SPECIAL SESSION ON AXIOMATIC DESIGN

Tutorial on the Fundamentals of Axiomatic Design

Technical Sessions

At the SAE World Congress 2007
http://www.sae.org/congress/
Cobo Center, Detroit, Michigan, USA
Wednesday, April 18
9:00 a.m. – 11:30 a.m. and 1:30 p.m. – 3:30 p.m.

What is Axiomatic Design and why should you be interested?

A powerful design method developed by Prof Nam Suh at MIT that …

- decreases design times and time to market.
- reduces design complexity and design iterations.
- maximizes the probability of satisfying the customer needs.
- improves communication and assists with collaborative design.
- fosters innovation and results in better designs.
- documents design decisions and design intent.

Suh's axioms are two simple rules that can be used to understand complex design problems, just as Newton's laws are simple rules that can be used to understand complex problems in engineering mechanics.

The sessions include top researchers, theoreticians and practitioners from around the world. The sessions start with a tutorial on the fundamentals of Axiomatic Design. Then seven papers are presented to discuss topics encompassing variety of issues in manufacturing and design.

TUTORIAL

Axiomatic Design 101: The Fundamental Elements of a Powerful Method

Cobo Center, Room W1-54B

Wednesday, April 18

9:00 a.m. – 10:00 a.m

Speaker: Dr. Christopher Brown

This tutorial is intended as an introduction and refresher for those who have no or limited experience with Axiomatic Design. Those with experience in AD and those teaching AD will benefit from Prof. Brown's special approach to teaching AD. Brown decomposes AD into three elements for implementation: axioms, structure, and process. The axioms are the universal rules for good design.

The structure shows how to describe the design for application of the axioms, and communicating the design and intent. The process shows how to develop the structure through decomposition and integration. Brown explains how to develop the decomposition to foster innovation and maximize the success of the design by applying the axioms.

Professor Christopher Brown, PhD, PE, has been teaching Axiomatic Design at WPI and in industry since 1990. Chris has spoken at conferences and published papers on his special approach to teaching Axiomatic Design. Chris started using Axiomatic Design as a graduate student in the early 1980s at the University of Vermont after meeting Nam Suh. The structure formulates the design so that the axioms can be applied. The structure also provides traceability for the design decisions. The processes of decomposition and integration used to create the design have been divided into clear steps to keep the design process on track and productive. Chris teaches special short courses for industry. http://www.axiomaticdesign.org/

TECHNICAL SESSION

Reliability and Robust Design in Automotive Engineering - Parts 6A&B
Axiomatic Design (M18)

Organizers:

Christopher A. Brown, Worcester Polytechnic Institute; Taesik Lee, Massachusetts Institute of Technology; Hilario L. Oh, Massachusetts Institute of Technology; Yih-Chyun Sheu, General Motors Corp.

Cobo Center, Room W1-54B

Wednesday, April 18
10:00 a.m. – 11:30 a.m and 1:30 p.m. – 3:30 p.m.

10:00 a.m. – 10:30 a.m. **Axiomatic Design Rules for Implementing Lean Manufacturing**
J T. Black, Auburn Univ.

The Toyota Motor Company has become a world leader in the automotive industry by redesigning the mass production system into the lean manufacturing system by changing the final assembly into a mixed model final assembly system to level the demand on their suppliers, converting the linear subassembly lines into U-shaped subassembly cells and redesigning the job shop into manufacturing cells. Final assembly operates with a takt time, and the cells are designed to have a cycle time slightly less than the takt time and to operate on a “make one, check one and move one on” (MOCO-MOO basis)”. Single-cycle machine tools are used with built-in devices to check parts (poka-yokes). Between the machines are devices (decouplers) designed to assist the standing, walking workers producing the parts in the manufacturing cells. This paper will discuss the Axiomatic Design rules for the system and cell designs and discuss an example of a lean manufacturing cell.

10:30 a.m. – 11:00 a.m. **Systems Approach to Sustain Lean Organizations**
David S. Cochran, System Design LLC

This paper describes a methodology called Collective System Design for leaders, managers and engineers to understand their existing organizational system design and to articulate and to sustain purpose in their lean/ organizational design efforts.

11:00 a.m. – 11:30 a.m. **Knowledge Management and Axiomatic Design**
Christopher A. Brown, Worcester Polytechnic Inst.

It is postulated that the value-adding intellectual activity in an enterprise can be formulated as an engineering design problem, using Axiomatic Design. Axiomatic Design formulates a decomposition structure that includes four domains: customer, functional, physical, and process. Knowledge exists within the entities in domains and in the relation between the entities in adjacent domains. Once an entity has been identified in one domain, a properly designed knowledge management system can suggest all the known solutions in the adjacent domains, and the interactions between the domains, along with details about how well these solutions work.

1:30 p.m. – 2:00 p.m. **Minimizing Information Content of a Design using Compliance Analysis**
A. M. M. Sharif Ullah, Khalifa H. Harib, Ahmed Al Awar, United Arab Emirates Univ.

This study shows that to minimize the information content at an early stage of a design process, three types of compliance are required, namely range, certainty, and requirement compliances. Range compliance measures the average belongingness of a numerical range to a vague linguistic class. Certainty compliance measures how clearly a piece of design information is known or given. Requirement compliance measures how strongly a design alternative fulfills the design requirement or range wherein the design range is linguistically defined. To demonstrate the effectiveness of the method, a case study that deals with the selection of optimal materials for a car body is presented. A computing tool is also developed to practice the method using computers.

2:00 p.m. – 2:30 p.m. **Design of the Occupant Protection System for Frontal Impact Using the Axiomatic Approach**
Sang-Ki Jeon, Delphi Korea; Gyung-Jin Park, Hanyang Univ.

The functional requirements (FRs) and design equation of a flexible system change in a continuous manner with respect to a variable such as time. An event driven flexible system is defined as a subcategory of the flexible system in that it changes in a discrete space. A design scenario is developed for the event driven systems. The design equation for each event should be defined by using the axiomatic approach and the design equations are assembled to form a full design equation. The design equation for each event can be established by sensitivity analysis. In conceptual design, the design order is determined based on the full design equation. Design parameters (DPs) are found to satisfy FRs in sequence. A design parameter may consist of multiple design variables. In detailed design, the design variables are determined. The occupant protection system is an event driven flexible system because the design matrix and its elements change according to the impact speed. The involved devices are designed based on the developed method. Functional requirements (FRs) at different impact speeds and corresponding design parameters (DPs) are defined. In detailed design, the full factorial design of experiments (DOE) is employed for the design variables of DPs to reduce the injury levels of the occupant. Computer simulation is utilized for the evaluation of the injuries. The results are discussed.

2:30 p.m. 3:00 p.m. **Balancing Design Functional Coupling and Sensitivity to Noise to Achieve the Design Target**

Hilario L. Oh, Massachusetts Institute of Technology

The primary objective in design is to achieve the target value of the design's response function. If a design fails to achieve the target value, it most likely fails in two ways: inconsistent functional output and in design involving multiple response functions, unable to converge to the multiple target values in spite of iterative adjustment of the design parameters. The former is symptom of a design not able to perform in the presence of variability, i.e., noise. The latter is symptom of a design that fails to perform in the presence of functional coupling. Both problems are best addressed at the conceptual stage of the design at which only design solution that is inherently robust to noise and functionally uncoupled is entertained. If this is not possible, the alternative is to exploit the interaction between control variables and variables that are sources of noise and functional coupling to render the design insensitive to them. Thus situations may arise wherein the same control variables are involved in reducing the effect of functional coupling and of noise. In these situations, balancing the conflicting needs to reduce design functional coupling and sensitivity to noise is the key to achieving the design targets. In this paper, we formulate the metrics for design functional coupling and design sensitivity to noise. These metrics are then used to balance the conflicting needs of reducing the two in an illustrative example.

3:00 p.m. 3:30 p.m. **Achieving Design Target in the Presence of Functional Coupling**

Taesik Lee, Hilario Oh, Massachusetts Institute of Technology

The primary objective of design is to achieve the target value of its function. While principles and techniques of Robust Design address the issue of achieving target values in the presence of different types of variations and disturbances, there exists a unique challenge in achieving design targets when multiple response functions are interrelated. In order to overcome the challenge, we must avoid functional couplings and obtain the interrelationship structure as flexible as possible. In the Axiomatic Design process, such interrelationships are represented by coupling terms in a design matrix. From the targeting aspect of design, it is important to achieve a desirable design matrix structure to, first, avoid any functional coupling in a design matrix and, secondly, maximize allowable sequences of adjusting DPs. This can be achieved by examining the structure of a design matrix to identify off-diagonal terms causing coupled and decoupled sub-structure and then eliminating an optimum set of off-diagonal terms. This paper presented a structured method based on the graph representation to effectively determine the optimum set of off-diagonal terms to eliminate from a large design matrix.

Also: Tuesday 17 April 2:30 p.m. Room M2-29 2007-01-0685

Axiomatic Design of Automotive Roof Structures

Stephen A. Batzer, Robert Burgess, Engineering Institute; Christopher A. Brown, Worcester Polytechnic Institute