maintenance
In-process Quality Testing

CIM BENEFITS

Productivity Percentage Gains

GROUP TECHNOLOGY	
New part design	52
Shop drawings	30
Industrial engineering	60
Production floor space	20
Raw material stock	40
Setup time	69
Production time	70
Work in process inventory	62
Overdue orders	82
PROCESS PLANNING	
Planning activities	58
Direct labor	10
Material	5
Scrap and rework	10
Tooling	12
Work in process	5
MATERIAL REQUIREMENTS PLANNING	
Productivity	5 to 30
Work in progress inventories	30 to 50
Late orders	90
Labor requirements	10

Special Courses or Workshops Organized or Participated

1. "Finite Element Analysis," Short course (1 month) KAIST - Organizer and Lecturer.
2. "Computer-aided Mechanism Design," Short course, KAIST- Organizer and Lecturer.
3. "KIC '85 ; Korea Int'l Computer Graphics Conference '85," Oct, 28 - Nov.1, 1985, Seoul, Consultant and Lecturer.

Principal Investigator (PI) or Participation (PT) in Research Contract or Grant

1. Development of Design Technology for an LPG Carrier (I), Part II-Design of Cargo Tank System (MOST, Daewoo), 1983 -1985, (PI)
2. A Study on the Optimum Hull Form Development based on the Minimum Resistance Theory (Daewoo), 1984, (PI)
3. Stress Analysis of Breech Block of a 155m/m Artillery Gun (ADD), 1984, (PI)
4. Development of Mechanical Structural Design CAD Program (MOST), 1984, (PI)
5. Computer Applications in Mechanical Design (Matching with UNDP MECA Project) (MOST), 1984, (PI)
6. Development of Automatic Type-setting Machine-Control Part (Hankuk Phototype setter Development and Trading Co.), 1984, (PI)
7. Analysis and Design of Mechanisms a Rapier Weaving Machine (Sam Myung Co.), 1984-1985, (PI)
8. Structural Analysis of V Car White Body (Daewoo Co.), 1985 (PI)
9. Development of Mechanical Optimal Design CAD Programs (MOST), 1985, (PI)
10. Optimal Design and Stress Analysis of Automobile Frame (Asia Motor Co.), 1985(PI)
11. Development of Computerized Phototype Setter-Font Genèration, (MOST, Hankuk Phototype Setter Development and Trading Co.), 1985, (PI)

* MOST = Ministry of Science and Technology
KOSEF = Korea Science and Engineering Foundation

Invited Lectures and Seminars

1. "Dynamic Analysis and Design of Planar Mechanism with Clearance at Revolute Joints," ME Seminar, College of Engineering, U. of Iowa, Iowa City, Iowa, June 1985
2. "Elasto-Plastic Contact Problems," Dept. of Biomedical Engineering, College of Engineering, U. of Iowa, Iowa City, Iowa, June 1985
3. "CAD and Directions for CAD Applications", Gold Star Co., Seoul, November 9, 1985
4. "Mechanical Engineering and Computer Applications", Korea Air Force Academy, Seoul, November 26, 1985

Books

1. J.S. Lee and B.M. Kwak, An Introduction to Finite Element Method, in Korean, Dong Myung Sa, 1985, pp.450 (유한요소법 입문, 임상전, 곽병만, 이주성 공저, 동명사)

2. Proceedings of the First Pacific Area Conference on Orthopedics and Biomechanics, June 18, 1984 Seoul, Korea, pp.152 (Editor)

Conference Papers

Proceedings (Full Papers)

1. B.M. Kwak, and E.Y. Chao, "Mechanical Analysis of Conical Fit Connections in Modular Prosthesis Design," Proc. of the First Pacific Area Conference on Orthopaedics and Biomechanics, Seoul, Korea, pp.70-94, 1984

2. Y.S. Yoon, Y.I. Lee, Y.Y. Kim and B.M. Kwak, "Forces at the Femoral Head During Various Activities," Proc. of the First Pacific Area Conference on Orthopaedics and Biomechanics, Seoul, Korea, pp.64-69, 1984

3. Y.Y. Kim, B.M. Kwak, et al., "Salvage Procedures in Failed Hip Arthroplasties," Proc. of the First Pacific Area Conference on Orthopedics and Biomechanics, Seoul, Korea, pp.99-104, 1984.

4. Y.Y. Kim, B.M. Kwak, et al., "Salvage Procedures in Failed Total Hip Relacement," The Hip--Clinical Studies and Basic Research, Elsevier Science Publishers B.V., pp.321-324,1984.

5. Y.Y. Kim, B.M.Kwak, et al., "Replacement Arthroplastry Using the Charnley Prosthesis in Old Tuberculosis of the Hip Chinical Experience with 8-10 Year Follow-up," The Young Patient with Degenerative Hip Disease, J. Sevastik and I. Galdie(ed), Almgrist & Wiksell International, Stockholm, pp.217-226, 1985.

1. S.W. Cho and B.M. Kwak, "Optimal Design of Electric Overhead Crane Girders," J. of Mechanisms, Transmission, and Automation in Design, Trans. of the ASME, Vol.106, pp.203-208, 1984

2. B.C. Lee and B.M. Kwak, "A Computational Method for Elastoplastic Contact Problems," Computers and Structures, Vol.18, No.5, pp.757-765, 1984

3. K.N. An, B.M. Kwak, et al., "Determination of Muscle and Joint Forces: A New Technique to Solve the Indeterminate Problem," J. of Biomechanical Engineering, Trans. of the ASME, Vol.106, pp.364-367, 1984

4. J.K. Shin and B.M. Kwak, "A Design Method for Reducing the Effects of Clearances at Revolute Joints, Proc. of the Institution of Mechanical Engineers, Vol.199, No.C2, pp.155 - 158, 1985

5. B.M. Kwak and Y.J. Gil, "An Indirect Experimental Method for the Determination of Mechanical Properties of Ion-nitrided Layer and Residual Stress Distribution," Trans. of the Korean Society of Mechanical Engineers, Vol.9, No. 2, pp.240-249, 1985

6. Y.Y. Kim, B.M. Kwak, et al., "Salvage Procedures in Failed Hip Arthroplasties," Orthopedics, Vol.8, No.1, pp.60-64, 1985

7. Y.Y. Kim, B.M. Kwak, et al., "Replacement Arthroplasty using the Charnley Prosthesis in Old Tuberculosis of the Hip -- Clinical Experience with 8-10 years of Follow-up," Clinical Orthopaedics and Related Researches.

8. S.G. Park and B.M. Kwak, "A Semi-Analytical Finite Element Method for Three Dimensional Contact Problems with Axisymmetric Geometry," To appear in Proc. Institution of Mechanical Engineers, 1986.

9. J.H. Rhyu and B.M. Kwak, "Optimal Stochastic Design of 4-bar Mechanisms for Tolerance and Clearance," To appear in Trans. ASME, J. Mechanisms, Transmissions, and Automation in Design, 1986.

10. J.W. Joo and B.M. Kwak, "Analysis and Application of Elastoplastic Contact Problems Considering Large Deformations," To appear in Computers and Structures, 1986.

References

Ref. 1

Technical Report on Unido Project No. DP/ROK/82/026/D/01/37
7. June 1984
Consultant in CAD Research

Ref. 2

Copies of this report, An Assessment of Artificial Intelligence Applications to Management, by R. Mayer et al., are available at no charge from: AFWAL/MS Wright Patterson Air Force Base, OH 45433 Attention: Dr. Vince Russo.