Axiomatic Design
Short Course and Workshop
WPI campus
June 16 and 17, 2008

PROGRAM

A two-day training course composed of lecture, discussion, examples, and practice for engineers and managers intending to learn Axiomatic Design.

Axiomatic Design solves design problems, fosters innovation, and shortens design cycles, while improving product and process designs, and promoting collaboration.

Axiomatic Design goes beyond lean in process and system design, and reduces time to market for product design.

Axiomatic Design structures the design and design process to avoid unintended consequences and unwanted interactions that cause delays in design and problems for adjustability and control in the design process and in products.

Faculty:

Christopher A. Brown, PhD, PE, FASME
Professor of Mechanical Engineering, WPI

- A leader and pioneer in the application and teaching of Axiomatic Design, with more than two decades of experience using and teaching Axiomatic Design in academia and industry.

Featuring:

- Lectures, examples and discussions on Axiomatic Design.
- Design exercises in applying the principles of Axiomatic Design.
- Participant selected design development with coaching and design reviews.
- Acclaro Software.
- Follow-up, individual design reviews

BACKGROUND

Axiomatic Design refers to a design system that can significantly improve any type of design activity and designed product. It is aptly applied to engineering design problems. The course does not cover drafting, CAD or industrial design.

Axiomatic Design theory starts with the premise that good design is governed by axioms, or laws, like physics is governed by physical laws. It was developed initially by Prof. Nam Suh at MIT in the late 1970s. Using a design structure and a design process, intended for the application of these laws, Axiomatic Design has been shown to reduce design times, facilitate documentation of design decisions and produce better designs.

Axiomatic Design assists with collaboration, and aids in innovation. Axiomatic Design allows for functional modeling early in the design process, which can eliminate the need for costly design iterations later in the design process.

COURSE LEADER

Professor Christopher Brown, PhD, PE, FASME, WPI, Mechanical Engineering

Chris Brown has been teaching Axiomatic Design at WPI and in industry since 1990. Students in his evening graduate course typically report that they start using axiomatic design at work within the first few hours of the course.

Chris started using Axiomatic Design when he was a graduate student after meeting Nam Suh in the early 1980s at the University of Vermont. As a senior research engineer, Chris used Axiomatic Design to design products and processes for Atlas Copco at their research center in Switzerland before coming to WPI. In the past few years Chris has been pleased to have had the opportunity to consult with Nam Suh on design problems.

"Chris Brown is one of the leading experts in the world on axiomatic design. He is a pioneer in developing effective teaching methods for applying axiomatic design and has developed a keen insight to the design theory and practice. Professor Brown's former students have had great success in industry in improving the productivity and quality of their products." Prof. Nam P. Suh, MIT, the originator of axiomatic design

THE APPROACH

This special approach to teaching Axiomatic Design has been developed and published by Prof. Brown over the past decade and a half. The objective of Brown's special approach is to teach people quickly and effectively how to use axiomatic design.

Brown divides the practice of axiomatic design into three elements: the axioms, the structure, and the process. These elements are presented, applied and practiced over the two days of the course at basic and advanced levels.

Through the years of teaching Axiomatic Design and Chris has collected a number of case studies and examples which will be used in the class.

PARTICIPANT PROFILE

The course is for engineers, managers, directors and vice presidents involved in product, process and system development and design. This would include all the traditional engineering disciplines as well as manufacturing engineers.

Participants apply Axiomatic Design to problems that they bring with them. This allows them to advance their own design work, which would benefit directly from the coaching during the process and design reviews. Participants will have the opportunity to work on designs in groups from their companies.

Specific technical and business functions that could find this course especially beneficial and of particular interest would be:

- Product Development
- Research & Development
- Engineering Design
- Project management
- Process Development
- Manufacturing

COURSE OBJECTIVE

The objective of the course is to supply the participants with enough knowledge and practice to be able to apply Axiomatic Design to their own tasks immediately after the course. For example, design engineers will learn how to decompose a design problem and find the best ways to fulfill functional requirements, and managers will learn how to evaluate designs through functional modeling, avoiding expensive iterations with prototypes.

The skills that will be acquired include:

- How to go from argument to analysis in evaluating competing designs
- How to apply the two design axioms, and corollaries, qualitatively and quantitatively to a wide variety of design and planning problems
- How to structure the design to facilitate the systematic application of the axioms
- How to formulate a functionally based design with constraints to align with the corresponding physical, process, and tooling elements
- How to develop functional requirements in a hierarchy so that at each level they are collectively exhaustive and mutually exclusive
- How to integrate physical elements and avoid physical coupling
- How to discern functional requirements and constraints
- How to recognize different kinds of coupling and address them
- How to avoid unintended consequences, so that a design remains controllable and adjustable
- How to apply axiomatic design to manufacturing processes and systems and go beyond lean

COURSE OUTLINE

Day One

1. Introduction to the design axioms – qualitative applications
The applicability of an axiomatic approach to design is established. The importance of functionally based design is presented in the context of functional and physical design domains. The two axioms, independence and information, are introduced. Independence is discussed in terms of making a design adjustable and controllable, and in avoiding unintended consequences. Correspondence between the design domains is introduced. Information is discussed in terms of maximizing the probability of fulfilling the design functions. The best designs are those that fulfill the functions with the greatest independence and the least information. Qualitative application to design is developed. Examples are presented and discussed.

2. Introduction to structuring and decomposing designs
In axiomatic design the design is structured so that the axioms can be applied. The structure is developed through a process of decomposition into hierarchies from general to specific, across design domains, which are corresponding descriptions of the design. No design can be better than its functional requirements (FRs). The essential elements for developing good FRs will be taught and practiced using several kinds of tests, including CEME (collectively exhaustive and mutually exclusive).

3. Applying axiom one - design matrices
The correspondence between the functional and physical domains is represented in a design matrix. The matrix can be evaluated to determine the level of independence. It can be used to determine if an order of adjustment of the elements of the physical domain is critical, and what orders of adjustment will eliminate inefficient iterations to achieve the desired functions. The design matrix is also used to evaluate competing designs.

4. Applying axiom two – calculating information content
Axiom two is often underutilized. It is used to select between alternatives that have the same level of independence. It can be used to improve yield in manufacturing and robustness in product design. Information is developed quantitatively from the probability of success. Information provides a common basis for comparing design alternatives with components that have different units.

5. Integration and Practical design
The final step is to integrate the elements of the physical domain that were identified and selected in the decomposition. A physical integration matrix will be used to check for unintended coupling between the physical elements. Clear links to the functional elements and identification of the corresponding physical elements are part of the design product.

COURSE OUTLINE

Day Two

1. Advanced Axiom One – Forms of coupling and how to address them
Case studies and examples will be presented. Means for identifying several individual kinds of coupling and how to deal with them will be covered. For example, DP-FR coupling is the most commonly encountered and is what the design matrix addresses primarily. FR-FR coupling cannot be addressed by manipulating the design matrix or selecting new DPs. FR-FR coupling results from poor development of the FRs and requires redefining FRs and constraints. The application of CEME to the FR definition process will be addressed. DP-DP coupling can occur during physical integration, and when existing designs are examined. Sequential coupling arises in process design when operations appear to have to be done in sequence. It can obscure other kinds of coupling when using the design matrix.

2. Advanced Structure – Creating domains, comparing themes
Based on advanced applications work there are several questions that need to be addressed as designs advance in their complexity and interaction with other designs and objectives and organizations, using case studies and examples. When do you add siblings or create a new level? How do you know if you are designing the process or the tooling, the mission or the equipment? When does it matter? Would the design process be expedited by creating another domain? Is it time to create a new domain or start another design process with another theme? Techniques for recognizing when the design would be expedited by a change in the structure and how to do it will be reviewed and discussed.

3. Assigning interactions – Quantitative approach - Inheritance in the design matrix
When should you write equations to express the DP-FR interactions, and how can you do it? How can you identify the interactions in the equations? What can you do to understand the interactions when the equations are not obvious? How do you assign tolerances through the interactions? When an off-diagonal child interacts, what influence should this have on the parents? How can you check to see if coupling is properly inherited through the design matrix?

4. Managing axiomatic design – Team work - staying on track
How do you exploit the potential of teams in design work? Apply the advanced approach to effective collaborative negotiations in addressing design options. Learn how to manage a design review and effectively critique design projects.

5. Further design reviews by appointment
Through the following six weeks design reviews can be scheduled with Professor Brown by appointment. Following that appropriate time and additional charges, if any, will be decided based on the individual situations.

BREAKOUT DESIGN EXERCISES

Day One

1a. Qualitative applications of axiom one, independence
- recognize DP-FR coupling
1b. Qualitative applications of axiom two
- differentiate designs with different levels of information

2. Introduction to structuring and decomposing design
- use Acclaro to decompose a design of your choosing by developing corresponding FR-DP hierarchies, working in groups or individually. Where the designs may involve proprietary information the design review will be done privately. Other designs will be reviewed by the entire group.

3. Applying axiom one - design matrices
- use Acclaro to develop design matrices for a design of your choosing, building on exercise 2, and working in groups or individually, with private or public design reviews.

Day two

1. Advanced Structure – creating domains, comparing themes
- case studies, using Acclaro address evaluate design objectives in a complex context, decide where the process and means to accomplish need to be developed separately. Develop strategies to address the creation of new designs, new decompositions along new themes, or new domains.

2. Assigning interactions – quantitative approach and inheritance in the matrix
- case studies, using Acclaro trace inheritance through the matrix.
- evaluate DP-FR coupling thorough the development of equations on self selected design problems.

3. Managing axiomatic design – team work - staying on track
Using Acclaro, working in teams and working on participant selected projects, create a design decomposition and review it. The design and the review process will be reviewed.

4. Additional design reviews
Using Acclaro, a design started in the class, or others, can be reviewed by email and phone or in person depending on the situation for the following six weeks.

MORE ABOUT THE PROFESSOR

Chris Brown is the author or co-author of over one hundred technical and scientific several articles, including several on how to teach Axiomatic Design. He has worked as a consultant applying Axiomatic Design to space travel, manufacturing, ski bindings and other products. He teaches a regular grad course that applies Axiomatic Design to manufacturing processes. He also teaches a course on the Technology of Alpine Skiing, and is a former NCAA All-American ski racer and Swiss certified ski coach. His oldest son is a graduate of Dartmouth's Thayer School of Engineering and raced in Europe with the US Ski Team, his youngest son is currently studying at St. Lawrence University and captains their ski team. Chris is founder and director of the WPI's Haas Technical Education Center for Computer-controlled Machining and of the WPI's Surface Metrology Lab. He is also the former director of the Manufacturing Engineering Program at WPI. He was previously with Atlas Copco at their European Research Center and with the Swiss Federal Institute of Technology's Materials Department in Lausanne, Switzerland. He got his PhD in Mechanical Engineering at the University of Vermont in 1983 working under Branimir von Turkovich studying machining and materials.