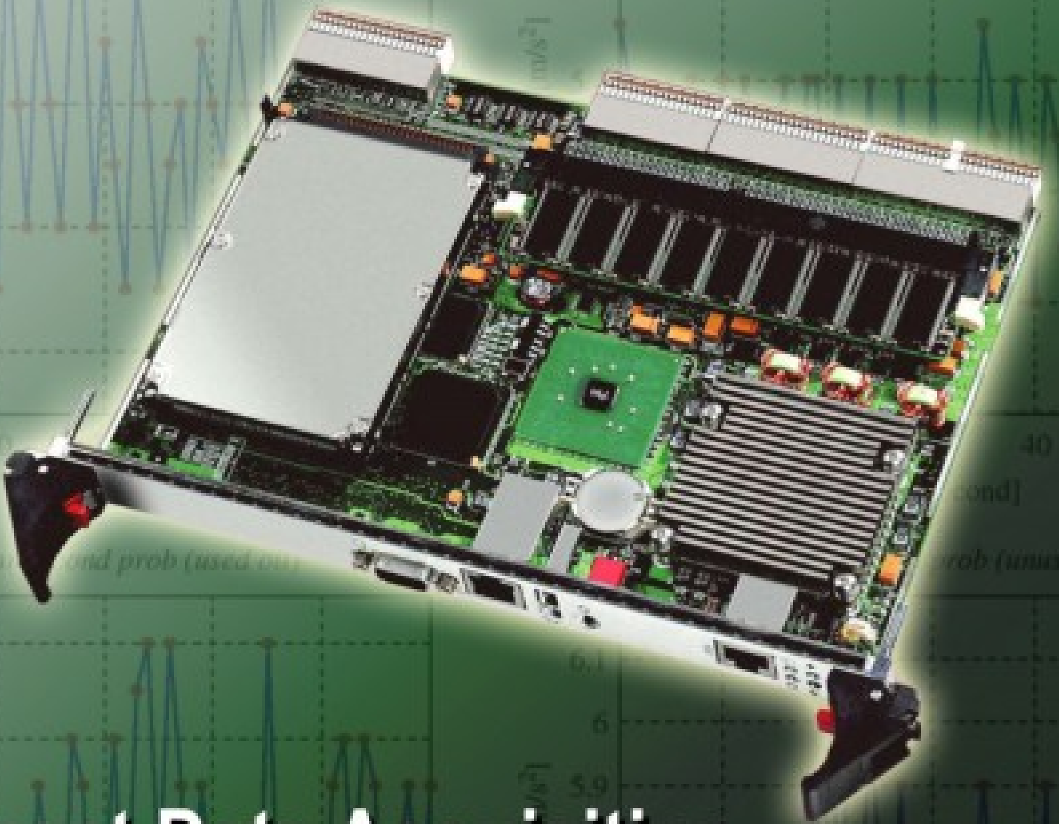
ISSN 1726-5479

SENSORS & TRANSDUCERS

11/12
vol. 16
Special



Intelligent Data Acquisition and Information Process Technologies and Their Applications

International Frequency Sensor Association Publishing

IFSA

Sensors & Transducers

Volume 16, Special Issue
November 2012

www.sensorsportal.com

ISSN 1726-5479

Sensors & Transducers Journal (ISSN 1726-5479) is a peer review international journal published monthly online by International Frequency Sensor Association (IFSA).
Available in electronic and on CD.

Contents

Volume 16
Special Issue
November 2012

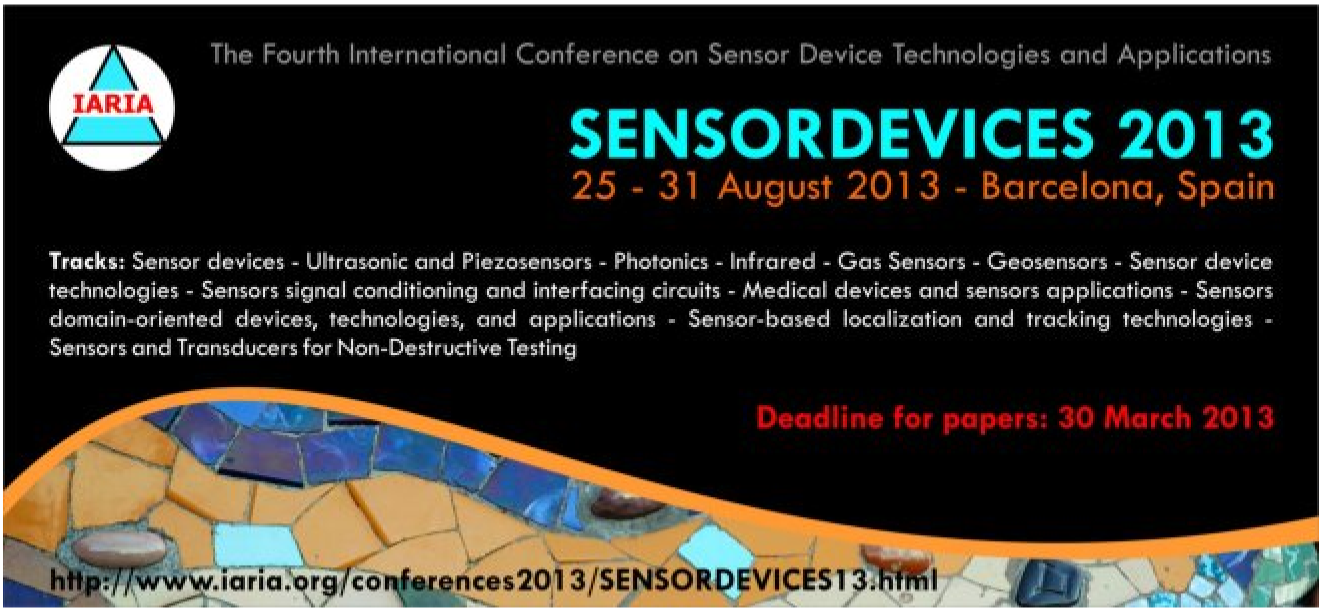
www.sensorsportal.com

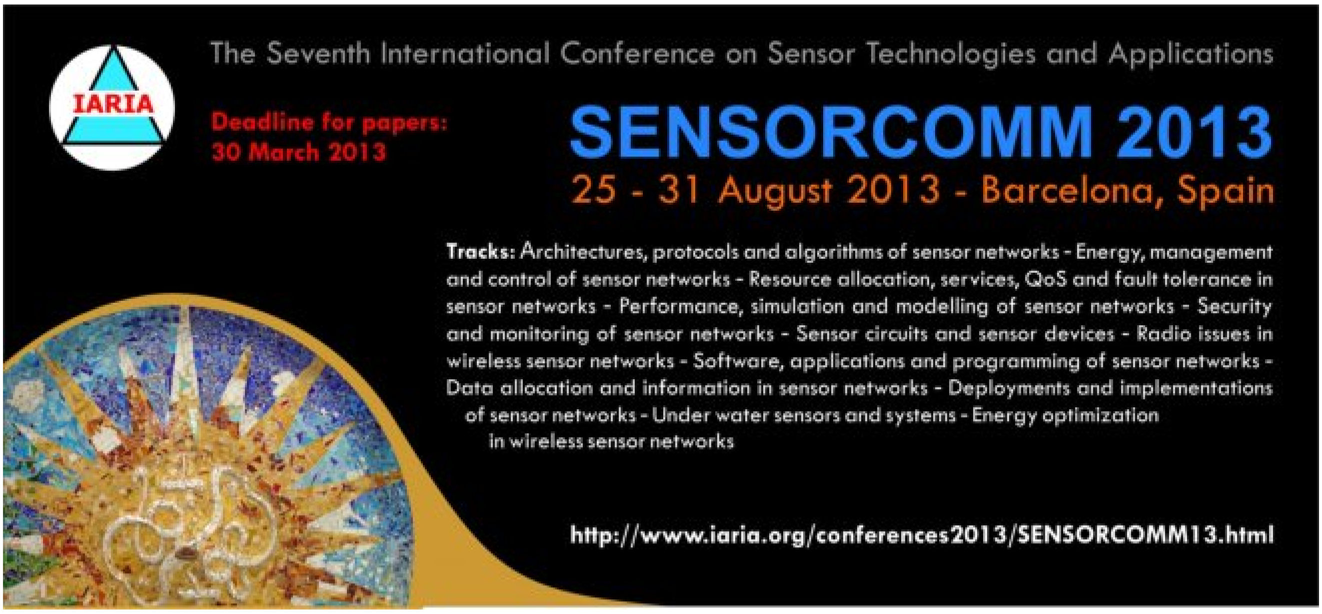
ISSN 1726-5479

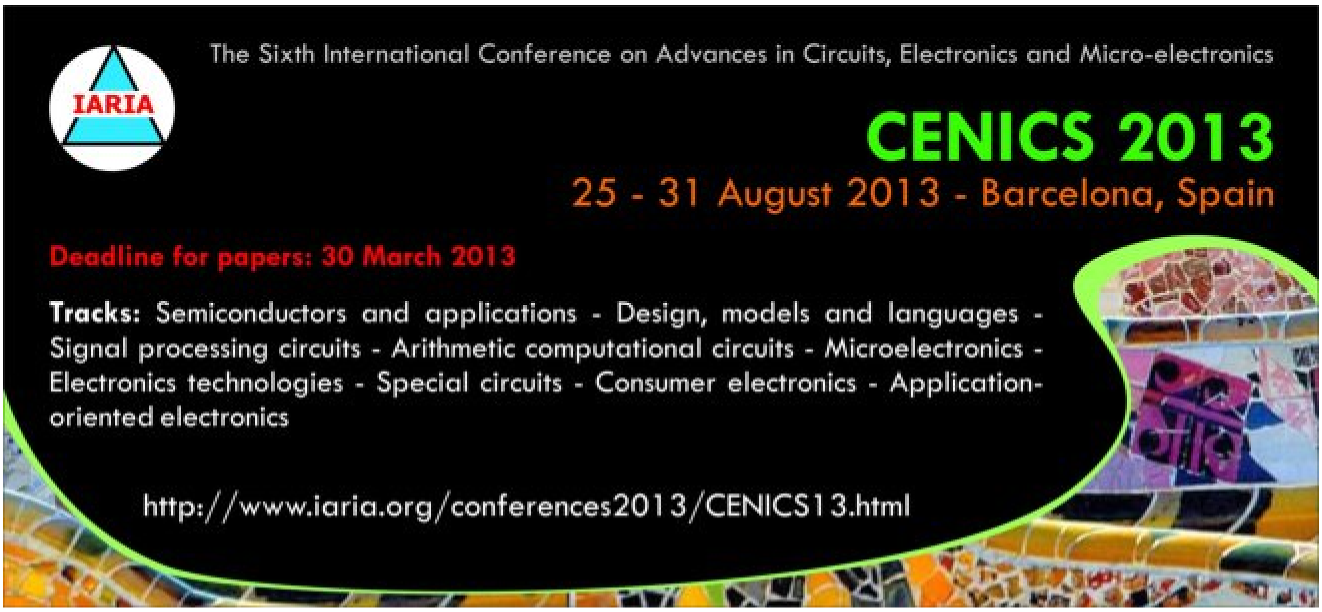
Research Articles

Authors are encouraged to submit article in MS Word (doc) and Acrobat (pdf) formats by e-mail: editor@sensorsportal.com
Please visit journal’s webpage with preparation instructions: http://www.sensorsportal.com/HTML/DIGEST/Submition.htm

International Frequency Sensor Association (IFSA).


IARIA
The Fourth International Conference on Sensor Device Technologies and Applications
SENSORDEVICES 2013
25 - 31 August 2013 - Barcelona, Spain
Tracks: Sensor devices - Ultrasonic and Piezosensors - Photonics - Infrared - Gas Sensors - Geosensors - Sensor device technologies - Sensors signal conditioning and interfacing circuits - Medical devices and sensors applications - Sensors domain-oriented devices, technologies, and applications - Sensor-based localization and tracking technologies - Sensors and Transducers for Non-Destructive Testing
Deadline for papers: 30 March 2013
http://www.iaria.org/conferences2013/SENSORDEVICES13.html


IARIA
The Seventh International Conference on Sensor Technologies and Applications
Deadline for papers: 30 March 2013
SENSORCOMM 2013
25 - 31 August 2013 - Barcelona, Spain
Tracks: Architectures, protocols and algorithms of sensor networks - Energy, management and control of sensor networks - Resource allocation, services, QoS and fault tolerance in sensor networks - Performance, simulation and modelling of sensor networks - Security and monitoring of sensor networks - Sensor circuits and sensor devices - Radio issues in wireless sensor networks - Software, applications and programming of sensor networks - Data allocation and information in sensor networks - Deployments and implementations of sensor networks - Under water sensors and systems - Energy optimization in wireless sensor networks
http://www.iaria.org/conferences2013/SENSORCOMM13.html


IARIA
The Sixth International Conference on Advances in Circuits, Electronics and Micro-electronics
CENICS 2013
25 - 31 August 2013 - Barcelona, Spain
Deadline for papers: 30 March 2013
Tracks: Semiconductors and applications - Design, models and languages - Signal processing circuits - Arithmetic computational circuits - Microelectronics - Electronics technologies - Special circuits - Consumer electronics - Application-oriented electronics
http://www.iaria.org/conferences2013/CENICS13.html

Sensors & Transducers Journal, Vol. 16, Special Issue, November 2012, pp. 144-151

Sensors & Transducers

ISSN 1726-5479

http://www.sensorsportal.com

Independent Axiom-based Robust Design for Nonlinear System

Xianfu Cheng
School of Mechanical and Electronical Engineering, East China Jiaotong University,
Nanchang 330013, China
Tel.: +86-13970099185
E-mail: chxf_xn@sina.com

Received: 11 September 2012 /Accepted: 11 October 2012 /Published: 20 November 2012

Abstract: Robust design and axiomatic design provide systematic and effective approaches to deal with quality problems for product design, and their integration will be better to improve product quality. In this paper, independence axiom is used to represent system structure and capture design requirements. The relation between robustness and coupling degree is firstly discussed. Then the sensitivity index is utilized to measure the sensitivity of functional requirements to the variation of design parameters, and a variable sensitivity analysis is utilized to consider model uncertainty for nonlinear system. Multiple objectives of robust design are traded off in the compromise decision support problem. An example has demonstrated the effectiveness of the proposed design method.

Keywords: Robust design, Independent axiom, Nonlinear system, Sensitivity analysis, Coupling degree.

1. Introduction

It is important to address the variability issue at the product design and development phase. Robust design provides effective approaches to deal with variability in product design. Andersson [1] argued that robustness should be considered as early as possible in the product design process. Robust performance is one of the most important concerns in design of any system since uncontrollable variations exist in the real industry, including manufacturing operations, variations in material properties, and operating environment. If these variations are not considered, they will degrade the performance and may result in a failure in practice [2].

A system is considered robust when its functional performance is insensitive to selected design parameters and environmental changes, while satisfying design and customer requirements [3]. To increase the flexibility of the product design, the conventional robust design may be effectively integrated with the concept of axiomatic design. By combining the basic concept of robust design with axiomatic design, high-quality products with a low cost can be produced while maximizing market leverage [4].

According to Suh [5], a design that maintains the independence of functional requirements is an ideal design, and an uncoupled design and a decoupled design are more robust than a coupled design. The independence axiom can be used as an approximate decoupling criterion to decouple the coupled design. Gu *et al*. [6] demonstrated that the design satisfying independence axiom generally led to robust design. Xiao and Cheng [7] discussed the relation between axiomatic design and robust design and revealed their consistency. Zhang *et al*. [8] verified the characteristics of system determine how the design parameters affect the functional requirements of system. Lu and Li [9] proposed a hybrid model based robust design method to handle model uncertainty using the matrix perturbation theory. Lu *et al*. [10] proposed a robust design approach to design the robustness of the nonlinear system under large uncontrollable variation based variable Sensitivity.

In this paper, a hybrid model based robust design and axiomatic design method is proposed to improve the robustness of nonlinear system with the variables sensitivity analysis. The robust design is obtained by solving a multi-objective optimization problem. This method can minimize the influence of the variations in the design variables and model uncertainty to the performance, and achieve the target values for functional requirements and decoupling of system design.

2. Mapping Process in Axiomatic Design and Coulping Analysis

The axiomatic design approach views the design process as a series of mappings among customer, functional, physical, and process domains. The independence axiom states that when there are two or more FRs, the design solution must be such that each one of the FRs can be satisfied without affecting the other FRs. That means we have to choose a correct set of DPs to be able to satisfy the FRs and maintain their independence. This mapping process between FRs and DPs is represented by the design equation.

$$\{\mathbf{FR}\}=[\mathbf{A}]\{\mathbf{DP}\}, \tag{1}$$

where $\mathbf{FR} = [FR_1, FR_2,\ldots, FR_m]^T$, is a vector of functional requirements, $\mathbf{DP} = [DP_1, DP_2,\ldots, DP_n]^T$, is a vector of design parameters; [**A**] is design matrix, $A_{ij} = \partial FR_i / \partial DP_j$.

To satisfy the independence axiom, the design matrix must be either diagonal or triangular. In this case, A_{ij}=0 (for $i \neq j$) means an uncoupled design; A_{ij}=0 (for $i<j$) means a decoupled design. The uncoupled design can easily lead to robust design. In some cases, the decoupled design is also acceptable and lead to robust design under specific situations. When the specified design ranges for FR_i satisfy the following requirement, the design can be considered as an uncoupled design.

$$\Delta \mathrm{FR}_i > \left(\sum_{\substack{j=1 \\ j\neq i}}^{n} (\partial \mathrm{FR}_i / \partial \mathrm{DP}_j) \Delta \mathrm{DP}_j \right) \tag{2}$$

Axiomatic design provides two quantities necessary for measuring functional coupling degree, namely, reangularity R and semangularity S. R measures the interaction between **DPs**, whereas S measures the interaction between **DPs** and **FRs**. R and S are defined, respectively, as follows:

$$R = \prod_{\substack{i=1,n-1 \\ j=1+i,n}} \left[1 - \frac{\left(\sum_{k=1}^{n} A_{ki} A_{ki} \right)^2}{\left(\sum_{k=1}^{n} A_{ki}^2 \right) \cdot \left(\sum_{k=1}^{n} A_{kj}^2 \right)} \right]^2 \tag{3}$$

$$S = \prod_{j=1}^{n} \left[\frac{A_{jj}}{\left(\sum_{k=1}^{n} A_{kj}^2 \right)^{1/2}} \right] \tag{4}$$

Both R and S measures are needed to identify whether functional independence has been achieved. For an uncoupled matrix, both R and S equal 1.0. When the matrix is decoupled, R and S are equal, but not 1.0; and when the matrix is coupled, the values of R and S are different from each other and tend to approach zero. The closer to 1 both the values of R and S are, the less the functional coupling for the overall system is. Maximizing R and S with a target value of 1 can be incorporated as a goal to achieve an uncoupled design.

Without loss of generality, consider the coupled design that consists of two FRs which is given by the following design equation.

$$\begin{bmatrix} FR_1 \\ FR_2 \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \begin{bmatrix} DP_1 \\ DP_2 \end{bmatrix} \tag{5}$$

To have a robust design, it must be maken sure that the off-diagonal elements are much smaller than the diagonal elements, i.e., $A_{ii} >> A_{ij}$.

If the variance for DP_i is $\sigma^2_{\mathrm{DP}_i}$, then the variance and covariance for FR_i may be expressed as

$$\begin{aligned} \sigma^2_{\mathrm{FR}_i} &= \sum_{j=1}^{n} A_{ij}^2 \sigma^2_{\mathrm{DP}_i} + 2 \sum_{j=2}^{n} \sum_{k=1}^{j-1} A_{ij} A_{ik} Cov(\mathrm{DP}_j, \mathrm{DP}_k) \\ \Sigma_{\mathrm{FR}} &= [A] \Sigma_{\mathrm{DP}} [A]^{\mathrm{T}} \end{aligned} \tag{6}$$

where Σ_{FR} is the covariance matrix.

In this study, it is assumed that design parameters DPs are statistically independent each other. Therefore

$$\sum\nolimits_{\mathrm{DP}} = \begin{bmatrix} \sigma^2_{\mathrm{DP}_1} & 0 \\ 0 & \sigma^2_{\mathrm{DP}_2} \end{bmatrix} \tag{7}$$

$$\sum\nolimits_{\mathrm{FR}} = \begin{bmatrix} A_{11}^2 \sigma^2_{\mathrm{DP}_1} + A_{12}^2 \sigma^2_{\mathrm{DP}_2} & A_{11} A_{21} \sigma^2_{\mathrm{DP}_1} + A_{12} A_{22} \sigma^2_{\mathrm{DP}2} \\ A_{11} A_{21} \sigma^2_{\mathrm{DP}_1} + A_{12} A_{22} \sigma^2_{\mathrm{DP}2} & A_{21}^2 \sigma^2_{\mathrm{DP}_1} + A_{22}^2 \sigma^2_{\mathrm{DP}_2} \end{bmatrix} \tag{8}$$

$$\begin{aligned} \sigma^2_{\mathrm{FR}_1} &= A_{11}^2 \sigma^2_{\mathrm{DP}_1} + A_{12}^2 \sigma^2_{\mathrm{DP}_2} \\ \sigma^2_{\mathrm{FR}2} &= A_{21}^2 \sigma^2_{\mathrm{DP}_1} + A_{22}^2 \sigma^2_{\mathrm{DP}_2} \end{aligned} \tag{9}$$

The above equation shows that the variances for FRs for coupled designs are larger than the variances for FRs of decoupled design under the same circumstances. It can be also concluded that the variances for FRs of decoupled design are larger than those for uncoupled design. The variance for the overall system is the sum of diagonal elements for covariance matrix Σ_{FR}. The larger the off-diagonal elements A_{12} and A_{21} are, and the smaller the R (Reangularity) is, the stronger the coupling is and the larger the variance of design system is. So the coupling should be avoided.

To measure the sensitivity of functional requirements to the variation of design parameters, the sensitivity index is utilized, which is defined as the ratio of variance for FR and DP, namely

$$S_v = \sigma_{\mathrm{FR}}^2 / \sigma_{\mathrm{DP}}^2 . \tag{10}$$

The sensitivity index has the robust feature. The smaller the S, the better the robustness of design system.

3. Description of Robustness Model

According to axiomatic design, the **FR** is function of **DP**, which can be also expressed as

$$\mathbf{FR} = f(\mathbf{DP}) \tag{11}$$

Suppose $\mathbf{FR}^*$ is the target value of functional requirements. To achieve this goal, a vector of design parameters should be chosen such that

$$\mathbf{FR}^* = f(\mathbf{DP}^*) \tag{12}$$

In reality, design parameters in the physical domain may have variations ($\Delta\mathbf{DP} = \mathbf{DP} - \mathbf{DP}^*$) caused by changes in the environment including material characteristics, geometrical properties, manufacturing processes, analysis/simulation model accuracy, loads, and/or operational environments. Once design parameters have variations, taking Taylor series expansion of **FR** at the nominal value $\mathbf{DP}^*$, functional requirements will produce random variations, namely.

$$\mathbf{FR} = f(\mathbf{DP}^*) + \sum_i \frac{\partial f}{\partial DP_i} \Delta DP_i \tag{13}$$

$$\Delta\mathbf{FR} = \mathbf{FR} - \mathbf{FR}^* = \mathbf{FR} - f(\mathbf{DP}^*) = \sum_i \frac{\partial f}{\partial DP_i} \Delta DP_i = [B]\Delta\mathbf{DP} , \tag{14}$$

where $[B]$ is the sensitivity matrix characterizing the sensitivity of **FR** to the deviation in **DP**. When the design system is linear, $[A]$ and $[B]$ are equal; and when the design system is non-linear, $[A]$ and $[B]$ are different from each other. For convenience, $[B]$ is simply denoted as B.

Usually, the traditional deterministic robust design is to minimize the influence of the uncontrollable variation to the performance based on a linear model. This linear model is obtained by the local linearization approach using Taylor series expansion method. It is well-known that this linear approximation is only effective around the neighborhood of the design point.

When the system has strong nonlinearity, it will produce a larger approximate error between the linear model and the practical system. Further, in real application, this accurate design matrix is sometime difficult to obtain due to complex process, operational environment or unknown dynamic [9]. Thus, a realistic approximation from the system is often taken as the nominal design matrix developed from experiment or data modeling. This approximation will cause the design matrix characteristic uncertainty. Thus, the traditional robust design may not work well by using the nominal design matrix only because the design matrix uncertainty still affects the system functional requirements. So, the nonlinear system is modeled as a linear structure using the variable sensitivity approach and the sensitivity matrix B is taken as a variable matrix for considering the influence of the nonlinear terms with $B \in [B_{\min}, B_{\max}]$ under $DP \in [DP_l, DP_u]$. The maximal and minimal values of the variable sensitivity in $DP \in [DP_l, DP_u]$ can be figured out through the system model.

Let $\Delta DP \in [\Delta DP_l, \Delta DP_u]$, and then the system model may be used to calculate the minimal value $B_{i,j}^{\min}$ and the maximal value $B_{i,j}^{\max}$

$$B_{i,j}^{\min} = \min B_{i,j}\,,\ B_{i,j}^{\max} = \max B_{i,j} \tag{15}$$

Then, the performance variations ΔFR may be rewritten as

$$[\Delta FR]^T \Delta FR = [\Delta DP]^T B^T B\, \Delta DP \tag{16}$$

According to the singular value decomposition theory, any real symmetric matrix $\boldsymbol{B}^T \boldsymbol{B}$ can be decomposed as

$$B^T B{=}\lambda \mathrm{diag}(\sigma_1, \sigma_2, \ldots, \sigma_n,)\, \lambda^T, \tag{17}$$

where σ_i is the singular value of $\boldsymbol{B}$, and the corresponding orthogonal eigenvector is denoted as λ_i.

Since the matrix $\boldsymbol{B}^T \boldsymbol{B}$ varies within its bound, its singular values are also bounded as $\sigma_i \in \left[\sigma_i^{\min}, \sigma_i^{\max}\right]$. In order to achieve the robustness under the larger uncontrollable variation, the following optimization objective can be considered [10]

$$\min\max\left(\sigma_i^{\max}\right) \tag{18}$$

4. Robust Design Optimization Framework

Multi-objective robust design needs to have a trade-off between the target and variance of each objective as well as trade-offs among optimization objectives. The coupling relation among multiple objectives makes it difficult to optimize multiple quality characteristics simultaneously. The independence axiom helps to find an ideal design, which can maintain functional independence, and can be used as an approximate decoupling criterion to reduce coupling degree among optimization objectives [11]. These requirements define three major categories of optimization objectives and three major categories of constraints for the proposed model as follows.

Three major categories of optimization objectives:
(a) The first category of optimization objectives is to minimize the sensitivity index SV, which make functional requirements insensitive to the variation of design parameters;
(b) The second category of optimization objectives is to minimize the maximal singular value σ_{max} to make functional requirements insensitive to the model uncertainty;
(c) The third category of optimization objectives contains R and S. Maximizing R and S with a target value of 1 can be considered as a goal in order to obtain an ideal design.

Three major categories of constraints:
(a) The first category of constraints is to achieve an ideal design;

(b) The second category of constraints is the deterministic constraints, which are the conditions the design system must satisfy, such as performance, cost and others;
(c) The third category of constraints is the bounds of design parameters.

5. Case Study

To demonstrate this approach, an example is adopted from Shen *et al.* [11] concerning improving the impact power of an ABS resin product. The impact power y_1 is mainly determined in the extruding process, where the screw rotation rate in revolutions per minute (n) and the process temperature (t) are the key control factors. Since the resin liquidity y_2 is also an important characteristic, the liquidity was also observed. The region of interest is 242 r/min $\le n \le$ 298 r/min and 236° C$\le t \le$ 264 °C. For convenience, the design parameters are defined as $DP_1=(n-270)/28$ and $DP_2=(t-250)/14$, thus they vary in [-1, 1]. The functional requirements are defined as $FR_1=(y_1-21.531)$ and $FR_2=(y_2-52.030)$, respectively.

Then the mapping between FRs and DPs is

$$\begin{bmatrix} FR_1 \\ FR_2 \end{bmatrix} = \begin{bmatrix} \begin{array}{l} 0.612-1.142DP_1 \\ +0.049DP_2 \end{array} & 0.262-1.492DP_2 \\ 0.021-0.5DP_1 & \begin{array}{l} 1.329-0.3DP_2 \\ +0.098DP_1 \end{array} \end{bmatrix} \begin{bmatrix} DP_1 \\ DP_2 \end{bmatrix}$$

The design objective is to select the design parameters DPs from $\mathbf{DP} \in$ [-1, 1] to have a robust performance against uncertainty. Suppose both the variance for DP_1 and DP_2 are 0.025. The larger of the FR_1 and FR_2 is the better. The reangularity R, semangularity S, sensitivity index S_v and singular value σ^{max} can be computed using MATLAB program. In DSP model for robust design, the target values of system goals are set to T_{Sv1}=0.3, T_{Sv2} =1.5 and T_σ=1.25, respectively. The results of the proposed robust design method are shown in Table 1.

Table 1. The results of robust design.

	n (r / min)	t (°C)	y_1 (MPa)	y_2 g/10min	R	S	S_{v1}	S_{v2}	σ^{max}
Initial values	250	240	19.5878	50.7076	0.5256	0.9228	3.5920	2.34	2.3485
Solution of robust design [11]	271.6016	254.1636	21.5091	52.4	0.9887	0.9999	0.3480	1.5520	1.2689
The proposed method	271.5247	253.2138	21.5431	52.3222	0.9979	0.9999	0.32	1.6	1.2632

As seen in Table 1, only the liquidity y_2 and sensitivity index S_{v2} in reference [11] are better than that of the proposed robust design method, but the solution can be acceptable. The proposed method decreases the coupling degree (namely R=S=1.0). The singular value is smaller due to consider the design matrix uncertainty. So it demonstrates that the proposed method can provide stronger robustness for quality characteristics, and achieves better trade-offs among design objectives, variability and coupling degree.

In this section, the formulation and solution of a compromise decision support problem (DSP) for combined axiomatic and robust design is used to assess the impact of uncertainty encountered in multi-objective optimization. The compromise DSP is a mathematic construct that is used to support design decisions in problems involving multiple objectives [12]. The multiple objectives are formulated as system goals (involving both system and deviation variables) and the deviation function is solely a function of the goal deviation variables, as shown in Fig. 1.

Given:
Product design engineering model;
Functional requirements FR_1, FR_2,…, FR_m, and constraints, where m is number of FRs;
Design parameters DP_1, DP_2,…, DP_n, and bounds, where n is number of DPs.
Target for sensitivity index: T_{Sv}
Target for sensitivity index: T_σ
Find:
Nominal values of DPs: $\mathbf{DP}^*$;
The largest singular value σ_i of the sensitivity matrix $[B]$;
Deviation variables: d_i^- , d_i^+ i =1, 2, 3, 4
Satisfy:
System constraints:
R - S=0;
h_i(DP)=0; i =1, 2, …, p
g_i(DP)≤0; i =1, 2, …, $p+q$
System goals:

$$R-1.0+d_1^- - d_1^+ = 0.0$$

$$\mathrm{S}-1.0+\mathrm{d}_2^- - \mathrm{d}_2^+ = 0.0$$

$$S_v/T_{Sv} - 1.0 + d_3^- - d_3^+ = 0.0$$

$$\sigma^{\max}/T_\sigma - 1.0 + d_4^- - d_4^+ = 0.0$$

Bounds:

$$DP_{il} \le DP_i \le DP_{iu}\ ;\quad i = 1,\cdots,n$$

d_i^- , d_i^+ ≥0, $d_i^- \cdot d_i^+$ =0; i =1, 2, 3, 4

Minimize: deviation function:

$$Z = \sum_{i=1}^{4} w_i (d_i^- + d_i^+);\quad \sum w_i = 1;\quad w_i \ge 0$$

Fig. 1. DSP model for independent axiom-based robust design for nonlinear system.

5. Conclusion

In this paper, the novel robust design method is proposed to achieve better quality improvement of the nonlinear system. The independence axiom in axiomatic design is used to reduce the correlation among quality characteristics. The system robustness is analyzed simultaneously to minimize the influence of the variations in the design variables and model uncertainty to the performance. Through solving the multi-objective optimization using cDSP, the robust design can be obtained to have the trade-off between the variations in the design parameters and the design matrix characteristic uncertainty However, when the dimensions of the problems become larger, this optimization will cause a higher computational cost.

Acknowledgements

This work was supported by the National Natural Science Foundation of China under Grant No. 51165007.

References

[1]. P. Andersson, On Robust Design in the Conceptual Design Phase: a Qualitative Approach, *Journal of Engineering Design*, Vol. 8, No. 1, 1997, pp. 75-89.

[2]. S. Caro, F. Bennis, P. Wenger, Tolerance Synthesis of Mechanisms: A Robust Design Approach, *Journal of Mechanical Design,* Vol. 127, No. 1, 2005, pp. 86–94.

[3]. A. Zakarian, J. W. Knight, L. Baghdasaryan, Modelling and Analysis of System Robustness, *Journal of Engineering Design*, Vol. 18, No. 3, 2007, pp. 243-263.

[4]. M. H. Wang, A Systematic Approach for the Robust Design of Scalable Product Platforms, in *Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Engineering Manufacture,* Vol. 220, 2006, pp. 1983-1995.

[5]. N. P. Suh, Axiomatic Design: Advances and Applications, *Oxford University Press*, 2001.

[6]. P. H. Gu, B. Lu, S. Spiewak, A New Approach for Robust Design of Mechanical Systems, *Annals of the CIRP*, Vol. 53, No. 1, 2004, pp. 129-133.

[7]. R. B. Xiao, X. F. Cheng, An Analytic Approach to the Relationship of Axiomatic Design and Robust Design, *International Journal of Materials and Product Technology*, Vol. 31, No. 2/3/4, 2008, pp. 241-258.

[8]. J. Zhang, P. H. Gu, No. S. Bao, G. J. Zhang, Analytical Robust Design of Non-linear Mechanical Systems, *Chinese Journal of Mechanical Engineer,* Vol. 45, No. 10, 2009, pp. 207-215 (in Chinese).

[9]. X. J. Lu, H. X. Li, Perturbation Theory Based Robust Design under Model Uncertainty, *Journal of Mechanical Design,* Vol. 131, No. 12, 2009, pp. 1-9.

[10].X. J. Lu, H. X. Li, C. L. Philip Chen. Variable Sensitivity-based Deterministic Robust Design for Nonlinear System, *Journal of Mechanical Design*, Vol. 132, No. 6, 2010, pp. 1-7.

[11].L. Shen, J. Yang, and Y. Zhao, An Integration Design Optimization Framework of Robust Design, Axiomatic Design, and Reliability-based Design, *Quality and Reliability Engineering International*, Vol. 27, 2001, pp. 959-968.

[12].G. Hernandez, J. K. Allen, F. Mistreem, The Compromise Decision Support Problem: Modeling the Deviation Function as in Physical Programming, *Engineering Optimization*, Vol. 33, No. 4, 2001, pp. 445-471.

Sensors & Transducers Journal

Guide for Contributors

Aims and Scope

Sensors & Transducers Journal (ISSN 1726-5479) provides an advanced forum for the science and technology of physical, chemical sensors and biosensors. It publishes state-of-the-art reviews, regular research and application specific papers, short notes, letters to Editor and sensors related books reviews as well as academic, practical and commercial information of interest to its readership. Because of it is a peer reviewed international journal, papers rapidly published in *Sensors & Transducers Journal* will receive a very high publicity. The journal is published monthly as twelve issues per year by International Frequency Sensor Association (IFSA). In additional, some special sponsored and conference issues published annually. *Sensors & Transducers Journal* is indexed and abstracted very quickly by Chemical Abstracts, IndexCopernicus Journals Master List, Open J-Gate, Google Scholar, etc. Since 2011 the journal is covered and indexed (including a Scopus, Embase, Engineering Village and Reaxys) in Elsevier products.

Topics Covered

Contributions are invited on all aspects of research, development and application of the science and technology of sensors, transducers and sensor instrumentations. Topics include, but are not restricted to:

- Physical, chemical and biosensors;
- Digital, frequency, period, duty-cycle, time interval, PWM, pulse number output sensors and transducers;
- Theory, principles, effects, design, standardization and modeling;
- Smart sensors and systems;
- Sensor instrumentation;
- Virtual instruments;
- Sensors interfaces, buses and networks;
- Signal processing;
- Frequency (period, duty-cycle)-to-digital converters, ADC;
- Technologies and materials;
- Nanosensors;
- Microsystems;
- Applications.

Submission of papers

Articles should be written in English. Authors are invited to submit by e-mail editor@sensorsportal.com 8-14 pages article (including abstract, illustrations (color or grayscale), photos and references) in both: MS Word (doc) and Acrobat (pdf) formats. Detailed preparation instructions, paper example and template of manuscript are available from the journal’s webpage: http://www.sensorsportal.com/HTML/DIGEST/Submition.htm Authors must follow the instructions strictly when submitting their manuscripts.

Advertising Information