TITLE OF INVENTION

Method and computerized system for robust engineering and optimization of complex phenomenon.

1. FIELD OF THE INVENTION

The invention described herein relates in general to a method and computerized system for robust engineering and optimization of complex phenomenon, and more particularly, to a guided methodology, which dictate the proper sequence and techniques for robust engineering, characterization and optimization; and a computerized system which allows a user through a wizard-based graphical-user-interface to plan-setup-create robust engineering model and to evaluate its parameters; and to automatically compute-analyze-optimize-verify the robust engineering model with the help of a task-specific knowledge based system and optimization algorithms; and together with a system to track-store-retain the scientific knowledge for future usage. The most novel feature of the invention is its ability to in an integrated way provides the discussion of complex trade-offs between practical limitations and statistical preferences in an experiment as well as presents the generic technical issues and the core experimental features found in an industrial experiment, to support robust engineering, characterization and optimization activities for complex phenomenon.

2. BACKGROUND OF THE INVENTION

Experimental design is both an art and a science. The science deals with the mathematics and formalities of developing experimental plans. This is what most of the literature is about. The art of experimental design provides the framework for an effective test program that is maximally responsive (subject to practical limitations) to the questions that the investigators wish to answer. It deals with such important but seemingly nonstatistical topics as defining the goals of the program, establishing the proper response and control variables, assuring appropriate scope and breadth, understanding the various sources of experimental error, appreciating what can and cannot be randomized, and so forth. These issues consume much of the time of those responsible for designing experiments in the complex world.

Experimental methods are widely used in research and in industrial, however, sometimes for very different purposes. For scientists, the primary goal in scientific research is usually to show the statistical significance of an effect that a particular factor exerts on the dependent variable of interest. While for the Engineers in industry, the primary goal is usually to extract the maximum amount of unbiased information regarding the factors affecting a production process from as few (costly) observations as possible.

In many systems and processes of manufacturing engineering, the boundary conditions and physical phenomena are so complex that it is beyond the present technical capability to obtain satisfactory analytical or numerical models. As such, experimentation is necessary to define the behavior of the system and/or processes. Design Of Experiments (Experimental design) can be defined as a systematic attempt to construct theories that correlate wide groups of observed facts through the purposeful changes of the inputs (factors) to a process in order to observe the corresponding changes in the outputs responses. Experimental design is a scientific approach that allows the researcher to better understand a process and to determine how the inputs affect the response.

Engineers and scientists design and create products/processes to perform certain functions and performance. They designed experiments to empirically investigate the effect of various parameters on the responses of the products/processes or systems being studied. Such activities require cost and functionality predictions. When limited experiments are conducted in R&D laboratories it is impossible to predict exact output responses because laboratory conditions are quite different from downstream condition arising from large-scale manufacturing or customer requirements.

The technique of laying out the conditions of experiments involving multiple factors was first proposed by the Englishman, Sir R.A.Fisher. [Fisher, R.A. (1930), (1966).]. The method is popularly known as the factorial design of experiments. A full factorial design will identify all possible combinations for a given set of factors. Since most industrial experiments usually involve a significant number of factors, a full factorial design results in a large number of experiments. To reduce the number of experiments to a practical level, only a small set from all the possibilities is selected. The method of selecting a limited number of experiments that produces the most information is known as a partial fraction experiment. [Box, G.E.P., Hunter, W.G., and Hunter, J.S. (1978); Montgomery, D.C. (1992)]. Although this method is well known, there are no general guidelines for its application or the analysis of the results obtained by performing the experiments.

Although designs of experiments methodologies are well established, several problems and controversies still remain in existing experimental designs techniques. [Khuri, A.I., and Cornell,

J.A. (1987); Box, G.E.P. (1988); Hoadley, A.B., and Kettenring, J.R. (1990); Vining, G.G., and Myers, R.H. (1990)]. The problem addressed by this invention concerns the lack of integration and understanding of both the hardcore techniques and the soft management procedures among existing design of experiment methods. The main reason is the industry's failure to use statistical design of experiments at all. This is not too surprising a result considering the lack of understanding and application of statistical experimental design up until a few years ago. [Taguchi, G., and Phadke, M.S. (1984); Pignatiello, J.J., and Ramberg, J.S. (1985); Taguchi, G. and Wu, A. (1985); Kackar, R.N., and Shoemaker, A.C. (1986); Taguchi, G. (1987); Phadke, M. (1989)]. This is because the understanding and application of design of experiment is difficult because of it inherent complexity on the tools and methods. In addition, the statisticians who design experiments with scientists and engineers (the "experimenters") usually have to bridge a gap in knowledge and experience. The second reason for failure of an industrial designed experiment is poor experimental planning and management. Insufficient planning can create an "implementation gap" described above which can lead to experimental failure. A poor experimental planning lead to poor communication and execution; and poor design is an aspect of poor planning. These views show that there is a need to shape the experimental planning process to develop the information necessary for good planning, design, execution and management.

In summary, the use of experimental design tools can be complex, intimidating, and can require a significant amount of time and effort to learn and master.

Other inventors have created several types of computerized systems for protocol design, troubleshooting, and/or optimization employing design of experiment methods. [Meeker, W.Q., Hahn, G.H., and Feder, P.I. (1975); Lee, N.S., Phadke, M.S., and Keny, R.S. (1988); Welch, W.J., Yu, T.K., Kang, S.M., and Stack, J. (1990); Wu, C.F.J., Mao, S.S., and Ma F.S. (1990)]. However, none integrate a combination of a wizard-based user interface, a task-specific knowledge base which generate the experiment protocol and templates, an efficient and productive automated support for tedious tasks, (e.g. data analysis, graphical plots and report writing, etc.); a project data file which keeps track of a scientific project from beginning to end, and retains facts about subjects, tasks, measurements; a guided methodology, which dictate the proper sequence for robust engineering, characterization and optimization.

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4. SUMMARY OF THE PRESENT INVENTION

In accordance with the present invention, a method and computerized system (software toolkit) is developed based on the convergent and integration of a set of multi-disciplinary technologies, mainly robust design engineering, statistical sciences and advanced software engineering. This invention uses these converged techniques to provide a practical approach to the art of experimental designs and analysis techniques for robust engineering, characterization and optimization (i.e. finding optimal design solutions that are insensitive to disturbances). The most important feature of the proposed invention is its ability to in an integrated way, provides discussion of complex trade-offs between practical limitations and statistical preferences in an experiment as well as presents the generic technical issues and the core experimental features found in an industrial experiment, to support robust engineering, characterization and optimization activities.

In accordance with the present invention, a method and computerized system is provided which is comprised of a wizard-based graphical-user-interfaces for planning and setting up of robust experiment, analyzing the experiments and interpreting the results; a task-specific knowledge base which generate the robust experiment protocol and templates; an efficient and productive automated computational capabilities and support for tedious tasks, (e.g. data analysis, graphical plots and report writing, etc.); a project data file which stored into task-specific knowledge base, which keeps track of a scientific project from beginning to end, and retains facts about subjects, tasks, measurements; a guided methodology, which dictate the proper sequence and techniques for robust engineering, characterization and optimization.

The present invention provides a rigorous and universal framework to design and analyze all comparative experiments. The core idea is that there is a simple underlying geometric structure, and that a well-designed experiment is one that effectively utilizes this structure under the real constraints of time, money, and experimental environment in which the experiment must be conducted. The three main highlights of the experimental geometry are the number of experimental factors, the possible settings for the factors, and any constraints that may exist on how the settings can be combined.

The present invention emulates the role of “do-it-yourself“ robust design expert, interacting and guiding the user with a wizard-base computerized system to gather, identify, generate and analyze information needed to solve a variety of optimization and robust design of system, products and/or processes problems. It is used to find the controllable parameters and its settings for which the variation (noise) has a minimal effect on the system, product and/or process functional characteristics.

The present invention provides a systematic methodology, which automatically creates robust design experiment based on user-defined input factors and levels, output responses, noise parameters and experiment objectives. The computerized system selects the orthogonal array and assigns the factors to the appropriate rows and columns. It will automatically perform the three basic steps in analysis: main effect, analysis-of-variance, and optimum studies. This help the engineers to design and analyze experiments more rapidly and cost-effectively, because it automatically generates fewer runs, provides automated analysis techniques, and intelligently capture and retain more information than traditional approaches to experimentation.

The present invention provides a method and computerized system based on incorporating quality in to product design and measuring quality by deviation from target. The method and computerized system optimizes design, solve problems and build robust products. The method and computerized system is created based on engineering in ideal function, anticipating the effects of noise factors upfront in the design process, developing a "noise factor management" strategy, and lowest possible cost solutions.

The present invention provides a method and computerized system with complete reference framework for planning, designing and analyzing of experiments. This is important because it save cost by reducing warranty, rejection and cost of development.

The present invention provides a method and computerized system that uses a new quality definition and objective based on reduction of variations around the target with least cost. It uses a new approach to reduce variation without actually removing the cause of variation, resulting a consistent performance by making product/process insensitive to the influence of uncontrollable factors.

The present invention uses "on-target engineering" approach which involves identify the significant control parameters that will minimize the variations caused by the noise factors (noise factors represent conditions, which cause variation in the process and have an adverse effect on performance the process, but are too difficult or expensive to control.); use the identified significant control parameters to shift the mean onto the target (for static nominal-the-best problem) or adjust the slope onto the target (for dynamic problem).

In sum, with the present invention, an on-target engineering method and computerized system (software toolkit) with methodology is provided for developing products and processes that are insensitive to noise based on statistical principles. By defining on-target performance and variability, this invention provides engineers with the mean to make products and processes insensitive to sources of variability.

The role of the present invention is to bridge the gap between the user, who is inexperienced in the hardcore statistical techniques (such as robust engineering, characterization, optimization and statistical techniques), and the soft management procedures among existing design of experiment methods.

Another role of the present invention is to develop the information necessary for good planning, design, execution and management for robust engineering, characterization and optimization of complex phenomenon as well as solution to many problems in many disciplines of engineering science.

Another role of the present invention is to offers a reliable, quantifiable and efficient means to attain six-sigma quality in all stages of product commercialization.

Another role of the present invention is to help engineers and scientists to work consistently by providing a disciplined approach and a consistent framework.

Another role of the present invention is to help to organizes data collection, integrate embedded robust design knowledge and document the project work and knowledge.

Another role of the present invention is to simplifying the design and analysis of complex processes or products, specifically for developing of new robust products and processes, as well as for optimizing the quality and performance of an existing product and processes.

5. OBJECTS AND ADVANTAGES OF THE PRESENT INVENTION

Accordingly, several objects and advantages of the present invention are:

(a) It provides an easy-to-use robust design optimization tool that helps to optimize a wide variety of robust design and optimization problems. It provides wizard-based graphical-user-interfaces that are designed for ease-of-use; and only requires the user to follow the wizard to generate experiment protocol and templates. This allows novice, intermediate and even advanced experimental design practitioners to quickly and easily perform designed experiments to obtain the maximum information from the minimal number of experimental runs.

(b) It provides a task-specific knowledge base which generate the experiment protocol and templates, that can stipulates the way of conducting the minimal number of experiments which could give the full information of all the factors that affect the performance parameter.

(c) It provides an efficient and productive automated computational capabilities and support for tedious tasks, (e.g. data analysis, graphical plots and report writing, etc.). It provides a menu-based wizard driven environment for planning and setting up of experiment, analyzing the experiments and interpreting the results. It includes a complete set of robust designs, a wide variety of statistical, and graphical tools for analyzing and visualizing the experimental data.

(d) It allows the user to save tested experiment protocol and templates into a project data file stored into task-specific knowledge base, which can later be accessed by others. The project data file which keeps track of a scientific project from beginning to end, and retains facts about subjects, tasks, measurements. It allows the user to easily identify standard and previously optimized experiment protocol and templates by the use of a project knowledge base. Therefore, an inexperienced user can productively make use of the experience of others, which is stored in the project knowledge base.

(e) It provides a guided methodology, which dictate the proper sequence for robust engineering, characterization and optimization. It is designed to get maximum benefit from powerful modeling techniques without learning a complicated software package or statistical language. It does not require proficiency in artificial intelligence, advanced mathematics or statistics. Thus, virtually everyone can learn how to use this invention and start solving real world problems within a few hours.

(f) It helps engineers and scientists to work consistently through a disciplined approach with a consistent framework, organizes data collection with embedded robust design knowledge and document project work and knowledge.

By implementing this invention, engineers can increase process yields, increase product/process quality and performance, reduce development costs, achieve faster time-to-market, and increase customer satisfaction, etc. It is cost-effective because it enables the creation of prototype models quickly and inexpensively. It assists in developing accurate models in less time, even if with limited experience with statistical techniques.

Other objects and advantages of this invention in an industrial environment are that it:

(a) It provides simultaneous optimization of several factors can be studied at the same time making it possible to gain insight into their simultaneous effect on the response variable and gain an understanding of the relationship between the input factors and the response, and interaction effects among the various parameters with only a small amount of experimental data.

(b) It provides rapid data collection and decision making because the number of observations needed to make a decision can be minimized, thus reducing costs associated with the investigation, and interactions between variables can be detected and determined.

(c) It provides and creates a mathematical model relating the response to the input factors, which is often referred to as process/product characterization. This can be used to determine and qualify the settings of the input factors that optimize the response. Experimental errors can be estimated and conclusions can be drawn using knowledge gained and this is useful information for determining sample sizes for follow-up studies.

(d) It provides and satisfies the need for a quick and efficient method of characterizing and optimizing new and evolving technology for industries such as manufacturing, processes, biotech and pharmaceuticals.

Further objects and advantages of this invention will become apparent from a consideration of the drawings and the ensuing description.

6. SCOPE OF THE PRESENT INVENTION

The present invention provides the novice, intermediate and even advanced experimental design practitioners with a unique method and computerized system which has the advantages of a wizard-based graphical-user-interfaces for planning and setting up of robust experiment, analyzing the experiments and interpreting the results; a task-specific knowledge base which generate the robust experiment protocol and templates; an efficient and productive automated computational capabilities and support for tedious tasks, (e.g. data analysis, graphical plots and report writing, etc.); a project data file which stored into task-specific knowledge base, which keeps track of a scientific project from beginning to end, and retains facts about subjects, tasks, measurements; a guided methodology, which dictate the proper sequence and techniques for robust engineering, characterization and optimization.

The scope of the present invention is very wide because the present invention provides the essential method and computerized toolkit for engineers and scientists, no matter what the industry, wherever the design, development and manufacture of a product requires the combination of sophisticated science, engineering and good manufacturing techniques, the present invention can be used.

In general, the potential areas of application of this invention can be broadly classified into two types of optimization problems, i.e. the static and dynamic optimization problem, which can be solved by using the optimization methods described in the present invention.

The first type is the static optimization problem, and it is used in scenarios where the performance of the system is known in advance and operates at a fixed target value, and is optimized by the relationship between input control parameters and output responses to a specified target value. The present invention static optimization are applicable to cases where the quality characteristic's target has a fixed level and the robustness objective is to minimize the mean square deviation from the target. Input parameters, noise factors, and output values are used in static optimization. The static characteristics are calculated from at least three samples of data in each experimental run. Noise factors are used in the experiment to force variability to occur, rather than depending on the random variation and sources of variability.

The second type is the dynamic optimization problem, and is used in scenarios where the performance of the system is not known in advance and operates over a range of values and is optimized by the relationship between dynamic input signal factors and output responses. The dynamic optimization is applicable to cases where the quality characteristic operates over a range of values, and is used to optimize system tunability rather than to optimize the response to a fixed value. The dynamic characteristic is used when an adjustment factor is known based on

the physics or engineering analysis of the system that is referred to as a signal factor represented by simple linear equation in which the input parameter may be used to adjust the mean response.

The potential areas of application of this invention include system optimization, robust product design, analytical simulation, technology development testing, process development, problem solving in many areas of manufacturing and service industries.

While the above description contains many specifics these should not be construed as limitations on the scope of the invention, but rather as an exemplification of one preferred embodiment thereof.

Many other variations of the present invention are possible, such as to provide problem-solving solution in general but not limited to the following:

(a) What system, product and/or processes are we trying to make and can we do it?

(b) What are the critical input parameters and noise variables that affect the system, product and/or processes? Which control parameters are more significant than the others?

(c) How to combine different parameters settings to get the best results and substitute a less expensive part to get the same performance?

(d) What is the information necessary for adjustment to target value? What is the countermeasure for the attenuation of noise effects caused by unknown factors?

(e) How to search for robustness condition in a system, product and/or processes? What need to be done to reduce performance variation around the target?

(f) How to set up the process such that it is insensitive to noise factors? How the uncontrollable parameters affect the performance?

(g) How to improve the system, product and/or processes with good reproducibility?

(h) How to perform concurrent research on future and current products? How to retain the knowledge gained in this work for the future and across the company?

Accordingly, the scope of the present invention should be determined not by the embodiments illustrated, but by the appended claims and their legal equivalents.

7. BRIEF DESCRIPTION OF THE DRAWINGS

The above and other advantages of the invention will become more apparent from the following description taken in conjunction with the accompanying drawings wherein like references refer to like parts and wherein:

FIGURE 1 : The generalized flowchart of the present invention.

FIGURE 2A : Schematic view of a typical static optimization problem being studied.

FIGURE 2B : Schematic view of a typical dynamic optimization problem being studied.

FIGURE 3 : The eight steps methodology of the present invention.

FIGURE 4 : The block diagram of the ideal energy function modeling.

FIGURE 5 : The function modeling template for systems/processes studies.

FIGURE 6 : Template for formalization of Problem Diagram (P-Diagram).

FIGURE 7 : Checklist and template for robust design project and investigation objectives.

FIGURE 8 : Template for assignment of input parameters.

FIGURE 9 : Template for assignment of noise parameters.

FIGURE 10 : Template for output parameters.

FIGURE 11 : The embedded knowledge-based of the present invention.

FIGURE 12 : Flowchart explaining the flow of entire computerized system according to the eight steps methodology embodiment of the present invention.

FIGURE 13A : Computerized system for creating robust design – assignment of inner array.

FIGURE 13B : Computerized system for creating robust design – assignment of outer array.

FIGURE 13C : Computerized system for creating robust design – assignment of output responses.

FIGURE 13D : Computerized system for creating robust design – display of inner and outer arrays.

FIGURE 14 : Computerized system for displaying robust experiment design layout worksheet (inner and outer array).

FIGURE 15 : Computerized system for data entry of the performance measurement data.

FIGURE 16 : Exemplifies an example of a computerized screen for computing the experiment results using analysis of mean.

FIGURE 17A : Computerized screen of a Problem-Diagram for performing experiment analysis.

FIGURE 17B : Computerized screen of a data plot for performing experiment analysis.

FIGURE 17C : Computerized screen of a factorial effect table for performing experiment analysis.

FIGURE 17D : Computerized screen of a graphical technique for displaying 2-Dimemsional mean effects and interaction plots.

FIGURE 17E : Computerized screen of a graphical technique for displaying 2-Dimemsional Signal-to-Noise ratio effects and interaction plots.

FIGURE 17F : Computerized screen of a graphical technique for displaying a significant mean effect and interaction 2-Dimemsional plots.

FIGURE 17G : Computerized screen of a graphical technique for displaying a significant Signal-to-Noise ratio effect and interaction 2-Dimemsional plots.

FIGURE 17H : Computerized screen of a graphical technique for displaying a 3-Dimemsional surfaces and contour plots to help interpret results.

FIGURE 17I : Computerized screen of an Analysis of Variance (ANOVA) for performing experiment analysis.

FIGURE 17J : Computerized screen for sensitivity analysis as well as optimization of decisions with suggested optimal settings.

FIGURE 18 : Computerized screen for printing experimental results.

FIGURE 19 : Computerized screen of a report writer for quick experimentation documentation and for data storage and archival.

FIGURE 20 : Computerized screen for quick online help function and documentation.

8. DETAILED DESCRIPTION OF THE INVENTION

Embodiments of the present invention will be described in further detail with reference to the accompanying drawings.

8.1. The eight-step methodology of the present invention.

FIGURE 1 illustrates the overall generalized flowchart of the present invention, i.e. the robust engineering and optimization method. The concept of the present invention is based on the "Formulate-Find-Satisfy-Minimize" continuous improvement cycle. The idea behind this invention is to computerize a method and system to "search for a condition with good reproducibility by obtaining the information necessary for adjustment and stabilization to target value". The main idea is further explored to solve optimization problem by formulating its environment to find its optimal relationship equation so as to satisfy the experiment constraints and objectives through minimizing the variance and shifting the mean to target. It is based on this concept that a method and computerized system for robust engineering and optimization of complex phenomenon is invented.

FIGURE 2A illustrates a typical type of static optimization problems solved by the present invention. These problems can be defined as a system with inputs parameters denoted by the vector $X=[x_1,...,x_m]^T$ and output responses denoted by the vector $Y=[y_1,...,y_n]^T$. The factors that affect the relationship between input X and output Y are called noise variables $N=[e_1,...,e_n]^T$. The relationship between X and Y may be nonlinear within the area of interest and can be characterized empirically using the present invention.

FIGURE 2B illustrates another typical type of dynamic optimization problems solved by this invention. The typical types of problem include research for improvement, stability and reproducibility in engineering systems, products, processes or technology development. These problems can be defined as a system (composed of multiple design parameters) with input signal factors denoted by the vector $M=[m_1,...,m_m]^T$ and output responses denoted by the vector $Y=[y_1,...,y_n]^T$. The design parameters chosen without restriction are called design parameters $X=[x_1,...,x_n]^T$. The factors that affect the relationship between input M and output Y are called noise variables $N=[e_1,...,e_n]^T$.

FIGURE 3 illustrates the detailed eight-steps methodology of the present invention for robust engineering and optimization method, which can be used to solve both the static and dynamic optimization problems.

8.1.1. Step 1 - Describe and develop a system model that identifies system and sub-systems that contain detail elements of the product or process.

The first step in the present invention is to "Describe System", which means to describe and develop a system model that identifies system and sub-systems that contain detail elements of the product or process. This shall be carried out by a team includes representatives from all appropriate disciplines required to conduct the experiment. An important objective of this step is to provide all of the necessary information to allow the results of the system to be replicated by an independent party.

The present invention uses a technique called "function modeling" as its primary form of representation to describe the system. In function modeling a system, the present invention uses four aspects of a system: its behavior, its task, its constraints, and its architecture, and these four aspects of a function map directly to those of a system: a function uses its mechanisms (architecture) to convert its inputs (task) into its output (behavior), in the presence of constraints.

FIGURE 4 illustrates the block diagram of the ideal energy function modeling. The main objective of the ideal energy function modeling is to ensure that these systems and processes perform useful work by converting as much of the input energy as possible to a targeted output performance. The systems and processes will be tuned to be optimally efficient with respect to the required energy transformed and made insensitive to the external source of disturbances. For complex systems/process, review subsystems/ sub-processes and select activities responsible for that ideal energy function. The ideal function modeling is used to explore how the system and/or process would perform if it were free of any external disturbances, noise or constraints limiting its performance. This ensures that the variations occur in the real system are exposed and with this good understanding of the variations from the ideal state, the system could be made more robust.

FIGURE 5 illustrates a function modeling template for systems/processes studies, and the steps involves:

(a) Start with a process flow diagram, which shows the major steps of the process. And then decompose the system or process into sub-systems, each with its own parameters, in

order to study the components and their interactions (i.e. develop hierarchies of models that represent the system at various levels of abstraction).

(b) Provide descriptions of any equipment, materials, reference materials, process parameters, special conditions, and personnel skills and knowledge necessary to perform the process. Use graphic diagrams with label connections to work with the function models to provide an intuitive user understanding and simplify the task of decomposing the models.

(c) Describe the detailed activities necessary to perform the process in written work instructions, which could guide a skilled person, unfamiliar with the process, through all the steps to complete the process.

(d) Define the intended behavior of the system, desired target measurements and historical record of the complex behavior of a system. For complex systems/process, review subsystems/sub-processes and select activities responsible for the function.

8.1.2. Step 2 - Formulate problem by defining elements such as inputs, outputs, noise parameters and objectives of the study, etc.

The second step in the present invention is to "Formulate Problem", which means to formulate problem by defining elements such as inputs, outputs, noise parameters and objectives of the study, etc. This second step is to formulate the optimization problem by defining elements such as input (function and process signal), outputs, noise, control parameters, quality characteristics and objectives of the study, etc. This is to be completed by a group of engineers in a brainstorming session. This will involves creating a description of the process and establishing initial values for the input and output parameters of the process. The description of the system helps to establish a baseline of equipment, materials and methods used for the process. The concept of the system is based upon sound scientific and engineering principles, experimental evidence. Before conducting the experiment, the knowledge of the system (product/process) under investigation is of prime importance for identifying the factors likely to influence the outcome.

Although function modeling is a natural representation of systems in the present invention, it is useless unless it can support the different phases of an experiment. The function model only provides a concise structure around which to build knowledge of generic scientific procedures as well as specific topics.

FIGURE 6 illustrates the template for formalization of a Problem-Diagram based on the information derived from the function modeling from step one. The elements of the Problem-Diagram are defined as follows:

(a) the objective of the study, as well as the output response (quality characteristics which are measured during an experiment run) and the evaluation criteria and measurement methods.

(b) the control parameters (Parameters which are intentionally varied in order to determine their impact on the output responses) and the number of settings for each control parameter. A control parameter is a parameter over whose nominal value the designer has direct control. The nominal values of control parameters are therefore varied over a range of feasible values during the optimization or robustification process.

(c) the process control signal (Factors that modifies or adjust the process technology).

(d) the product function signal (Factors that tune the product function performance onto any desired target).

(e) the noise variables or compounded noise variables (Parameters which can influence the output parameters but are not intentionally varied). A noise parameter is a design parameter over whose nominal value the designer has no direct control. The nominal values of noise parameters are set by the system requirements, user input, or the environment. There are four types of noise variables; firstly, the external noise is defined as the causes of variability are completely external to the system when the system/process/product is used as intended; e.g. environment variation, Setup conditions, misuse and abuse, etc.; secondly, the internal noise is defined as the causes of variability are completely internal to the system when the system/ process/ product is in production; e.g. components variation, process parameter variation, process drift, material properties variation, etc.; thirdly, the deterioration noise is defined as the causes of variability are completely internal to the system when the system/process/ product is in used over time; e.g. normal wear and tear over time, buildup of impurities, Loss of materials over time, etc.; fourthly, the surrogate noise is defined as the causes of variability due to measurable variations, similar to experimental error, but not measurement error; e.g. location and time of sampling, replication of measurement over time, etc.

(f) the interaction effects present in control factors (The dependence of one experimental factor on the level of another experimental factor for its contribution to the measured response.) can be broadly classified into four main types; the first type is material

properties parameters such as specific density, modulus of elasticity, shear and bulk modulus, yield strength, ultimate tensile strength, coefficient of thermal expansion, electricity and thermal conductivity, etc.; the second type is derived properties parameters such as induced load, spring stiffness, beam deflection, electrical resistance, etc.; the third type is dimensional parameters such as roundness, width, length, diameter, angle, thickness, parallelism, etc.; the fourth type is environmental parameters such as applied load, ambient temperature, ambient pressure and humidity, applied voltage and ampere, etc.

(g) the held-constant factor (held-constant factors are controllable factors whose effects are not of interest in the experiment).

(h) the nuisance factors (Nuisance Factors are not controlled, and are not of primary interest in the experiment).

(i) the gage repeatability and reproducibility analysis to ensure precision of measurement

FIGURE 7 illustrates the checklist and template for robust design project and investigation objectives used to help in the formalization of a Problem-Diagram.

FIGURE 8 illustrates the assignment of input parameters template to be used to help in the formalization of a Problem-Diagram. The input parameters is the factors the engineer can control and specify to define the optimum combination of set points for satisfying the voice of the customer. The engineer must define the settings for the range, the scale factor, and the level of each of the input parameter

FIGURE 9 illustrates the assignment of noise parameters template to be used to help in the formalization of a Problem-Diagram. The noise parameters is any source of variability that is external to the product such as environmental effects, unit-to-unit variability or effects of deterioration which the engineer cannot control or difficult to control. The engineer must define the settings for the range, the scale factor, and the level of each of the noise parameter

FIGURE 10 illustrates the assignment of output responses template to be used to help in the formalization of a Problem-Diagram. The output response is the performance measure obtained when an experiment is run at each level of the factors under study, and it can be either continuous (quantitative) variables or discrete (qualitative) variables. The engineer must define the settings for the computational method, the noise per signal and replicate per noise, of each of the output responses.

8.1.3. Step 3 - Select a model and a design that are suitable for the objectives and generate the design for experiment and its worksheet.

The third step in the present invention is to "Generate Design", which means to select a model and a design that are suitable for the objectives and generate the design for experiment and its worksheet. Designing an experiment in the present invention involves the selection of the most efficient experimental designs and the construction of the resulting experimental layout. This can be done using the wizard-based graphical user interface for planning and setting up the experiment. The knowledge based in the present invention provides a wide range of robust experimental designs templates and protocols.

FIGURE 11 illustrates the embedded knowledge-based system of the present invention. It consists of a complete robust design rules and expert system for orthogonal arrays ranging from OA4 to OA81.

The computerized system will help the engineer to optimize robust experimentation, answer all the objective questions, ensure design be balanced, statistically efficient and economically feasible. The computerized system with it embedded knowledge base will help the engineer to decide which robust design to set up, how data are to be collected and then automatically compute, analyze and display the required results.

The computerized system will enable the engineer to estimate the experimental errors; identify significant factors; estimate model parameters, as well as estimate the effect of each factor independently; test model for adequacy, and adequately cover the experimental region of interest. This third step involves using the computerized system to generate a crossed orthogonal array with inner (control) and outer (signal and/or noise) array suitable for achieving the objectives, and print out the design for experiment and its experiment worksheet. Once the elements such as input signals, output responses, noise factors, control parameters are defined, a crossed orthogonal array with inner (control) and outer (noise) array suitable for the objectives need to be selected and the experiments worksheet generated and printed out for the engineer to conduct the experiment as per the level combinations. The size of the experimental space is determined by the number of control factors and the span of their levels.

8.1.4. Step 4 - Conduct or Simulate the experiment run according to the worksheet and enter experiment results.

The fourth step in the present invention is to "Conduct Experiment", which means to conduct or simulate the experiment run according to the worksheet and enter experiment results. This fourth step is to conduct and/or simulate the experiment run according to the worksheet and enter the experiment results into the computerized system. In this step, conducting the experiment involves execution of the experiment as developed in the planning and design stages The following preparation and coordination are necessary to insure that the experiment is conducted according to the plan as designed by the computerized system:

(a) A well documented plan and clear instructions and schedule to guide the progress of the experiment to all those who assist with the experiment must be provided.

(b) Develop a method of collecting experimental data that helps insure the accuracy of the data and its traceability to experimental conditions.

(c) It is necessary that all the experiments be conducted according to the experiments worksheet as per the level combinations. The interaction columns and dummy variable columns shall not be considered for conducting the experiment, but are needed while analyzing the data to understand the interaction effect. The output response under study is noted down for each experiment.

These preliminary efforts are essential for executing the experiment smoothly, with the least effort and in the shortest amount of time. Therefore, failure to consider these aspects of conducting an experiment can lead to erroneous measurements, biased results, or even to no data at all.

8.1.5. Step 5 - Compute the experimental data, calculate statistical results and generate graphical output.

The fifth step in the present invention is to "Compute Results", which means to compute the collected experimental data from step four, then calculate the statistical results and generate the graphical reports. The computerized system of the present invention will automatically compute the calculations and convert raw data into meaningful information and knowledge for the engineer to do analysis. In the present invention, since each robust engineering experiment run is a combination of different factor levels, the sequence of computation is:

(a) Compute the Analysis of Mean (ANOM) statistics using the output values for the corresponding level settings (either static or dynamic optimization method).

(b) Generate the factorial effect table using the ANOM from prior step (a) (either static or dynamic optimization method).

(c) Plot the factorial effect chart using the factorial effect table from prior step (b) (either static or dynamic optimization method).

(d) Plot the significant effect 2D chart using the factorial effect table from prior step (b) (either static or dynamic optimization method).

(e) Plot the significant effect 3D chart using the factorial effect table from prior step (b) (either static or dynamic optimization method).

(f) Compute Analysis of variance (ANOVA) statistics using the output values for the corresponding level settings (either static or dynamic optimization method).

8.1.6. Step 6 - Analyze and interpret statistical and graphical outputs to determine the relative effect and the relative importance of various factors.

The sixth step in the present invention is to "Analyze Relationship", which means to analyze and interpret statistical and graphical outputs to determine the relative effect and the relative importance of various factors. This sixth step is to analyze and interpret the statistical and graphical outputs generated from step five, so as to determine the relative effect and the relative importance of various parameters. This step involves the interpretation of the experimental results using numerical or graphical methods. In the present invention, the analysis includes determination of the most significant factors, selecting the optimal levels for those factors, understanding the nature and degree of variation in the process, and computing a prediction of the expected results at the recommended factor settings.

The computerized system will provide the tabulation of experimental results so that the summarized data can be easily analyzed to determine the relative effect of the various factors. By analyzing the data from the analysis of mean (ANOM), the sensitivity and analysis of variance (ANOVA), the engineer can analyze the relationship and decide which independent factor dominates over other and the percentage contribution of that particular independent variable. During analysis the actual experimental results with those hypothesized before the experiment should be compared. Sometimes new theories will be required to explain the

experimental results, or that additional experimentation will be needed to address unanswered questions.

In sum, the activities involves in this step are described as follows:

(a) Analyze the data from matrix experiments by using the analysis of mean (ANOM) method to determine the effects of the various design parameters on the overall product response to compute the expected performance and determine the optimum condition.

(b) Estimate error variance and determine the relative importance of various factors using the analysis of variance (ANOVA) method. Pool factors and interaction together that are not significant and to determine if interaction is present and/or significant.

(c) Study factor influences and determine the improvement using 2D and 3D graphical plots as well as sensitivity analysis to determine what factor levels maximize the signal-to-noise ratio and by how much and which factors affect the mean and/or have little effect on the signal-to-noise ratio, etc.

8.1.7. Step 7 - Optimize and adjust system sensitivity and performance to meet optimum conditions/objectives.

The seventh step in the present invention is to "Optimize System", which means to optimize and adjust system sensitivity and performance to meet optimum conditions/objectives. This seventh step is to optimize and adjust the system sensitivity and performance to meet optimum conditions/objectives based on the knowledge gained from step six. In the present invention, system optimization involves the determination of the parameters, which will best meet the overall objectives of the system. First, the optimum target values are established for each critical parameter. Then, the source of variations around these target values is determined to help maintain robust performance. The present invention is used to establish the optimum parameters to understand the nature of variations in the system.

The present invention's approach to system optimization requires a number of experimental cycles to optimize a system. The cycles will progress through three stages, exploring the nature of system parameters at an increasing level of detail at each stage. The three stages of system optimization in the present invention are classified as, first screening stage where experimentation involves taking a rough look at a large number of variables in order to determine those variables which have a significant effect on system results; second focused stage where experimentation involves looking at fewer variables in more detail than in a

screening experiment; third system modeling/simulation stage where experimentation involves developing precise mathematical models of the process which can be used to accurately predict process results under various conditions.

For the smaller-the-better and larger-the-better and the operating window static problems, there is no adjustment factor, and the two-step optimization approach is not applied. The mean and the variance are minimized simultaneously. For the nominal-the-best and dynamic problems, the two-step optimization approach is applied. First, the sensitivity to noise is minimized. Second, the performance is shift to the target.

The two-step optimization approach requires the classification of the control parameters into four groups as shown as follows:

(a) The factors that have a strong effect on the signal-to-noise ratio should have their level chosen to optimize the signal-to-noise ratio.

(b) The factors that have a weak effect on the signal-to-noise ratio and a strong effect on the mean value of the quality characteristic can be used for tuning. If there is no such factor, it is possible to pick a factor that has a strong effect on the mean and the signal-to-noise ratio.

(c) The factors that have a weak influence on both the signal-to-noise ratio and the quality characteristic as well as excess tuning factors should be set to minimize cost or used to optimize other performance considerations.

Based on the mean and signal-to-noise plots of the control factors, the optimal control factor level settings are determined. By performing an Analysis of Means (ANOM), the effect of each control factor setting can be determined, and thus a prediction can be made about the system response under the combination of the optimal control factor settings.

8.1.8. Step 8 - Verify the repeatability of the optimization results with a confirmation experiment.

The eighth step in the present invention is to “Perform Verification”, which means to verify the repeatability of the optimization results with a confirmation experiment. This eighth step is used in the present invention to verify the repeatability of the optimization results, and to ensure that the measured responses were not a result of experimental error. (i.e. verify the optimum conditions suggested by the matrix experiments do indeed give the projected improvement). The

optimum setting is a unique set of parameter combinations within the experimental space (not one of the experimental trials used). The verification procedure is run twice, once for the optimum control factor settings, and to repeat/replicate one of the main experiment runs. There are four possible outcomes of the verification test which can be categorize as follows:

(a) The first possible outcome is classified as "High Repeatability", which means that the optimum conditions yield a result that match the predicted result. The replicated experiment result also match the initial experiment result.

(b) The second possible outcome is classified as "Low Repeatability", which means that the optimum conditions yields a result that do not match the predicted result. Similarly, the replicated experiment yields results that also do not match the initial experiment result. But both are off by the same amount. This problem is usually due to a uniform shift in the data, with respect to a change in the mean. Although the optimum setting has been correctly identified, some significant factor has changed and is affecting the results.

(c) The third possible outcome is classified as "Poor Repeatability Due to Experimental Error", which means that the optimum conditions yield a result that does not match the predicted result. Similarly, the replicated experiment yields results that also do not match the initial experiment result. And both vary by different amounts. This problem is usually due to measurement problems or nuisances. E.g. instrument error, poor experimental technique, mathematical mistakes, broken equipment, misread data, improperly set control factors, or poor communication.

(d) The fourth possible outcome is classified as "Poor Repeatability Due to an Interaction", which means that the optimum conditions yield a result that does not match the predicted result. However, the replicated experiment yields a result that match the initial experiment result. This problem is usually due to a strong interaction that has not been examined in the main experiment, and interactions are considered to be too significant to be simply nuisance factors.

If the verification of the observed and the projected experiments match, the suggested optimum conditions will be adopted. Otherwise, the additive model underlying the matrix experiment has failed, and the corrective actions include:

(a) Finding better quality characteristics or signal-to-noise ratios.

(b) More experimentation to isolate factors.

(c) Further investigation of noise factors.

(d) Finding different control factors and levels.

(e) Selecting different signal-to-noise ratio using physics and engineering concepts.

(f) Considering interactions among the control factors.

(g) Considering additivity grouping of the control factors.

Engineer can use the knowledge gained from the present invention experiment to improve system robustness. The present invention experimental results may be used to develop more robust system limits, to modify how certain steps of the system are performed, or to choose the best materials and equipment. Any changes in the system itself will require changes to the documentation that supports the system. A new and improved robust system baseline may be established, which requires that characterization be completed for the new baseline. With a better understanding of system variations, a positive control plan can be established to control the variation of all inputs to the system. After optimization, the engineer is in a better position to apply an effective control program to the system.

8.2. The computerized system of the present invention.

In the preferred embodiment the computerized system is primarily programmed in Visual C++, running on any Windows Operation System. However, the present invention can be implemented in other programming languages and systems. The present invention encompasses, together with the eight-step methodology described in the present invention, a wizard-based graphical user interface, the utilization of a robust experimental design knowledge base, automated computational algorithms for robust engineering, and a project data storage system.

The computerized system has an easy to use wizard-driven interface, and the worksheet has unlimited columns and rows (with unlimited repetitions), incorporated with an icon based button bar provides quick access to frequent menu functions. The computerized system is invented to permits imports data from common spreadsheet format (Lotus, Excel, etc.) and ASCII delimited files. The computerized system has a worksheet editor permits easy data entry and is capable of handling moving signal factor levels through experimental trials. The computerized system is invented with robust engineering function that provides for automatic generation of the most efficient experimental design using an embedded knowledge-based system.

The computerized system is invented to provide for user-defined arrays for developing specialized, efficient, experimental designs with on-line experiment planning and design help.

The computerized system also provides for various cases of analysis with fully automatic standard and signal-to-noise ratio to original units transformation for static and dynamic characteristic analysis which include:

(a) Dynamic Characteristics (Zero point proportional equation, Reference point proportional equation, Linear equation Double Signals); and

(b) Static Characteristics (Small-the-better, Larger-the-better, Nominal-the-best, Non-dynamic operating window).

The computerized system is invented with data analysis function to provide for automatic calculation of performance statistics, such as signal-to-noise ratio, raw data mean (non-dynamic), and linear coefficient and sensitivity (dynamic), response table for level averages, selective and automatic pooling and variance component estimation, summary and components analysis of variance, high/low table shows level averages in ascending orders and the difference between maximums and minimums as well as prediction for optimal and other conditions.

The computerized system is invented with graphical techniques function to provide for color graphic display and printing of effects graph, interaction graph, coefficients table, residuals graph, prediction graph, contour plots, 3-D graphics, etc. It also provides dual response graph displays for signal-to-noise ratios and linear coefficients help to analyze the dynamic characteristics. The computerized system also provides the response tables and high/low tables to make analysis for optimization easier. It can also display up to four graphs on one screen for easy comparison, or display one graph on one screen, and the graphs can be previewed, printed to printer or file in portrait or landscape.

FIGURE 12 is a flowchart explaining the flow of entire computerized system according to the eight steps methodology embodiment of the present invention.

FIGURE 13A exemplifies a computerized screen for selecting input (Control) parameters array and assigning of variables to inner (Control) array; the selection is based on the total number of degrees of freedom (determine the minimum number of experiments to be conducted) and the number of independent variables and number of factor levels for each independent variable. The assignment order in which the independent variables are assigned to the inner array column is very essential. In case of mixed level variables and interaction between variables, the variables are to be assigned at right columns as stipulated by the orthogonal array.

FIGURE 13B exemplifies a computerized screen for selecting outer (signal and/or noise) array and assigning of variables to outer (noise) array; the selection is based on the number of either some compounded signal and/or noise factors. The compounding of noise factors is used when

the noise factor levels are expensive to run and the analysis of the control parameters and noise factors interactions is required. The noise factors make randomization and blocking unnecessary, but they are good practices when noises are not thoroughly accounted for in an experiment.

FIGURE 13C exemplifies a computerized screen for assigning the Output Responses; the assignment of the output responses (which sometimes refer to as the quality characteristics) is based on the characteristics of the responses (either static or dynamics), together with the computational method, noise per signal as well as the replicate per noise.

FIGURE 13D exemplifies an example of a computerized screen for viewing and displaying robust engineering (inner and outer) arrays; the type of arrays and type of design as well as the array layout are displayed.

FIGURE 14 exemplifies an example of a computerized screen for displaying robust experimental design layout information and worksheet. The computerized system uses a combination of an inner (control) array and an outer (signal and noise) array, which allows each experiment combination of the inner array to be run at two or more combinations of the signals factors. The inner (control) array does not change regardless whether the experiment is a static or dynamic characteristics type. The outer (signal and noise) array is changed to accommodate both the signal factors and a set of compound noise factors.

FIGURE 15 exemplifies an example of a computerized screen for entering the performance measurement data; this is the data entry screen for the robust engineering project. The data are collected either by conducting or simulating the experiment or by obtaining the data through some historical data and using neural network to predict the experimental data and results.

FIGURE 16 exemplifies an example of a computerized screen for computing the experiment results; this involves computing the experimental data, calculate the statistical results and generate the graphical reports. The computerized system will automatically compute the analysis of mean (ANOM) statistics, generate the factorial effect table, plot the factorial effect chart as well as the significant effect 2D/3D chart and compute analysis of variance (ANOVA) statistics, etc.

FIGURE 17A exemplifies an example of a computerized screen of a Problem-Diagram for performing experiment analysis; this provide the formalization of the design summary of the scientific project which is derived from the function modeling of problem formulation.

FIGURE 17B exemplifies an example of a computerized screen of a data plot for performing experiment analysis; this provides an insight into the behavior of the data.

FIGURE 17C exemplifies an example of a computerized screen of a factorial effect table for performing experiment analysis; this is used to analyze the relationship and decide which independent factor dominates over other and the percentage contribution of that particular independent variables.

FIGURE 17D exemplifies an example of a computerized screen of a graphical technique for displaying 2-Dimemsional mean effects and interaction plots to help interpret results; this graphical technique provides an approach to study factor influences and decide which independent factor dominates over other and the percentage contribution of that particular independent variables and determine the improvement.

FIGURE 17E exemplifies an example of a computerized screen of a graphical technique for displaying 2-Dimemsional Signal-to-Noise ratio effects and interaction plots to help interpret results; this is used to analyze the relationship and decide which independent factor dominates over other and the significant of that particular independent variables.

FIGURE 17F exemplifies an example of a computerized screen of a graphical technique for displaying a significant mean effect and interaction 2-Dimemsional plots to help interpret results; this is used to analyze the relationship and decide which independent factor dominates over other and the significant of that particular independent variables.

FIGURE 17G exemplifies an example of a computerized screen of a graphical technique for displaying a significant Signal-to-Noise ratio effect and interaction 2-Dimemsional plots to help interpret results; this is used to analyze the relationship and decide which independent factor dominates over other and the significant of that particular independent variables.

FIGURE 17H exemplifies an example of a computerized screen of a graphical technique for displaying a 3-Dimemsional surface and contour plots to help interpret results; this is used to analyze the interactive relationship and decide which independent factor dominates over other and the significant of that particular independent variables.

FIGURE 17I exemplifies an example of a computerized screen of an Analysis of Variance (ANOVA) for performing experiment analysis; Analysis of variance (ANOVA) is a statistical technique that allows the engineer to determines which control parameter is the most significant and their relative contribution to the system. It is a parametric statistical procedure which is used to determine if reliable differences exist among two or more sample means; e.g., an experiment with three conditions.

FIGURE 17J exemplifies an example of a computerized screen for sensitivity analysis as well as optimization of decisions with suggested optimal settings; this sensitivity analysis is used to

determine what factor levels maximize the S/N ratio and by how much and which factors affect the mean and/or have little effect on the S/N ratio. This is then used to determine the effects of the various design parameters on the overall product response to compute the expected performance and determine the optimum condition.

FIGURE 18 exemplifies an example of a computerized screen for printing experimental results; the computerized system has a printer output function whereby experimental results can be sent directly to the printer, saved on a file or viewed directly on the screen. It is able to generate and prints data collection sheets for all conditions of each experimental run (control, signal and noise factors).

FIGURE 19 exemplifies an example of a computerized screen of a report writer for quick experimentation documentation and for data storage and archival; the report writer provide user with the toolkit to document and track the scientific project work and knowledge from beginning to the end so that user's know-how are stored and retained into task-specific knowledge base and reused by other users.

FIGURE 20 exemplifies an example of a computerized screen for quick online help function and documentation; the online help provides user with the complete "frequently asked questions" as well as the key concepts and foundation which are documented in an easy to use and understand format.

9. CLAIM(S)

I claim:

1. A method and computerized system comprised of:

(a) a guided methodology, which dictate the proper sequence and techniques for robust engineering, characterization and optimization;

(b) a task-specific knowledge base which generate the robust experiment protocol and templates;

(c) a wizard-based graphical-user-interfaces for planning and setting up of robust experiment, analyzing the experiments and interpreting the results;

(d) an efficient and productive automated computational capabilities and support for tedious tasks, (e.g. data analysis, graphical plots and report writing, etc.);

(e) a project data file which stored into task-specific knowledge base, which keeps track of a scientific project from beginning to end, and retains facts about subjects, tasks, measurements;

2. A method and computerized system of claim 1 wherein an integrated robust engineering and optimization environment based on an on-target engineering method and computerized system (software toolkit) with a eight-step methodology for developing products and processes that are insensitive to noises, based on the converging of statistical principles, knowledge-based engineering, software engineering, and robust design; and more particularly based on claim 1, to a computerized method and system which allows a user through a wizard-based graphical user interface to create robust experimental model and to evaluate its parameters, and to automatically optimize the model with the help of some task-specific knowledge based optimization algorithms. Most importantly, the present invention helps engineers and scientists to work consistently through a disciplined approach with a consistent framework, organizes data collection with embedded robust design knowledge and document project work and retain critical knowledge for future usage.

3. A method and computerized system of claim 2 wherein the planning and setting up a robust design of experiment for robust engineering and optimization of complex phenomenon, the method comprising the steps of:

(a) detailing the elements of the robust experimental design through a function modeling technique :

i) draw the process flow diagram which shows the major steps of the process and develop hierarchies of models that represent the system at various levels of abstraction.

ii) describe the equipment, materials, reference materials, process parameters, special conditions, and personnel skills and knowledge necessary to perform the process.

iii) detail the activities necessary to perform the process in written work instructions, which could guide a skilled person, unfamiliar with the process, through all the steps to complete the process.

iv) define the intended behavior of the system, desired target measurements and historical record of the complex behavior of a system.

(b) formalizing of a Problem-Diagram based on the information derived from:

i) the project and investigation objective of the robust experimental design.

ii) the output response (quality characteristics which are measured during an experiment run) and the evaluation criteria and measurement methods.

iii) the control parameters (parameters which are intentionally varied in order to determine their impact on the output responses) and the number of settings for each control parameter.

iv) the process control signal (factors that modifies or adjust the process technology).

v) the product function signal (factors that tune the product function performance onto any desired target).

vi) the noise variables or compounded noise variables (parameters which can influence the output parameters but are not intentionally varied).

vii) the held-constant factor (held-constant factors are controllable factors whose effects are not of interest in the experiment).

viii) the nuisance factors (nuisance factors are not controlled, and are not of primary interest in the experiment).

ix) the interaction effects present in control factors (The dependence of one experimental factor on the level of another experimental factor for its contribution to the measured response.)

4. A computerized method and system of claim 3 wherein the creation of a robust design of experiment to be carried out by a user for robust engineering and optimization of complex phenomenon, the steps of the method comprising:

(a) enter the problem-diagram information of claim 3 into the computerized system, the information including:

i) the input control parameters to be varied in the experiment and the number of settings for each control parameter,

ii) the output response and the evaluation criteria,

iii) the noise variables or compounded noise variables.

(b) generate a robust experimental design protocol in accordance with the model type input in step (a); and wherein the user changes are suggested by a set of knowledge-based system.

(c) evaluate the experiment design generated in step (b) by utilizing the information input in step (a).

(d) create the robust experimental layout protocol and worksheet specifying each individual trials of the robust experiment to be performed by the user.

(e) conduct or simulate the robust experiment run according to the worksheet and record experiment results.

(f) compute the experimental data from step (e), then calculate the statistical results and generate the graphical reports, and the computation consisting:

i) Computing the Analysis of Mean (ANOM) statistics (either static or dynamic optimization method);

ii) Computing and generating the factorial effect table (either static or dynamic optimization method);

iii) Computing and plotting the factorial effect chart (either static or dynamic optimization method)

iv) Computing and plotting the significant effect 2D chart (either static or dynamic optimization method)

v) Computing and plotting the significant effect 3D chart (either static or dynamic optimization method)

vi) Computing the Analysis of variance (ANOVA) statistics (either static or dynamic optimization method)

(g) analyze and interpret statistical and graphical outputs to determine the relative effect and the relative importance of various factors from step (f).

(h) optimize and adjust the system sensitivity and performance to meet optimum conditions/objectives based on the knowledge gained from step (g).

(i) verify the repeatability of the optimization results with a confirmation experiment to ensure that the measured responses were not a result of experimental error.

(j) communicate a summary of report on the analysis performed in step (f) to (i) to the user.

(k) document the robust experiment data and results into a project file for future retrieval and knowledge retention.