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HYDROFORMING TOOL-DESIGN ADVISOR: (HTDA) PROGRAMMATIC GOALS, OBJECTIVES, AND STATUS REPORT

J. T. Greer, J. H. Dixon, Neil Davis, and M. A. Spann

FABRICATION SYSTEMS DEPARTMENT
Y-12 DEVELOPMENT DIVISION

June 30, 1989

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Hydroforming Tool-die Design Advisor (HTDA): Programmatic Goals, Objectives, and Status Report

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Oak Ridge Y-12 Plant*

INTRODUCTION

The hydroforming process is important to the Y-12 mission because of its ability to produce precision, thin-wall part geometries that otherwise would be very difficult and expensive to manufacture using standard machining techniques. The hydroforming equipment was primarily obtained from commercial vendors; however, considerable expertise is required to utilize these machines with low-percentage part and/or tool-die rejection rate. Extensive engineering and operations "know-how" are necessary in order to maintain the current efficiencies, precision, and consistent quality. Key individuals who possess this knowledge are approaching retirement age and will be required to transfer their knowledge and expertise to other "less experienced" individuals.

A systematic approach is needed to "capture" this vast knowledge, with minimum impact to current hydroforming activities, yet be consistent with future Y-12 computerization and integration (long-term strategic) plans. A plausible solution that meets these requirements, as a phased implementation and development effort, has been developed and reviewed by several representatives from the Development, Metal Preparation, and Engineering Divisions. Significant technical and implementation issues have been solved by utilizing a group (technical team) approach. The results include a full programmatic plan including: 1) a software and hardware specifications/requirements plan; 2) a phased implementation and knowledge capture plan; and 3) a final integration, verification, documentation and acceptance plan. Each plan must meet all requirements and yet still be flexible enough to accommodate future automation and/or computerization of the hydroforming tool-die design cycle. Other long-term needs such as computer recordkeeping, database management, and archiving of all pertinent information and data of the Y-12 hydroforming activities, can be accommodated by modifying or adding additional software/hardware modules.

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DESCRIPTION OF THE PROBLEM

The design of the tool-die and other assemblies necessary to produce the desired results for thin-wall parts requires several elements of knowledge and information. After the required information has been gathered, the hydroforming expert will analyze the geometric description, compare with past hydroforming experience, and determine the appropriate tool-die and draw-ring compensations and procedures necessary to produce the part.

Once the decision has been made to produce the part, the hydroforming expert must also determine the fabrication procedures, select the hydroforming equipment to be used, decide the schedule, set priorities, determine if the part (or similar part) has ever been made here at Y-12, etc. After all of the above steps have been completed, the design details for the punch are determined. These compensations and design considerations are determined by hydroforming experts who have several years experience. The expert utilizes his skills to interpret the geometric characteristics, using graphical and analytic tools, to determine the final compensation for the tool-die (punch) design. The hydroforming expert then passes this information and design considerations to the engineer/draftsman who uses this information to modify the tool-die dimensions (e.g., from the "ideal" contour description of the inner part contour) to produce the tool-die engineering drawing. The NC engineer also utilizes this information to generate the necessary NC data for machining, inspection, etc.

The primary focus of the HTDA effort is to capture the knowledge and hydroforming expertise of key experts who have established methods that are consistently accurate in determining compensations for the tool-die design, and to provide this information to the design engineer/draftsman.

DESCRIPTION AND DEVELOPMENT OF THE HTDA

Knowledge Capture

The HTDA functionality will initially be focused at two primary objectives: 1) capture the essence, both qualitatively and quantitatively, of the hydroforming experience base (rules) that are used to determine the compensation of the tool-die and draw-ring; and 2) capture the pertinent features of the geometric shape so that the "captured" knowledge can be appropriately applied.

Hydroforming experts are questioned on specific techniques and hydroforming knowledge; this information is used to generate the HTDA knowledge base. In addition, a technical group has been formed that meets on a regular schedule to discuss the goals, implementation and design issues related to the software/hardware design of the HTDA.

Information Flow of the HTDA System

The minimum set of information that must be entered into the "electronic media," as shown in Figure 1, are the directives, part geometry, and material. The directives are composed of all process information, special instructions, and other information not easily represented by graphical formats (e.g., an inspection criteria and/or plan). The material type is a separate category and describes the materials used for fabrication (e.g., commercial stainless steel, other metals, plastics, etc.). The geometric description is used to derive particular attributes and/or parameters needed for the tool-die compensation, etc. The methods used to store, classify, and analyze geometries will be discussed in later sections.

SHORT-TERM GOALS AND PHASE ONE FUNCTIONALITY

General Description

In order to concentrate on the main objectives, as stated before, the two primary software modules that will be included in the short-term plan (Phase I) includes the Graphical Entry and Classification Module (GECM) and the Knowledge System and Decision Module (KSDM). Figure 2 illustrates how these modules are related and shows the Phase I configuration used by the knowledge engineer and hydroforming expert to capture and verify the results of the KSDM. These modules are necessary "stepping stones" for all future activities. The Phase I development milestone includes the successful operational of these modules for specific test cases. These test cases are predetermined and represent a good "cross-section" of symmetric prototypes that have been encountered in the past. The Design Consideration report (see Figure 2) is a comprehensive report that fully describes the contour classification, the rules that were applied, explanation of rationale for each rule used to determine the final conclusions, and compensation guidelines.

Future HTDA development phases will augment these modules and expand the knowledge base to include a more comprehensive and complete knowledge base. In other words, the HTDA system will be developed and/or augmented in incremental stages as the knowledge base grows and as new knowledge comes available. The "incremental" approach is necessary because of the complexity of the process and the inability to "model" or fully describe the hydroforming process in "exact" (deterministic) terms. Furthermore, the "experience base" covers a wide spectrum of knowledge, information, and disciplines; lack of "total understanding" should not be construed as a prerequisite for failure. Distinct and "defendable" knowledge can be utilized to develop a "useful and profitable" system.

When geometric descriptions cannot be handled, the HTDA will recognize the condition and alert the user that the part/geometry does not lie within its current "knowledge base." The HTDA will provide "definitive reasoning" for all decisions. In other words, all results will be accompanied with the "rational," rules, and analysis used to arrive at each decision.

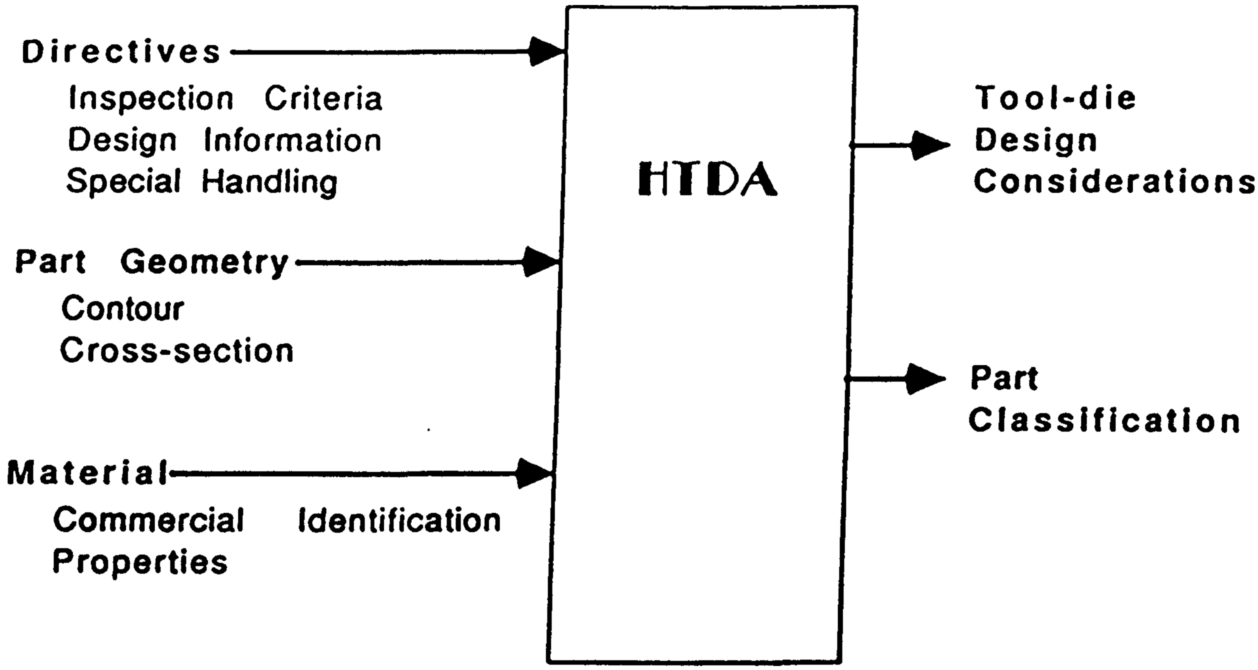

FIGURE 1
HTDA INFORMATION FLOW: INPUTS AND OUTPUTS

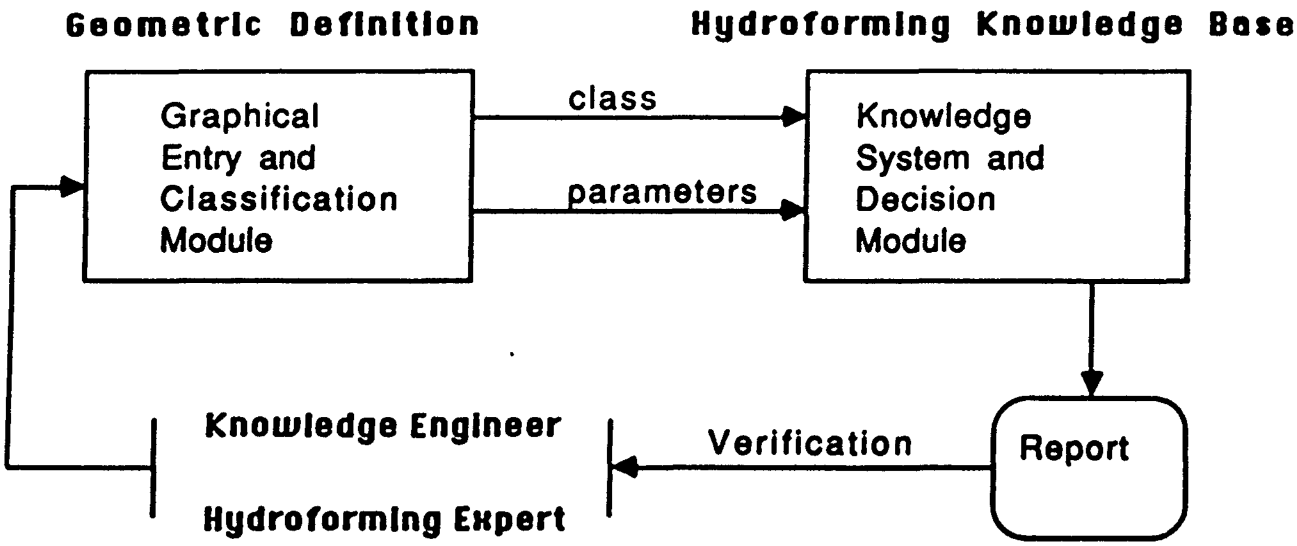

FIGURE 2
PHASE ONE OPERATIONAL AND DEVELOPMENT MILESTONE

Description of the GECM

The GECM is used to enter part geometries (contours) using an interactive (user friendly) interface. In addition, the GECM provides error and consistency checking as the contour is being entered. The geometric definition is described by a contour which is broken into regions that are used for classification and analysis. The HTDA is initially limited to symmetric parts; non-symmetric parts are rarely done at Y-12 and would be considerably more complicated to describe and analyze and hence will not be included in the short-term goals.

The short-term goals of the HTDA project requires that only the necessary information be used to describe the geometry. In other words, a limited set of the hydroforming classes will be used. However, most of the geometries fall into one of the five basic classifications and these describe approximately 90 percent of the part classifications that have been encountered at the Oak Ridge Y-12 facility.

For the short-term, five general categories will be used for classification. These class categories represent a wide variety of variations and will depend upon the specific geometric attributes (i.e., dimensions of particular geometric features). Several sub-classes are acceptable and will be included in the initial repertoire of part geometries that can be handled.

The classification procedure is based upon syntactical methods that use a limited set of graphic primitives to describe contour; namely point, line, arc, and curve. These primitives are ordered and inspected by the GECM to determine the proper classification.

Description of the KSDM

After the geometric description has been entered and properly classified by the GECM, the results are passed to the KSDM for processing. The KSDM utilizes all hydroforming knowledge that has been "captured" and begins to apply this knowledge to the task of deciding the best compensation for the tool-die, draw-ring, etc. The results are assembled and formatted into a report that can be reviewed by the expert for confirmation and accuracy. This report will essentially be a complete "data dump"; in other words, the inputs, decisions, decisions processes, and rational will be included in the report.

The software tools that are best utilized in this module have not yet been totally defined; however, the primary objective for the short-term plan is "good representation of the problem." Because of the highly analytic nature of the hydroforming decision making process and the strong dependency upon the geometric description, most expert-system shells do not meet the integration/interface requirements of this project. A PC-based expert shell is currently being used as a "knowledge base" development tool, but the final expert-system shell has not been selected.

LONG-TERM GOALS AND DESCRIPTION OF FUNCTIONALITY

The long-term goals include automation of the design cycle, including the actual compensation being applied to the contour of the tool-die geometric descriptions. Figure 3 shows the three different development phases, information flows, and software structure. Each "square-cornered" rectangle block in Figure 3 represents a distinct software module that performs a particular function and is based upon the expertise and "captured knowledge" of the appropriate expert(s) who normally perform these tasks. The following sections describe these functional attributes for each phase.

Description of Each Development Phase

The Phase I functionality includes the ability to interactively enter hydroforming contours, from a standard Tektronix terminal. The GECM will also interactively (in real-time) classify the part and give the user an immediate appraisal of the geometry being entered. The GECM will do all necessary checks to insure that the geometry has been properly entered, etc. Once the geometry and other information has been entered, the KSDM module will produce a report to describe how the design compensation for the punch and draw-ring would be applied. The report will contain the predicted compensations and all information and decisions used to generate the compensations.

The Phase II objective is to capture the knowledge of the engineer/draftsman, and to develop the Tool-die Compensation and Drawing Generation Module (TDC/DM). This module will generate an accurate compensated contour. The Complete Geometric Definition (CGD) database will be used to acquire the complete geometric description. By utilizing the results of the KSDM and the CGD, the TDC/DM will produce a fabrication drawing, procedure modifications, and other information that will be of interest in the fabrication process. The fabrication drawing will contain information about the tool-die, wrap material and dimensions, special handling and procedures, and other process dependent information.

The KSDM was not included in Phase I because it could degrade the ability and effectiveness of the (necessary) feedback and conformation of the results. In other words, the hydroforming expert could more efficiently review a "textual" description of the compensation rather than a "numerical" description of the compensated contour. Accuracy is very important to the complete success of the project; furthermore, the application of the compensations are also done utilizing the expertise of the engineer/draftsman. This expertise is the essence of the Phase II development.

The Phase III objective is to format the CGD information for transfer to other systems and/or groups. Utilizing ANVIL to read predefined data files will facilitate linkage with other processes and/or computer systems that need the geometric details of the compensation (e.g., the NC machining support groups, etc.). Phase III also includes the ability to archive a complete hydroforming design/fabrication cycle and to query the hydroforming database.

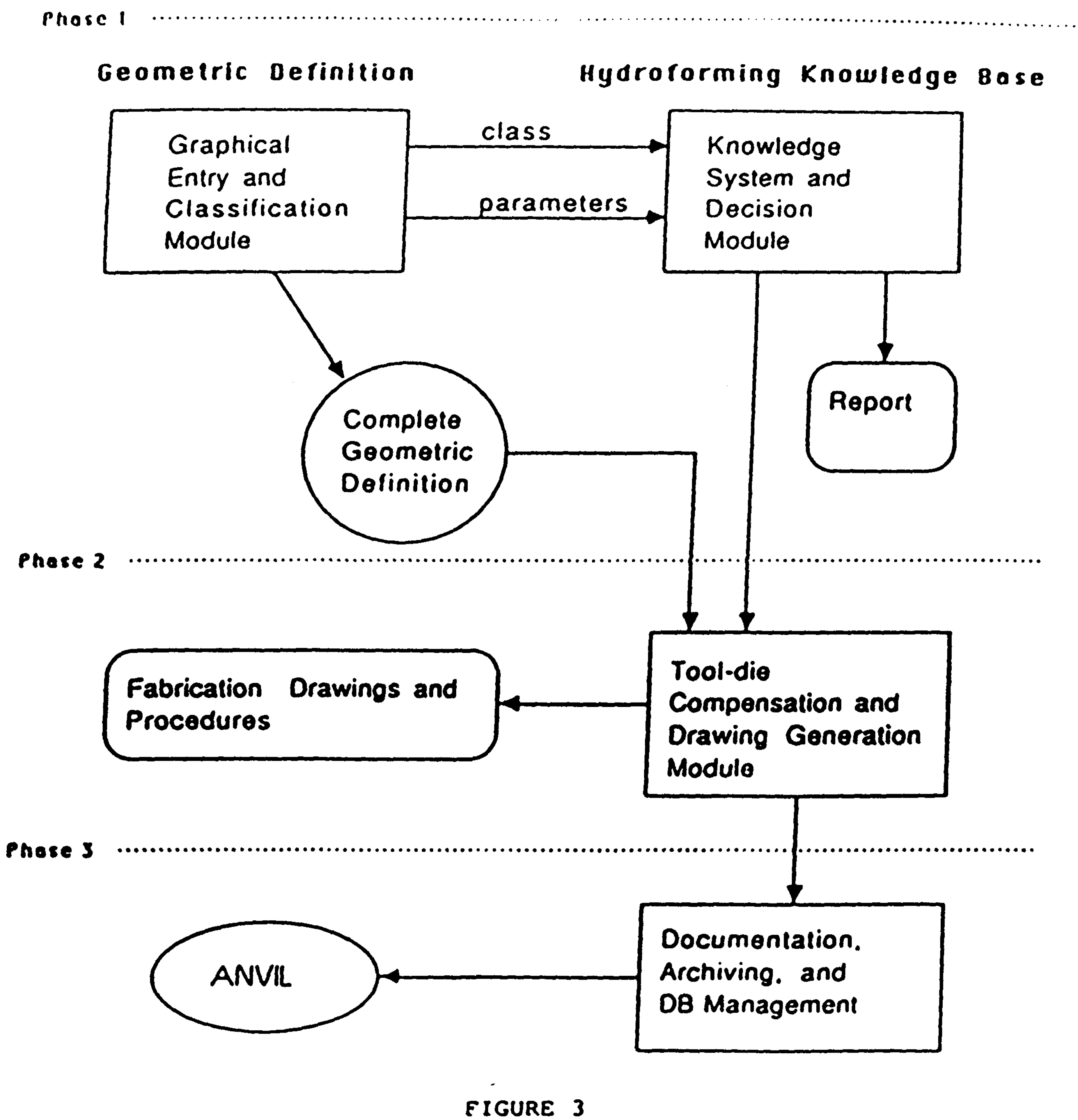

FIGURE 3
LONG-TERM PROGRAMATIC PLAN WITH INCREMENTAL PHASES

CURRENT STATUS AND DEVELOPMENT ACTIVITIES

The graphic input section of the GECM will be completed on or before July 20, 1989. A "first-cut" prototype is now being tested and "debugged." The GECM is being developed using interactive graphic tools and utilizes a simple, "user-friendly," menu-driven interface that can be accessed using any standard graphics (Tektronix) terminal.

The GECM is currently being prototyped using available interactive graphic tools. The weekly technical meetings are used to discuss and resolve technical problems that are encountered during the software development.

The "expert knowledge" needed to complete the operational milestone will be limited to standard geometric prototypes (the five general classes of part geometries with the appropriate "rules" that apply for each class). Significant progress has been made in capturing the necessary knowledge to accomplish the Phase I objectives. Technical issues that arise are also being addressed in the group meetings. The KSDM software design structure is near completion and code development should begin within four weeks.

CONCLUSIONS

The HTDA project represents the pulling together of the expertise of several individuals with a wide spectrum of knowledge and expertise. The HTDA project has only been in existence for three months, yet the progress has been significant considering the complexity of the problem. Once the objectives and goals were understood, a very intense effort was launched that has led to an efficient development team.

The software design of the GECM has begun and code development is under way. A prototype version is now being tested and evaluated. The software design of the KSDM, both functionally and architecturally, is near completion. A software "design review" (sometimes called a "walk-through") will be done before coding begins. Completion of the Phase I development milestone is scheduled for October 1, 1989.

The HTDA represents a major challenge to accomplish the goals and functional requirements that are described in this report. Several methods and tools are being developed specifically for the purpose of capturing "human expertise and knowledge," and each development phase represents a major "learning experience" for the software development team.

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