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ARTIFICIAL INTELLIGENCE IN THE MATERIALS PROCESSING LABORATORY

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INTRODUCTION

Materials science and engineering provides a vast arena for applications of artificial intelligence. Advanced materials research is an area in which challenging requirements confront the researcher, from the drawing board through production and into service. Advanced techniques results in the development of new materials for specialized applications. Hand-in-hand with these new materials are also requirements for state-of-the-art inspection methods to determine the integrity or fitness for service of structures fabricated from these materials.

The many facets of materials science and engineering form a complex mixture of interests in compositional variances, processing parameters and service environments. All need to be considered in designing and implementing an advanced material for a particular function. It is anticipated that artificial intelligence can provide many benefits in sorting out some of the complex relationships which help to produce ideal materials for extreme conditions. Sorting out compositions from process parameters is complicated and normally requires expertise from many sources. These sources can often take the form of humans who have vast experience in a specific area and thereby are domain experts in a very focussed area. This knowledge may be accessible from either the persons themselves or from the published literature. On the other hand, with the rapidly evolving materials technology in today's society, one often must include current results from actual or simulated experiments to obtain the knowledge required to attain specific goals.

Selection of the expert system implementation or platform most suited to meeting required goals also presents interesting challenges in the materials world, because the knowledge or awareness of artificial intelligence is quite new and only within the last few years has any real effort been made to incorporate new AI technologies into the realm of new materials technologies.[1-4]

Two problems of current interest to the Materials Processing Laboratory at UAH are an expert system to assist in eddy current inspection of graphite epoxy components for aerospace and an expert system to assist in the design of superalloys for high temperature applications. Each project requires a different approach to reach the defined goals. The first project has been in existence several months now, while the second will be undertaken during Spring of 1990. Hence this paper will describe results to date for the eddy current analysis, but only the original concepts and approaches considered will be given for the expert system to design superalloys.

EDDY CURRENT INSPECTION OF GRAPHITE EPOXY FILAMENT COMPONENTS

Composite materials have many beneficial characteristics which enhance their role in today's aerospace systems. Lightweight, but still very strong, even at high temperatures, graphite epoxy filaments have been fabricated to replace structures traditionally constructed of metals.

Most activity has occurred in the airframe and missile industries, with some interest currently being developed in Space structures. A major component of the Space Station is the truss structure, which is still being proposed to be made of graphite epoxy composites. Several problems still exist in selecting graphite epoxy for an aerospace structure. No accurate structural models based on traditional fracture mechanics can predict reliabilities for these structral members in the presence of flaws. Determining flaws also presents a major difficulty. Flaws can arise from fabrication errors, impact damage during assembly, and obviously in Space, impact damage and erosion from atomic oxygen. A major need exists in being able to measure the integrity of the graphite-epoxy structures during fabrication and in Space. Many research groups are involved in developing NDE techniques to detect flaws in graphite epoxy structures. Primary interest is to not only to determine that there is a flaw, but more importantly, the size and nature of the flaw. This project seeks to develop the capability to utilize simple heuristics types of logic to determine the flaws in real time, as compared to the more time consuming methods based upon statistical and computationally intensive methods.[5-6]

Eddy current inspection is a nondestructive testing technique which utilizes a high frequency electromagnetic field to induce eddy currents in the material under test. The magnitude of the eddy currents induced in the materials provides a response of the material which should indicate a measure of the integrity of the material. Since graphite fibers have a measurable conductivity, eddy current methods can be applied for inspection purposes. Unfortunately, due to the very low conductivity, the signals are weak. Several methods have been developed to increase the signal-to-noise ratio, including signal processing schemes and design of special eddy current transducers. A horseshoe or E-probe design has advantages in that it can concentrate more magnetic flux within the fiber, in addition to providing directional selectivity. Finite element models of the two types are shown in Figure 1, where a.) is the normal pancake probe and b.) is a horseshoe or E-probe.[7-9]

A number of defects exist for composite materials, as shown in Table 1.The goal of the expert system is to assist in the determination of the nature, size and location of the flaws using knowledge which relates changes in resistance and reactance of the component being tested to identify a flaw type and depth. Knowledge is incorporated into the expert system through heuristics gained by measurements on known flaws and through finite element calculations on simulated defects. The location and size of the flaw will be determined to a large extent by the scanning parameters.

The eddy current inspection facility is a robot-scanned facility using an Indellidex 550 Robot. The scanning manipulator has 5 degrees of freedom and uses a programmable computer controller for trajectory and task programming. At this time no off-line programming tools exist. The system supervisor and the platform for the expert system is a MacIntosh II using a MacIvory engine. The robotic cell layout is shown in Figure 2. A major part of the problem, in addition to the expert system development, is the integration of the components making up the cell into a flexible and productive inspection facility. Developing off-line programming tools for the facility will become a major goal in later work.

The overall expert system architecture is shown in Figure 3. As mentioned earlier, the knowledge base consists of two types, computed and measured. This type becomes the principal form of knowledge in domains where few experts reside, but the availability of knowledge applicatble to a specific domain required for real-time processing of signals will most often take the form of a measured quantity.

The MacIntosh II platform was chosen for its enhanced user interface and graphical environment. The MacIvory board set represents a state-of-the-art symbolics processor residing inside the MacIntosh computer. The two enviroments are accessible through program calls, but do not run on top of one another. The rationale for choosing this platform for the expert system was to establish the capability of the system to support the various tasks required in taking eddy current data, processing computationally and symbolically to determine flaw sizes and locations, and then to generate three-dimensional graphic representations of the structure and the flaws. The over-all task description is very robust and represents a good test of the capabilities of the MacIvory enviroment. In any case, the computer controller for the robot can perform as the robot cell controller, allowing for the MacIntosh to function solely as a data acquisition and analysis module. Both cases will be tested.

Expert System for the Design of Superalloys

This section presents some of the concepts which evolved in developing a proposal to create such an expert system. The primary rationale behind the choice of an expert systems to be applied to the problem is that there is a lot of experimental data existing in the literature which presents a very complicated, and often ambiguous description of the essential elements or processing required to prepare a superalloy with specfic attributes. For example, in the proposed study, in order to basically weed out what are the most important parameters for stability to hydrogen environment, the literature repeatedly contradicts itself, i.e. there is a conflict between the experts.

Figure 4 shows the original concept for an expert system to assist in the design of superalloy systems. To implement such a robust system, will obviously take several man-years of effort. However, by developing the overall concept in modules which can provide a useful benefits for functions such as stability in hydrogen environments, the capabilities are appreciated. Rapid prototyping only one of the modules at a time will allow the system to evolve in conjunction with the ability to generate experimental data also.

Expertise for designing superalloys exists in a few researchers and within organizations desiring proprietary handling of data. Consequently the knowledge required for this effort is not only scattered, but also, in some cases, of such proprietary nature that one company will not share their knowledge with another organization. Computations on phase formations and kinetics of metallurgical reactions for particular compositions also are required for microstructural predictions. Hence the problem solving approach consists of heuristics, data from established databases, and computations as required. Choosing an expert system shell to prototype the system was difficult.

Several expert systems shells were considered for this project. Among all the choices available, Nexpert Object was chosen because of its capabilities. Both forward and backward chaining are allowed, program calls to computational or other types of procedures are allowed and a very easy to use human interface allows for simple rule construction and inferencing. Dynamic inferencing through its non-monotonic reasoning capability are essential in order to deal with the complexities of superalloys.

The project will begin in January, 1990 with the goal to develop a prototype system to design a superalloy system with optimal stability against hydrogen embrittlement within six months. The results will be interesting. Successful completion of the preliminary goals will obviously provide a foundation upon which to add other modules in order to build up the capabilities of the system. Also we anticipate that other expert systems for advanced materials design will be attempted in the near future.

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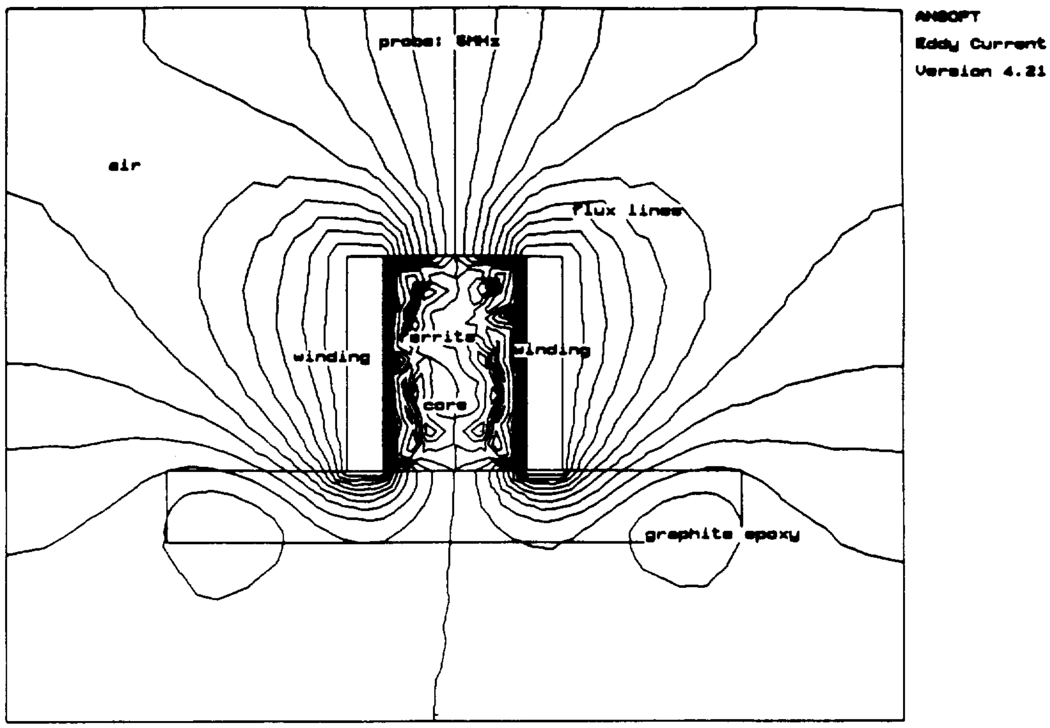
TABLE 1
DEFECTS IN COMPOSITE MATERIALS

FABRICATION DEFECTS	SERVICE DEFECTS
VOID CONTENT	MOISTURE INGRESS
STATE OF RESIN CURE	ULTRAVIOLET DEGRADATION
FIBER/MATRIX INTERFACE	TEMPERATURE EXTREMES
FOREIGN INCLUSIONS	MATRIX CRACKING
TRANSLAMINAR CRACKS	DELAMINATION
DELAMINATIONS	FIBER/MATRIX DEBONDING
FIBER ALIGNMENT	FIBER BREAKAGE
	IMPACT DAMAGE

FIGURE 1. Finite element models for a.) pançake probe and b.) E-probe for 5 megahertz electromagnetic coupling to graphite fiber. The coil is wrapped around the center bobbin in both cases. Note that the pancake probe produces a field 360 ° around the centerline, while the E-probe produces a flux across the direction of the fiber.

a.)



b.)

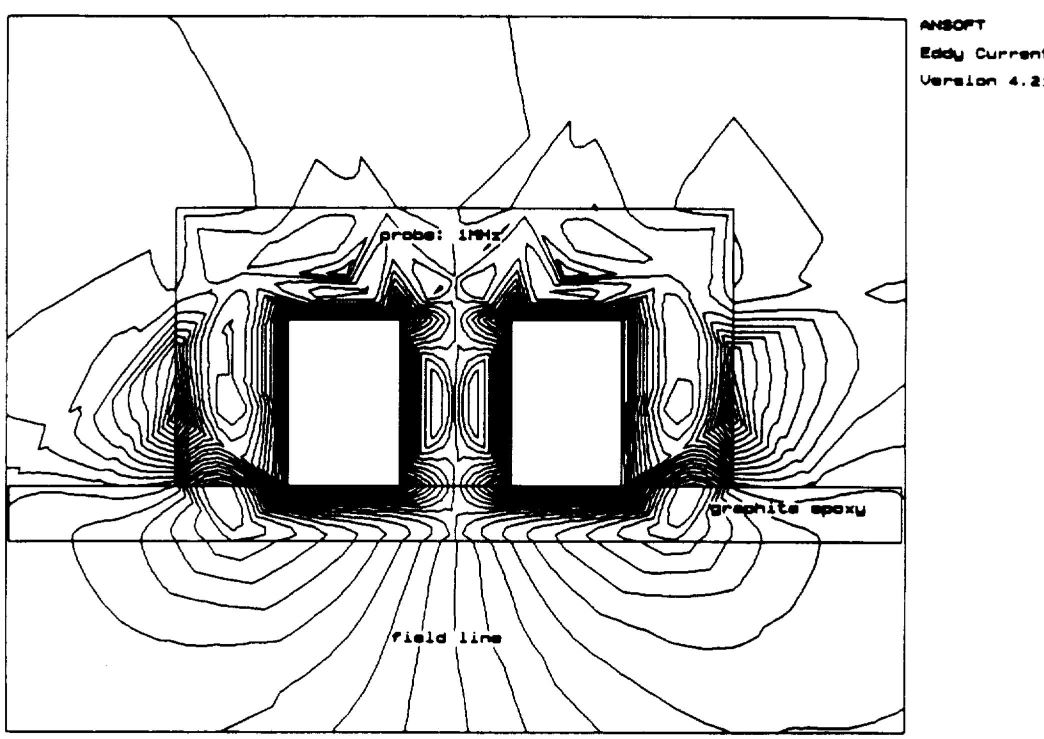


FIGURE 2. EXPERT SYSTEM FOR AUTOMATED EDDY CURRENT ANALYSIS

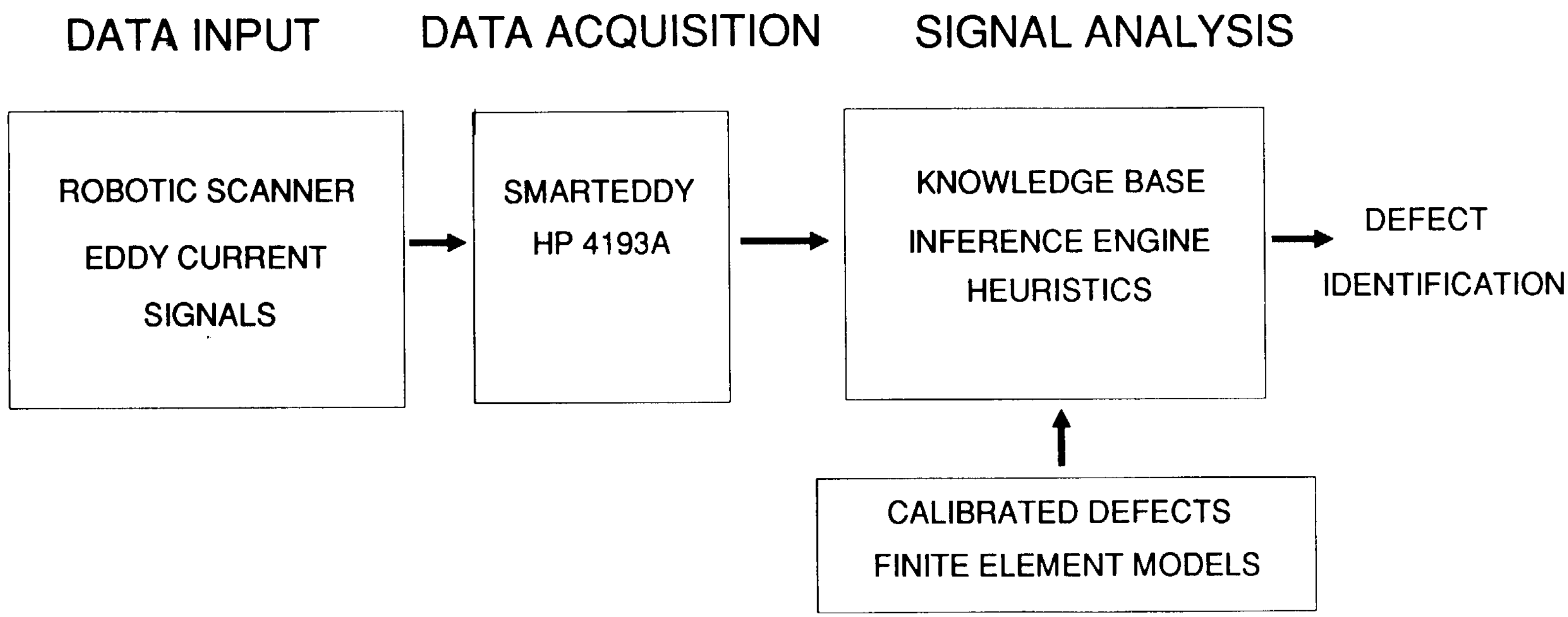


FIGURE 3. EXPERT SYSTEM ARCHITECTURE FOR EDDY CURRENT ANALYSIS

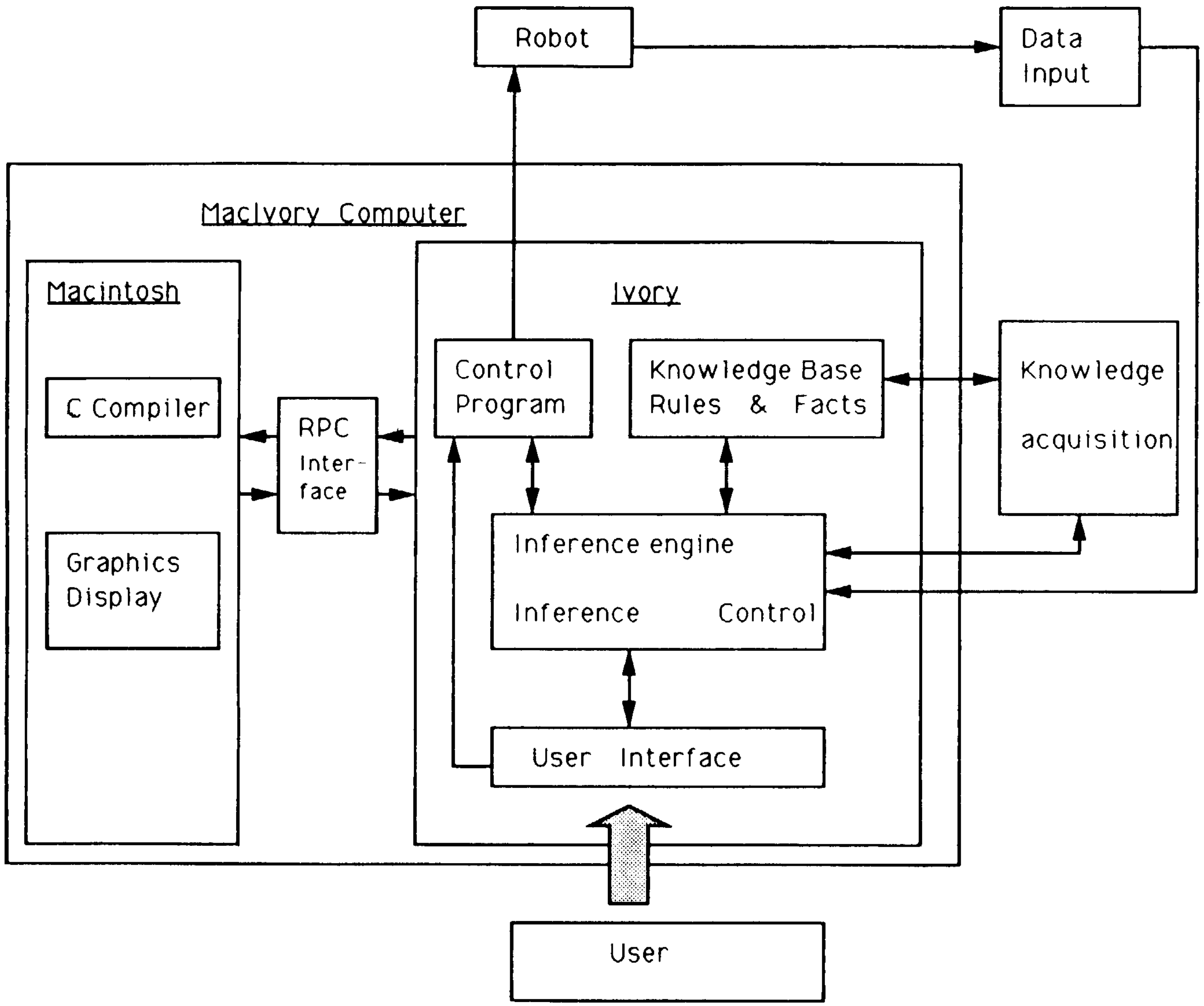


FIGURE 4 SUPERALLOY INTERACTIVE DESIGN APPROACH