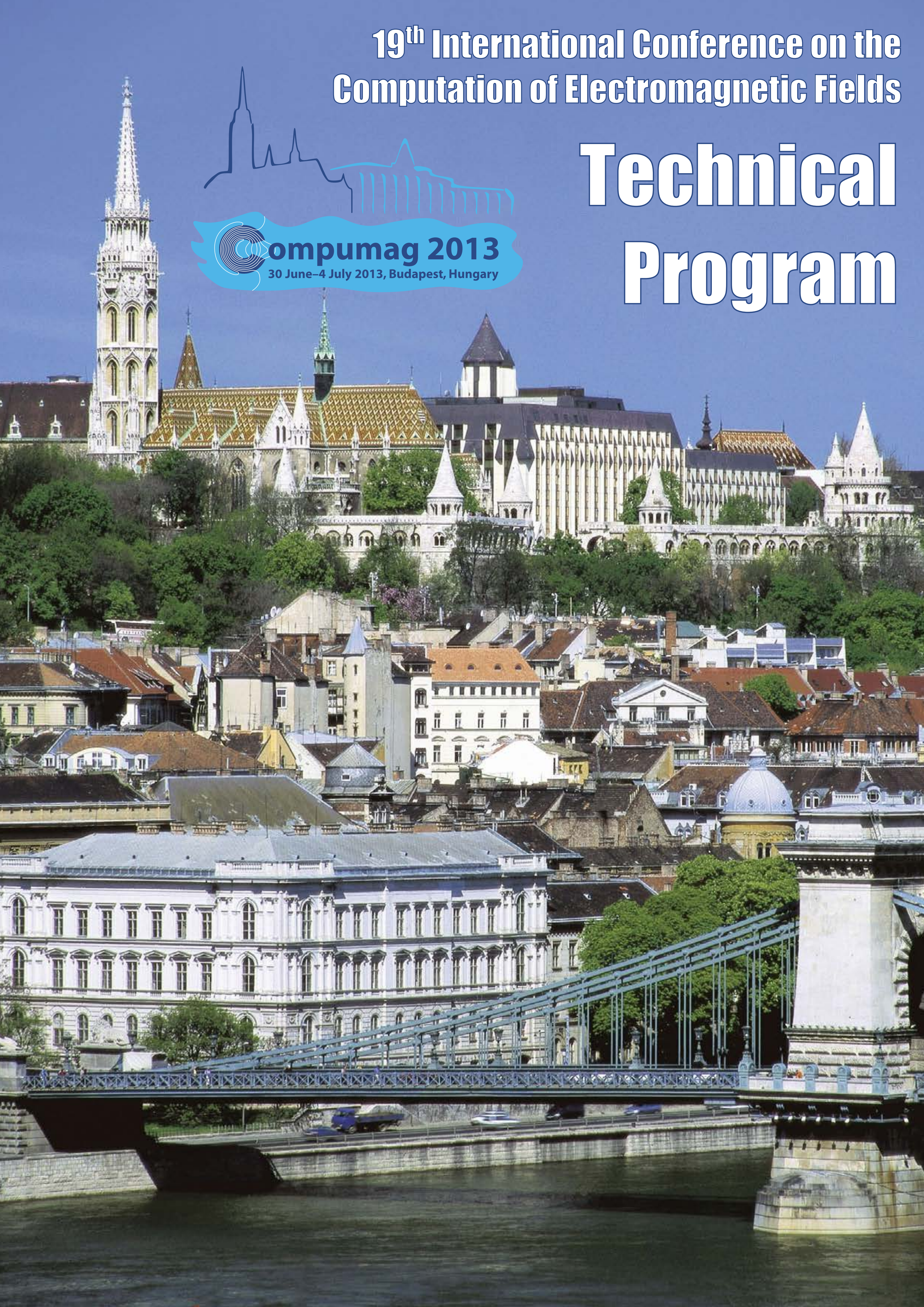
19th International Conference on the Computation of Electromagnetic Fields

Compumag 2013

30 June–4 July 2013, Budapest, Hungary

Technical Program



PD1-4
Topology Optimization Based on ON/OFF Method with Surface Smoothing
Kota Watanabe[1], Hajime Igarashi[2]
[1]Muroran Institute of Technology, Japan; [2]Hokkaido University

PD1-5
A Modification of Artificial Bee Colony Algorithm Applied to Loudspeaker Design Problem
Xin Zhang[2], Xiu Zhang[1], S. L. Ho[1], W. N. Fu[1]
[1]The Hong Kong Polytechnic University, Hong Kong S.A.R. (China); [2]City University of Hong Kong, Hong Kong S.A.R. (China)

PD1-6
Level Set-based Topology Optimization for the Design of Light Trapping Structures
Masaki Otomori[1], Takayuki Yamada[1], Kazuhiro Izui[1], Shinji Nishiwaki[1], Nozomu Kogiso[2]
[1]Kyoto University, Japan; [2]Osaka Prefecture University, Japan

PD1-7
Comparative Study of Reliability Evaluation Methods for Reliability-based Design Optimization of Electromagnetic Devices under Uncertainty
Ziyan Ren, Chang-Seop Koh
Chungbuk National University, Republic of Korea (South Korea)

PD1-8
Multi-objective Optimization Approach to Reliability-based Optimal Design of Electromagnetic Problems
Ziyan Ren, Dianhai Zhang, Chang-Seop Koh
Chungbuk National University, Republic of Korea (South Korea)

PD1-9
A Two-level Genetic Algorithm for Large Electromagnetic Optimization Problems
Fabio Henrique Pereira[1,2], Wonder Alexandre Luz Alves[1], Lucas Koleff[2], Silvio Ikuyo Nabeta[2]
[1]Nove de Julho University, Brazil; [2]São Paulo University, Brazil

PD1-10
Reliability-Based Optimum Tolerance Design for Industrial Electromagnetic Devices
Su-gil Cho[1], Junyong Jang[1], Su-Jin Lee[1], Kyu-Seob Kim[1], Jung-Pyo Hong[1], Woo-Kyo Jang[2], Tae Hee Lee[1]
[1]Hanynag University, Republic of Korea (South Korea); [2]Keyang Electric Machinery Co., Ltd., Republic of Korea (South Korea)

PD1-11
Evolutionary Algorithm-based Multi-criteria Optimization of Triboelectrostatic Separator
Frantisek Mach[1], Lukas Adam[1], Pavel Kus[1], Pavel Karban[1], Ivo Dolezel[2]
[1]University of West Bohemia, Faculty of Electrical Engineering, Czech Republic; [2]Academy of Sciences of the Czech Republic, Institute of Thermomechanics, Czech Republic

PD1-12
Adaptive Parameter Controlling Non-dominated Ranking Differential Evolution for Multi-objective Optimization of Electromagnetic Problems
Nyambayar Baatar, Kwang-Young Jeong, C.S. Koh
Chungbuk National University, Republic of Korea (South Korea)

Reliability-Based Optimum Tolerance Design for Industrial Electromagnetic Devices

Su-gil Cho[1], Junyong Jang[1], Su-Jin Lee[1], Kyu-Seob Kim[1], Jung-Pyo Hong[1], *Senior Member, IEEE*, Woo-Kyo Jang[2] and Tae Hee Lee[1], *Fellow, IEEE*

1Department of Automotive Engineering, Hanyang University, 222 Wangsimni-ro, Seoul 133-791, Korea
2Motor R&D 2Team, Keyang Electric Machinery Co., Ltd., Cheonan 331-802, Korea

The principle of tolerance design is receiving increased research focus to determine the optimal tradeoff between manufacturing price and quality. However, current tolerance designs are not suitable for products such as electromagnetic devices that require high reliability, i.e. a very small failure rate. In this paper, new tolerance design problem with high reliability is formulated. As an alternative, a reliability-based tolerance design is proposed in order to guarantee the reliability of the products while maximizing manufacturing tolerances. The proposed method quantifies the reliability using reliability analysis, which is reflected in the tolerance design. To validate the proposed method, our tolerance design is applied to two examples: a magnetic circuit and an IPM motor that contains tolerances of PM.

***Index Terms*— Electromagnetic devices, Optimization method, Permanent magnet motors, Reliability, Tolerance analysis.**

I. Introduction

In manufacturing, the tolerances of industrial products are inherent and inevitable giving rise to defective products. While design engineers would like to assign narrowed tolerances for the quality of products, manufacturers usually prefer to have wider tolerance due to the cost and difficulty of tolerance control. Thus, designers have to balance between maintaining quality and keeping manufacturing prices down through tolerance design.

Tolerance design techniques to find the best compromise between manufacturing price and quality is being extensively researched [1]. Out of them, Taguchi proposed an overall quality control system in order to produce robust products. In his books, the quality of a product is defined as the loss incurred due to the deviations of the products' characteristics from their target values. With the assistance of loss functions, several researchers have redefined the relationship between quality loss and manufacturing cost in one equation. However, these methods cannot provide a final design solution but only the direction to the optimum solution [2]. Thus, previous tolerance design techniques are not suitable for products such as electromagnetic devices that demand high reliability, i.e. a small failure rate.

In this paper, new tolerance design problem with high reliability is formulated and performed. As an alternative, reliability-based tolerance design proposed in this research quantifies reliability using reliability analysis, which is reflected to optimization of tolerance design. Because the proposed method uses directly statistical information of tolerance, it is accurate compared to existing approaches to consider in the design only the range of tolerance for simplicity. Therefore, it is suitable in the systems that require high reliability or have nonlinearity. To validate the proposed method, two examples are employed. First, a magnetic circuit is introduced as a mathematical example [9]. Its formulation is partly modified, with the relationship between the magnetic field and the induction values in the iron unchanged. Secondly, as an engineering example, the tolerance design of the released interior permanent magnet (IPM) motor that contains the tolerances of permanent magnet (PM) is performed. The failure rate of the IPM motor is defined as the specified value of the back electro motive force (EMF), which is influenced significantly by the tolerances of the PM. Therefore, it is necessary to employ tolerance design optimization in which the failure rate of the products is maintained within the required reliability while still maximizing the tolerances of PM. The quantification of the reliability of the IPM motor is estimated based on 5,232 data of IPM motors made by Keyang Electric Machinery, Korea.

II. Tolerance Design

As mentioned above, a quantitative measurement of the economic loss proposed by Taguchi is unable to control the allowable tolerances because its measurement has no direct relation to the tolerance range. Thus, measurements with relation to the tolerance range have been alternatively researched to enable the demanded tolerance range for quality to be ensured at low cost [4]. In this paper, we use the inverse power machining cost-tolerance model [5] given by

$$f(\delta) = c_0 \frac{1}{\delta^{c_1}} \tag{1}$$

where δ is the tolerance range of design variable and c_0 and c_1 are the model parameters usually determined by curve fitting from the empirical data for a particular machining process. General formulation for tolerance design can be expressed as

$$\begin{aligned} &\textit{Find} \quad \mathbf{X}_{\textbf{tolerance}}\ ,\ \boldsymbol{\delta}_{\textbf{tolerance}} \\ &\textit{Minimize} \quad \text{cost} = f(\delta) = \sum_{i=1}^{n}\left(c_0 \frac{1}{\delta_i^{c_1}}\right) \\ &\textit{Subject to} \quad g_j = \varepsilon(\mathbf{X},\boldsymbol{\delta}) \le \textit{allowed tolerance} \end{aligned} \tag{2}$$

Manuscript received September 18, 2013
Corresponding author: Tae Hee Lee (e-mail:thlee@hanyang.ac.kr).
Digital Object Identifier inserted by IEEE

where $X_{tolerance}$ is the representative value of design variable, $\delta_{tolerance}$ is the tolerance range of design variable and ε is the range of response due to range of tolerance. Therefore, g_j indicates that the maximum of the response is smaller than the allowed tolerance. Current tolerance designs use adverse condition of tolerance to evaluate the constraints. They are usually effective because the maximum value of response is determined by the terminal boundary value of tolerance range of design variable. Worst case tolerance design of magnetic devices is a typical example of them. In a complex and nonlinear system, the distribution of response may be skewed or asymmetric over the tolerance range. This can happen even though all of the distributions of design variables with tolerances are symmetric. The system may also have nonlinear or variable constraints over the tolerance range. This can happen that the maximum value out of responses is not determined by the terminal boundary value of tolerance range of design variable. In these cases, current designs are unsuitable for employing tolerance design. Therefore, a method that is able to quantify the system reliability in the design process is needed and will be demonstrated in next chapter.

III. The System Reliability

The probability of a system to satisfy the design requirement under tolerances is referred to as *reliability* [6]. Thus, the reliability is defined as

$$R = P\{Y(\mathbf{x}) \geq c\} = \int_{Y(\mathbf{x})\geq c} f_X(\mathbf{x})d\mathbf{x} \tag{3}$$

where $Y(\mathbf{x})$ is the performance function related to the design requirement. The probability density function (PDF) of limit state function is $f_X(\mathbf{x})$. R is the probability that is greater than requirement, c. In contrast, the probability that will not satisfy the design requirement is the *failure rate*.

If the reliability of the system is considered in an early stage of design, designers can systematically reduce the defective proportion of the product by a satisfactory level. In addition, it helps designers to save cost and time of the whole design process by preventing design feedback that may often result from unsatisfactory quality of the product.

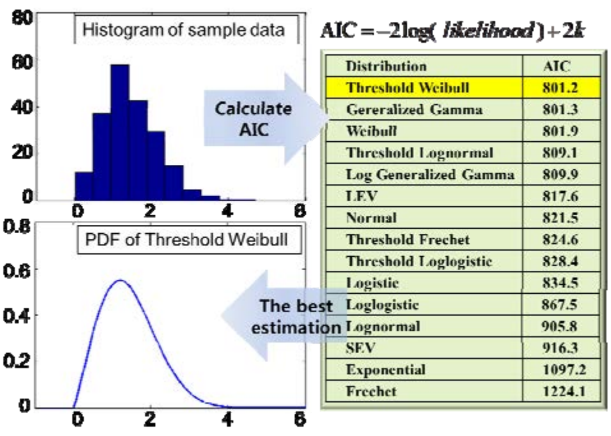


Fig. 1. Estimation procedure using AIC method.

For these reasons, many methods to obtain system reliability have been developed. Among them, in this paper, Akaike information criterion (AIC) method is considered as a reliability analysis technique. The AIC method was developed to determine the best estimated distribution in statistics [7]. This method is not based on any assumption on statistical information of tolerance since it directly uses discrete and limited data. Also, it is easy to implement, and its result is robust for the nonlinearity of responses. Recently, due to these advantages, the AIC method has been applied in engineering as a method to evaluate reliability [8]. AIC is defined in (4).

$$\begin{aligned}\text{AIC} &= -2\times(\text{maximum log likelihood of the model}) \\ &\quad + 2\times(\text{number of free parameters of the model})\end{aligned} \tag{4}$$

We interpret the result in (4) as follows. The first term in (4) is a measure of inaccuracy, badness of fit, or bias when the MLE of the parameters of the model are used. The second term, on the other hand, is a measure of complexity or the penalty due to the increased unreliability or compensation for the bias in the first term which depends upon the number of parameters used to fit the data.

Thus, when there are several competing models the parameters within the models are estimated by the method of maximum likelihood and the values of the AIC's are computed and compared to find a model with the minimum value of AIC. This procedure is called the minimum AIC procedure and the model with the minimum AIC is called the minimum AIC estimate (MAICE) and is chosen to be the best model. Therefore, for us the best model is the one with least complexity, or equivalently, the highest information gain. In applying AIC, the emphasis is on comparing the goodness of fit of various models with an allowance made for parsimony. Fig. 1 shows the minimum AIC procedure how it estimates the best model and its parameters from the data.

IV. Reliability-based Optimum Tolerance Design

A. *Example: a magnetic circuit*

In this section, reliability-based optimum tolerance design problem with high reliability is formulated. Because the proposed method uses directly statistical information of tolerance, the general formulation that use cost-tolerance model based on tolerance range need to be converted into the form using statistical information of tolerance, mean and deviation. Thus, the mean and deviation of the tolerances are considered as design variables, not range of the tolerances. The cost-tolerance model and failure rate based reliability analysis are used as the objective function and constraint functions, respectively. Modified formulation for reliability-based optimum tolerance design can be expressed as

$$\begin{aligned}&\textit{Find} && \boldsymbol{\mu}_{\textbf{tolerance}}\ ,\ \boldsymbol{\sigma}_{\textbf{tolerance}} \\ &\textit{Minimize} && \text{cost} = f(\boldsymbol{\sigma}) = \sum_{i=1}^{n}\left(c_0\frac{1}{\sigma_i^{c_1}}\right) \\ &\textit{Subject to} && G_j(\boldsymbol{\mu},\boldsymbol{\sigma}) = \Pr\left(g_j(\boldsymbol{\mu},\boldsymbol{\sigma}) \geq T_{allowed\ tolerance}\right) \leq R_{failure}\end{aligned} \tag{5}$$

where $\boldsymbol{\mu}_{tolerance}$ is a set of the means of design variables, $\boldsymbol{\sigma}_{tolerance}$ is a set of the variances of design variables due to their tolerances and G_j is the probability that will not satisfy the design requirement, allowed tolerance. It must be smaller than the required failure rate.

Compared to other tolerance design techniques, the proposed method can be conducted under the condition requiring a failure rate since the reliability analysis is simultaneously performed with the tolerance design.

B. Example: a magnetic circuit

Using the proposed method, an optimum tolerance design procedure to evaluate system reliability is developed as illustrated in detail in Fig. 2. The reliability evaluation in the left shaded box of Fig. 2 that estimate the system reliability to satisfy the design requirement is called MAICE loop. This procedure is continually employed during the optimization iteration. The primary optimization procedure shown in the center shaded box of Fig. 2 carries out design optimization based on sequential quadratic programing (SQP) method in MATBAL. The reliability and its sensitivity are computed at reliability evaluation using MAICE in the left shaded box.

C. Example: a magnetic circuit

A magnetic circuit has been considered to illustrate the characteristics of the proposed method. The number of turns is fixed at 400, while the nonlinear function expressing the relationship between the magnetic field and the induction values in the iron is assumed to be given by the following approximated mathematical form [9]:

$$\left[129.5 \cdot B_{fe} + 76.1 \cdot B_{fe} \cdot \exp\left(1.26 \cdot B_{fe}^{\,2}\right)\right] \cdot X_{fe} + B_{fe} \cdot \frac{X_{air}}{\mu_0} = N \cdot I \quad (6)$$

where B_{fe} and B_{air} are the magnetic field values in the iron and in the air gap, respectively, while X_{fe} is the total magnetic path length in the iron, X_{air} is the length of the air gap, and I is the value of the current injected in the coil.

The example definition can now be stated: suppose that the required induction field value is B^{norm}_{fe} =1*T*, and that the maximum allowed tolerance on B^{norm}_{fe} is ±5%. Suppose that the input parameters, $\{X_{air}, X_{fe}, I\}$, have uncertainty due to tolerance. Table I shows the input parameters, boundary conditions and initial values. Suppose that the distribution of the tolerance is the normal distribution. The problem consists of calculating the set of values for $\{\mu(X_{air}), \mu(X_{fe}), \mu(I), \sigma(X_{air}), \sigma(X_{fe}), \sigma(I)\}$ which ensures the widest possible set of tolerances for $\{\sigma(X_{air}), \sigma(X_{fe}), \sigma(I)\}$ while maintaining the required reliability, 95%. The formulation of the problem is defined as

$$\begin{aligned} &\textit{Find} && \boldsymbol{\mu}_{\mathbf{tolerance}},\ \boldsymbol{\sigma}_{\mathbf{tolerance}} \\ &\textit{Minimize} && \text{cost} = f(\sigma) = \sum_{i=1}^{3}\left(c_0 \frac{1}{\sigma_i^{c_1}}\right) \quad (7) \\ &\textit{Subject to} && G = P\left\{\left|g(\boldsymbol{\mu},\boldsymbol{\sigma}) - 1T\right| \geq 0.05T\right\} \leq 0.05 \end{aligned}$$

where g(μ,σ) is B_{fe} value that fulfills the condition in (6). Thus, the constraint, G, means that the failure rate in not satisfying the allowed tolerance is smaller than 5%.

Note that the reliability-based optimum tolerance design produces a better result than the result of the reference method using the tolerance design in terms of system reliability [9]. Fig. 3 shows the PDF of the induction field value, B_{fe}, at optimum. The proposed method searches the optimum which fulfills the required system reliability within the maximum allowed tolerance on B^{norm}_{fe}. On the other hand, the reference

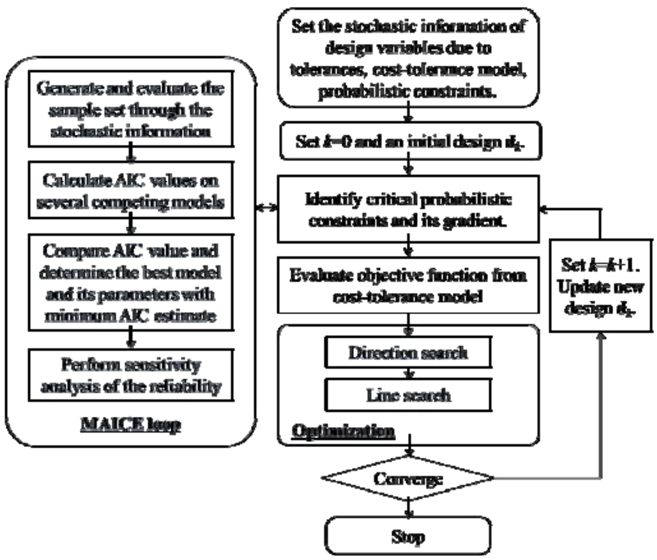


Fig. 2. Flowchart of reliability-based optimum tolerance design using MAICE.

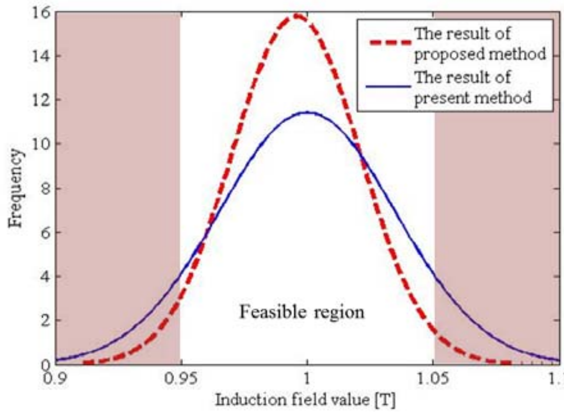


Fig. 3 PDF of B_{fe} between the results of proposed and reference method

TABLE I
PARAMETER DEFINITION FOR THE MAGNETIC CIRCUIT

Parameter	Search range	INITIAL VALUE	unit
$\mu(X_{air})$	[0.2, 0.7]	0.5	*cm*
$\mu(X_{fe})$	[10, 50]	30	*cm*
$\mu(I)$	[10, 30]	20	*A*
$\sigma(X_{air})$	[0.002, 0.02]	0.01	*cm*
$\sigma(X_{fe})$	[0.1, 1]	0.5	*cm*
$\sigma(I)$	[0.1, 1]	0.5	*A*

TABLE II
OPTIMAL SOLUTION FOUND BY PROPOSED METHOD

	Reference method	Proposed method
Parameter	[0.47, 50, 10.3, 0.002, 1, 0.26]	[0.7, 50, 14.6, 0.002, 0.97, 0.31]
Cost (Obj.)	69.2243	77.3814
Failure rate [%]	12.6	4.97

method only has a system reliability of 87%, i.e. a failure rate of 13% as shown in Table II. The difference between the result of proposed method and reference method is attributed to quantifying the system reliability as a constraint.

V. Manufacturing Tolerance of IPM Motor

Design of an IPM motor based on finite element analysis (FEA) has gained much attention in industry because interactions between the configurations of the motor are various and complex. However, although the IPM motor is designed with FEA, the performances of industrial products tend to decline compared with those of FEA due to manufacturing tolerances and can't be satisfied with those desired performance in certain cases. In particular, as shown in Fig. 4, the manufacturing tolerances of PM occur in manufacturing process. In this case, irregularly coated PM which is glued into the interior of the rotor not pressed causes defective products dissatisfied with back EMF. Thus, it is necessary to employ a reliability-based optimum tolerance design that can consider system reliability.

A. Analysis model

The motor selected in this paper is used for electric sub-water pump of hybrid vehicle as shown in Fig. 4. The rated power and the rated speed are 150 W and 3200 rpm. The detail specifications of this motor are listed in Table III. This motor is driven by rectangular voltage waveforms coupled with a given rotor position. The FEA of an IPM motor is performed by Maxwell 14.0, commercial FEA program.

B. Analysis of manufacturing tolerance from real experiment data

Tolerances can break out any parts of the motor, but the tolerances of PM are especially the decisive factor in the variation of performances. In the manufacturing process, irregularly coated PM is glued into the interior of the rotor rather than being pressed. Therefore, the thickness tolerances of the coating and space between the rotor and PM are considered as a possible problem that gives rise to defective products. In this research, we carry out inspections on the back EMF of 5232 IPM motors made by Keyang Electric Machinery. The histogram on the real experiment data from the industrial products and estimated PDF from AIC method are shown in Fig. 5.

C. Reliability-based optimum tolerance design of IPM motor

The problem definition is stated as follows: the required back EMF value is E =0.819V. Suppose that the thickness and width of the PM have uncertainties due to the manufacturing tolerances. Table IV shows the input parameters and boundary conditions. Suppose that the distribution of the tolerances is in a normal distribution. The problem consists of calculating the set of values for {μ(*Thickness*), μ(*Width*), σ(*Thickness*), σ(*Width*)} which ensures the widest possible set of tolerances for {σ(*Thickness*), σ(*Width*)} while the system reliability fulfills the required reliability, 99.9%. The formulation of reliability-based optimum tolerance design for IPM motor can be expressed as

TABLE III
Main Specifications and Requirements of IPMSM

	Value	Note
Type	IPMSM	-
Slot	6	-
Power	150 W	@3200rpm
DC link voltage	12 Vdc	-
Current limit	15 Arms	-

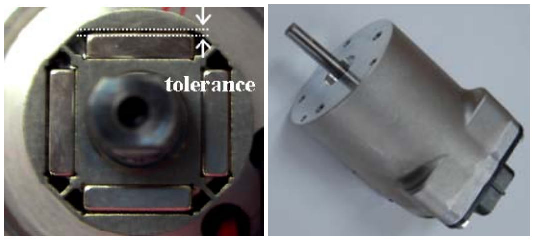


Fig. 4 Cross and side section view of fabricated rotor

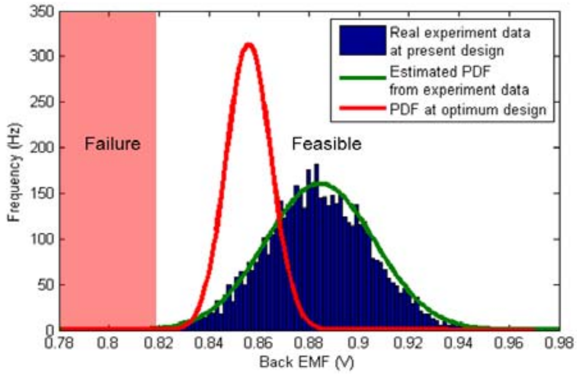


Fig. 5 PDF of the back EMF between the present design and the optimum design

$$\begin{aligned} &\textit{Find} && \boldsymbol{\mu}_{tolerance},\ \boldsymbol{\sigma}_{tolerance} \\ &\textit{Minimize} && \text{cost} = f(\sigma) = \sum_{i=1}^{2}\left(c_0 \frac{1}{\sigma_i^{c_1}}\right) \\ &\textit{Subject to} && G_1 = P\{g_1(\boldsymbol{\mu},\boldsymbol{\sigma}) \le E_{requirement}\} \le 0.001 \\ & && G_{2,3} = P\{g_{2,3}(\boldsymbol{\mu},\boldsymbol{\sigma}) \le \delta_{coated}\} \le 0.001 \end{aligned} \quad (8)$$

where g_1 is the constraint on the back EMF that fulfills the required back EMF. The g_2 and g_3 are the constraints of the minimum that is possible to insert PM into rotors. The mean and the deviation of the thickness and width are considered as the design variables. The required failure rate of the back EMF and the allowable coated space in PM are treated as the design constraints. The demanded failure rate is 0.1%, which is smaller than the currently released motor, 0.18%.

D. Result

Finally, we can find the optimum as given in Table V. The objective function, i.e. the manufacturing cost value, is increased by 3.5% compared with the present products. However, the number of defective motors is reduced from 18 to 7 per ten thousand due to the proposed method, as shown in Table V. Fig. 5 shows the PDF of the back EMF of the present design and the optimum design. As a result, it tells us to find the best compromise between manufacturing price and quality.

VI. Conclusion

In order to balance the conflict design targets between the manufacturing tolerances and the demanded high reliability, i.e. small failure rate, for electromagnetic devices, in this paper, a reliability-based optimum tolerance design method was proposed. The method quantified the reliability using a reliability analysis technique, which is reflected to optimization of the tolerance design. Due to this characteristic, it is more appropriate for the products that demand high reliability than other present tolerance design techniques that consider constraint as the only confidence interval. We tested this approach in two different problems. First, the result of magnetic circuit example presented by Sancho et al. [9] showed the higher reliability than the reference result. Secondly, the tolerance design of the IPM motor considering the tolerances of PM caused by mass-production was performed. The formulation was defined by the proposed method, which was reflected that the statistical information of the product provided by the industry, Keyang Electric Machinery. The result also satisfies the required performance, EMF, in spite of the conflicting constraints, which are high reliability and manufacturing cost. Thus, the proposed method was successfully validated, and we expect that this method will be a helpful tool for manufacturers.

Acknowledgment

The preferred spelling of the word “acknowledgment” in American English is without an “e” after the “g.” Use the singular heading even if you have many acknowledgments. Avoid expressions such as “One of us (S.B.A.) would like to thank ... .” Instead, write “S.B.A. thanks ... .” This work was supported in part by the U.S. Department of Commerce under Grant BS123456 (sponsor and financial support acknowledgment goes here).

References

[1] C.M. Crevering, *Tolerance design : a handbook for developing optimal specifications*, Prentice Hall, 1997.
[2] G.J. Park, T.H. Lee and K.H. Hwang, “Robust design: an overview,” *AIAA Journal*, vol.44, no.1, pp. 181-191, 2006.
[3] G. Taguchi, *Introduction to quality engineering: designing quality into products and processes*, Quality Resources, 1986.
[4] M.D. Al-ansary and I.M. Delab, “Concurrent optimization of design and machining tolerance using the genetic algorithms method,” Int. J. Mach. Tools Manufac., vol. 37, no. 12, pp. 1721-1731, 1997.
[5] G. Suthedand and B. Roth, “Mechanism design: accounting for manufacturing tolerances and costs in function generating problems,” *ASME Journal of Engineering for Industry*, Vol. 98, pp. 283-286, 1975.
[6] S.S. Rao, *Reliability-based design*, McGraw-Hill, Inc, 1992.
[7] Y. Sakamoto, M. Ishiguro, and G. Kitagawa, *Akaike information criterion statistics*, KTK Scientific Publishers, 1986.
[8] W. Lim and T.H. Lee, “Akaike information criterion-based reliability analysis for discrete bimodal information,” Trans. Of KSME (A), Vol. 36, pp. 1605-1612, 2012.
[9] S.S. Sancho, M.P. Angel, G.O. Emilio, A.P. Jose and J.F. Silvia, “A hybrid evolutionary programming approach for optimal worst case tolerance design of magnetic devices,” *Applied Soft Computing*, vol. 12, pp. 2425-2434, 2012.

TABLE IV
PARAMETER DEFINITION FOR IPM MOTOR

Parameter	Search range	Present design	unit
μ(*thickness*)	[2, 3]	2.75	*mm*
μ(*width*)	[10, 12]	11.75	*mm*
σ(*thickness*)	[0.01, 0.1]	0.03	*mm*
σ(*width*)	[0.01, 0.1]	0.04	*mm*

TABLE V
RESULT OF THE OPTIMUM TOLERANCE DESIGN IN IPMSM

	Present design	Optimum result
Parameter	[2.75, 11.75, 0.03, 0.04]	[2.81, 11.67, 0.025, 0.049]
Cost (Obj.)	58.333	60.408
Failure rate [%]	[0.18, 0.01, 0.01]	[0.07, 0.1, 0.1]

.