Association Journal of Interdisciplinary Technics in Engineering Mechanics, Vol. 2, No. 2, 2024
ISSN: 3049-0898

Mechanical Component Design: A Comprehensive Guide to Theory and Practice

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Abstract--- Any framework configuration decides the upsides of the plan boundaries to play out the predetermined assignments. The framework execution may fluctuate around its desired output due to uncertainties. Some of these uncertainties can be controlled while designing the system. The remaining uncertainties are not in control of the designer and are considered as noise. When the system is designed considering these uncertainties, the fluctuation around the desired output can be minimized. Robust design is a technique that ensures that the system will have minimum fluctuation around the desired performance affected by vulnerabilities. The powerful plan of system guarantees that the component will play out the predefined task under impact of vulnerabilities. In this research, a methodology for optimum robust design of mechanism is proposed and discussed, which designs optimum link lengths alongside the ideal connection length resiliences and ideal joint clearances. A technique for powerful plan improvement of component is proposed by considering the observations of parametric analysis of mechanism and robust design using the Taguchi method. The design parameters considered for robust design are all the link lengths, tolerance for all the link lengths and the joint clearances at the two closures of the coupler interface. The methodology is designed to work in loops, in the outer loop the optimization algorithm generated the population as a set of design parameters and in the inner loop, each set of design parameters from the population is analysed for robustness. In the proposed methodology, the joint clearance is considered as a clearance link. The orientation of the clearance link is considered in two ways, randomly orientated in the clearance circle and exactly determined by the dynamic force analysis.

Keywords--- System Mechanism, Taguchi Method, Mechanical Component.

Received: 02 - 03 - 2024; Revised: 05 - 04 - 2024; Accepted: 02 - 05 - 2024; Published: 28 - 06 - 2024

I. Introduction

The system design determines suitable values of the design parameters to perform the specified functional requirement. The desired performance of such a system may deviate due to uncertainties (Polini, 2016). Some of these uncertainties can be controlled while designing the system. The remaining uncertainties are not in control of the designer and are considered as noise. It is necessary to design the system considering all such uncertainties. The robust design ensures that the system has a minimum deviation from the desired performance under the influence of uncertainties. The research work is aimed at robust design optimization of mechanism. A methodology is proposed and discussed for optimum robust design of mechanism, which results in optimum link lengths (Morse et al., 2018). In this research, the effect of these two uncertainties is analyzed by performing experiments on two slider-crank mechanisms. The effect of joint clearance is analyzed by the first slider-crank mechanism, while the influence of link length tolerance and joint clearance is analyzed by the second slider-crank mechanism (Mazur, 2013). The robust design of mechanism by the Taguchi method is well-established in the literature, which is done in three steps. In the first stage, suitable system is decided for the specified task, in this case the system is a mechanism. In the subsequent stage, the upsides of the plan boundaries of the mechanism are designed using deterministic synthesis. In the third stage, suitable tolerances are allocated by tolerance design using the Taguchi orthogonal array. Two approaches for tolerance design are discussed and implemented for the robust design of four bar instrument for way phase. The entirely set in stone by applying resistance plan to a bunch of deterministically orchestrated systems. The observations of analysis of mechanism and tolerance design using Taguchi method are used for proposing a robust design methodology.

In the proposed methodology, the joint clearance is considered as a clearance link, whose orientation is determined in two different ways (Page, 2015). Parameter Variation of Robust Design shown in Figure 1.

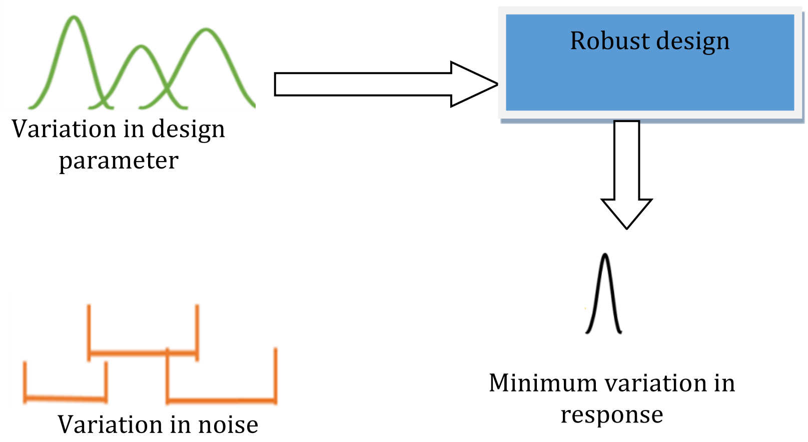

Figure 1: Parameter Variation of Robust Design

The design parameters are the dimensions of components to be manufactured. The variation in design parameters can be represented as a statistical deviation which is normal distribution about a mean value (Rao, 2019). The design parameter value is obtained in the parameter design stage and the deviation is obtained in the tolerance design stage. The noise parameter value is uncontrollable and varies randomly within upper and lower limits. The variation in response is obtained as a statistical deviation. The robust design aims to obtain the minimum value of the response variable with a minimum deviation.

II. Materials and Methods

In the system design stage, the concept of a system is developed. Here, the system to be designed is a four-bar mechanism (Savin-Baden & Major, 2023). Figure 2 shows the flowchart of the generalized process of robust design using the Taguchi method. The parameter design stage determines the values of the design parameters of a mechanism at ideal conditions. Initially, the goal capability for the union of a four-bar system is figured out according to the characterized task. The design parameter values are determined by deterministic synthesis. In the tolerance design stage, suitable tolerances are allocated to the deterministically designed mechanism.

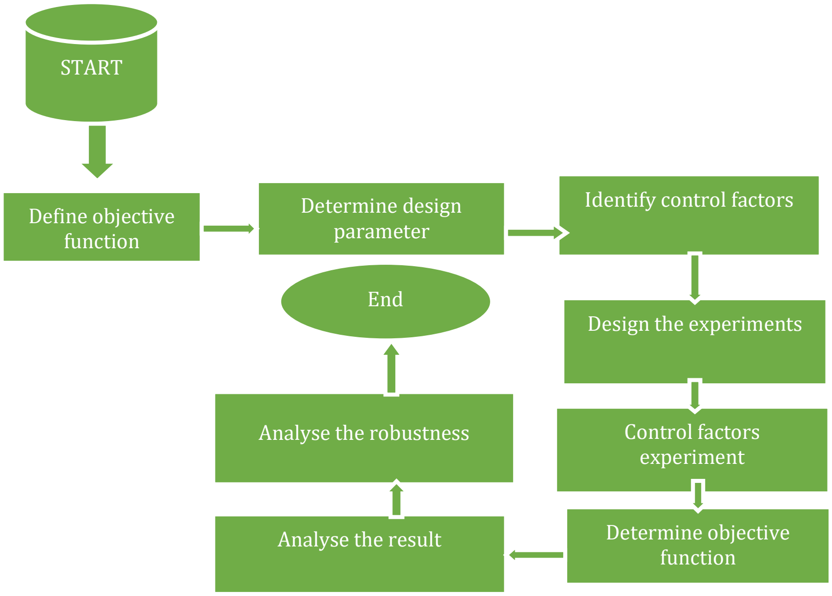

Figure 2: Generalized Robust Design of Mechanism Using the Taguchi Method

The factors which affect the performance of the mechanism are identified and are classified as control factors and clamor factors. In this execution, eight control variables and three commotion factors with three levels each are considered for examination. The investigations are planned involving Taguchi symmetrical clusters for the quantity of variables and their levels. The investigations designed for the control factors are considered as an inner array. The experiments designed for the noise factors are considered as an external exhibit. The planned trials are performed to decide the goal capability esteem (Odell-Miller, 2019). The objective function values are analysed using 'smaller the better Signal to Noise (S/N) ratio' and 'Analysis of Variance (ANOVA)' to determine suitable tolerances. The not entirely settled by plotting the typical dispersion of the goal capability values. In this work, two methodologies to tolerance design as mentioned in the literature are discussed. The first approach is proposed, where the tolerances are allocated at a common level to all the design parameters. The most influencing parameters were identified by determining S/N ratios and performing ANOVA for the robustness of the mechanism. The tolerance of the most influencing parameters was tightened and a confirmation run is performed to check for improvement in the robustness. The approach is implemented to iteratively improve the robustness of a mechanism.

Parameter design of mechanism: The parameter design is the first stage in robust design, where the design parameter values are determined at ideal conditions. The plan boundary upsides of the four-bar component for the way age still up in the air by deterministic union. In this part the method is talked about to decide the plan boundary upsides of the four-bar component, first, the boundaries of the four-bar system are examined alongside the goal capability, next the deterministic combination is performed to decide the plan boundary values.

Objective capability: The goal of blend is the minimization of mistake between the created way and the ideal part. Differential Evolution is used as the optimization algorithm. Objective function values of 500 designed mechanisms are sorted in ascending order. The tolerance design is applied to the best system having the most un-objective capability esteem, as 0.596. Tolerance design is done by allocating suitable tolerances to the best deterministic mechanism using Taguchi orthogonal arrays (Tomlinson & Masuhara, 2017; Collins et al., 2009; Juvinall & Marshek, 2020).

III. Numerical Results and Discussion

The heartiness of the system is investigated by plotting the typical appropriation of the goal capability values for every one of the three cycles. Figure 3 shows the ordinary appropriation of goal capability values for emphasis 1. The mean of the typical dissemination is 6.303 and the standard deviation is 2.791.

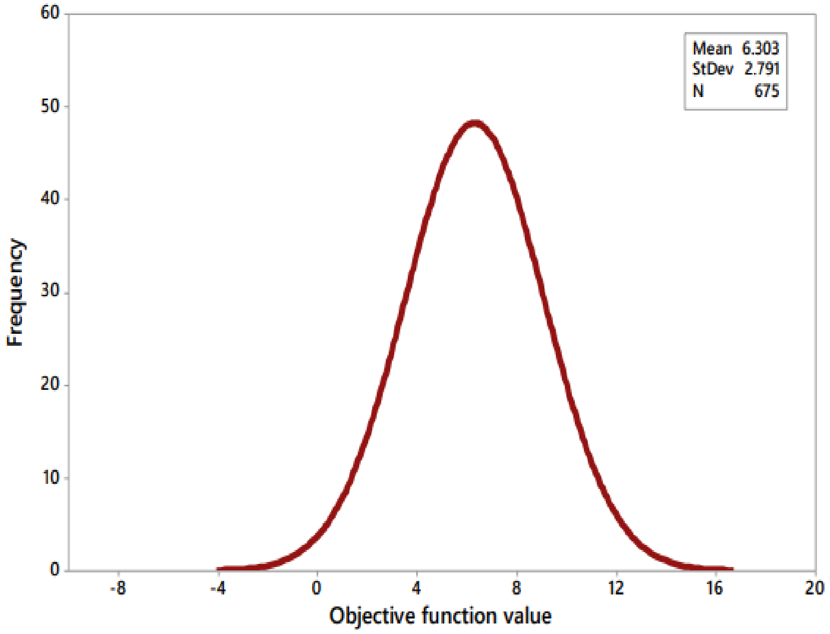

Figure 3: Normal Distribution of Objective Function Values, Common Tolerance, Iteration 1

Figure 4 shows the typical appropriation of goal capability values for emphasis 2. It is seen that the mean has improved to 5.245 while the standard deviation is 2.367. The vigor of the component is further developed subsequent to reexamining control factors in emphasis 2.

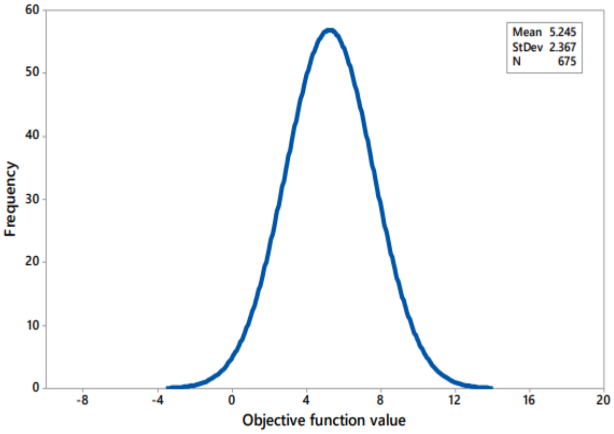

Figure 4: Normal Distribution of Objective Function Values, Common Tolerance, Iteration 2

Figure 5 shows the typical appropriation of goal capability values for emphasis 3. It is seen that the mean has additionally improved to 4.954, while the standard deviation is 2.443. Further improvement is seen in the heartiness of the component at cycle 3.

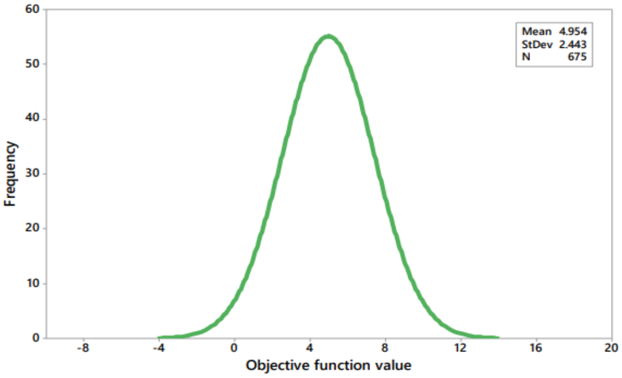

Figure 5: Normal Distribution of Objective Function Values, Common Tolerance, Iteration 3

The mean of the ordinary dissemination of the goal capability values has improved from 6.303 in the main emphasis to 4.954 in the third cycle. Consequently, the normal resilience level methodology for resistance configuration is appropriate for iteratively working on the power of the component.

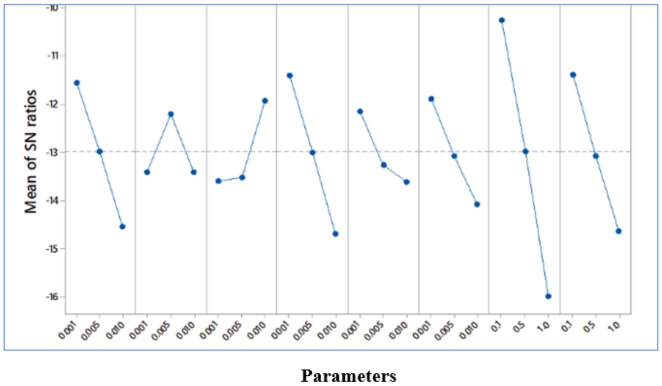

Figure 6: S/N Ratio Plot for Control Factors, Combined Tolerance

To determine the target capability values, a MATLAB program is created. Every analysis from using the MATLAB software is shown in the internal exhibit Figure 6. An iterative approach is the standard resilience level methodology. All of the control elements in the main cycle are given resiliences at the highest possible level of resistance. Since the resiliences of these variables are fixed and the majority of the impacting control is not fully established, the component gains superior strength. After a point-by-point analysis, this strategy makes sense for the resistance section. An instantaneous methodology is the consolidated resistance levels approach. By dissecting every control factor at every resilience level, the resistance distribution is completed. This leads to the distribution of resilience in a single step. This method makes sense for quickly understanding resilience designation.

IV. Conclusions

The Taguchi technique is used to introduce the system's vigorous plan. The system's robust design is completed in two stages. Deterministic union is used to resolve the system's components in the major stage, and a resistance plan is used to distribute the proper resiliences in the following stage. The powerful plan of a four-bar component for a manner age task is executed using the Taguchi approach. Deterministic amalgamation is used in the primary step to resolve the plan boundary values. For the resilience plan of the best deterministically combined component, two resistance planning methodologies—the normal resilience level methodology and the consolidated resistance levels approach—are used in the next step. While the linked resilience levels strategy just assigns the resiliences, the normal resilience level methodology fixes the resistance of the main affected limits in order to further increase the vigor iteratively. It was observed that the conventional resistance level methodology is useful for more point-by-point portions of the resistances, but the consolidated resilience levels approach is useful for quick resistance allocation.

References

[1] Polini, W. (2016). Concurrent tolerance design. *Research in Engineering Design*, *27*, 23-36. https://doi.org/10.1007/s00163-015-0203-2

[2] Morse, E., Dantan, J. Y., Anwer, N., Söderberg, R., Moroni, G., Qureshi, A., ... & Mathieu, L. (2018). Tolerancing: Managing uncertainty from conceptual design to final product. *CIRP Annals*, *67*(2), 695-717. https://doi.org/10.1016/j.cirp.2018.05.009

[3] Mazur, M. (2013). *Tolerance analysis and synthesis of assemblies subject to loading with process integration and design optimization tools* (Doctoral dissertation, RMIT University).

[4] Page, T. (2015). A study into the use of tolerance analysis in the mechanical design of medical devices. *International Journal of Design Engineering*, *6*(2), 116-139. https://doi.org/10.1504/IJDE.2015.076376

[5] Rao, S. S. (2019). *Engineering optimization: theory and practice*. John Wiley & Sons.

[6] Savin-Baden, M., & Major, C. (2023). *Qualitative research: The essential guide to theory and practice*. Routledge. https://doi.org/10.4324/9781003377986

[7] Odell-Miller, H. (2019). *A comprehensive guide to music therapy: Theory, clinical practice, research and training*. Jessica Kingsley Publishers.

[8] Tomlinson, B., & Masuhara, H. (2017). *The complete guide to the theory and practice of materials development for language learning*. John Wiley & Sons.

[9] Collins, J. A., Busby, H. R., & Staab, G. H. (2009). *Mechanical design of machine elements and machines: a failure prevention perspective*. John Wiley & Sons.

[10] Juvinall, R. C., & Marshek, K. M. (2020). *Fundamentals of machine component design*. John Wiley & Sons.