Mechanism and Machine Theory 84 (2015) 67–89

Contents lists available at ScienceDirect

Mechanism and Machine Theory

journal homepage: www.elsevier.com/locate/mechmt

Interval computation and constraint propagation for the optimal design of a compression spring for a linear vehicle suspension system

Hassen Trabelsi [a,b], Pierre-Alain Yvars [a,*], Jamel Louati [b], Mohamed Haddar [b]

[a] LISMMA, Institut Supérieur de Mécanique de Paris (SupMeca), 3 rue Fernand Hainaut, 93407 Saint Ouen Cedex, France
[b] U2MP, Ecole Nationale d' Ingénieurs de Sfax Université de Sfax (ENIS), BP N 1173-3038, Sfax, Tunisia

ARTICLE INFO

Article history:
Received 16 May 2014
Received in revised form 22 September 2014
Accepted 26 September 2014
Available online 8 November 2014

Keywords:
Interval computation
Constraint satisfaction problem
Compression spring
Optimization
Preliminary design
Linear suspension system

ABSTRACT

In this paper an optimization design method based on existing intervals and constraint satisfaction problem "CSP" computer tools is proposed. The method was used in the preliminary design to size a compression spring implemented in a linear vehicle suspension system. Compared to conventional design methods, our design method avoids the passing through two stages of sizing (static and dynamic). Using the numeric CSP approach, static and dynamic requirements can be coupled in the same step of sizing. It also avoids the falling on the loop "design–simulate–back to the initial step in case of failure", as the design parameter values of the compression spring generated by the numeric CSP satisfy all imposed requirements, and the simulation results of the system behavior are always successful and respect all posted constraints. This is due to the fact, that in the CSP, all analytical relation types static and/or dynamic defining the product and its behavior are implemented and integrated from the beginning. So the production of a qualifying system can be achieved from the first time without any need for resizing the system. The general idea of the proposed design method consists of expressing the design variables by intervals; integrate all imposed constraints of different types before the simulation step and solve the problem using the CSP. The generated intervals represent the domains of possible values for the design variables of the product. The obtained result which can be a solution or set of solutions, affirms that the suggested method is valid and potentially useful to size dynamic systems easily and effectively.

1. Introduction

The design activity of mechanical systems is now part and partial of the context of integrated and collaborative design. It requires supporting tools and methodologies adapted throughout the design process [1–4]. We are interested here in problems of optimal design [5–7] of components and we propose an improvement to these tools and methodologies using constraint satisfaction techniques [6–17]. Our approach is applied to an optimal sizing case of a compression spring [18–27]. The springs are structural elements designed to maintain and store the energy and mechanical work based on the principle of the flexible deformation of the material. They are among the components of the most heavily loaded machines and are usually used as:

- Energy absorbing and for commands and reversing devices,
- Interceptors of static and dynamic forces,
- Elements for the creation of strength joints,

* Corresponding author. Tel.: +33 149452925; fax: +33 149452929.
E-mail address: pierre-alain.yvars@supmeca.fr (P.-A. Yvars).

http://dx.doi.org/10.1016/j.mechmachtheory.2014.09.013

- Dampers in the anti-vibration protection,
- Devices for control and measuring force.

Several software tools are available for sizing springs, particularly compression springs one. In most cases it is either a software validation of a given size, or tools allowing very low variability specifications (predefined choices of design variables). We find in [18–22] design optimization tools for springs according to one or more values of the performance variables (weight, cost …).

Generally the algorithm used in those software tools is based on the design process described in Fig. 1. In this approach we generally find three main steps: The first one consists of fixing the design variable values which requires high expertise to provide the initial dimensions. Before moving to the dynamic study, the designer carries out a static test and sets the safety factors according to the imposed requirements. The next step is to achieve the dynamic modeling then to make the dynamic test. So the designer is before two situations. In the first case, if the resulting behavior of the system fulfills the imposed constraints in the specifications document subsequently, the design parameters used in the simulation will be taken as a solution. In the second case, if the system response does not satisfy the imposed constraints, the designer has to change the parameters taking into account the previous simulation. The same sizing steps must be repeated until obtaining the optimal solution (in our case we look to optimize the weight of the compression spring). For most of these works, the designers use mathematical evolutionary algorithm or simulated annealing to minimize the cost function. The optimization phase is mainly based on stochastic methods. These methods do not provide the optimum global, they are just approximation methods. The optimization is global only when the function to be optimized is differentiable and convex.

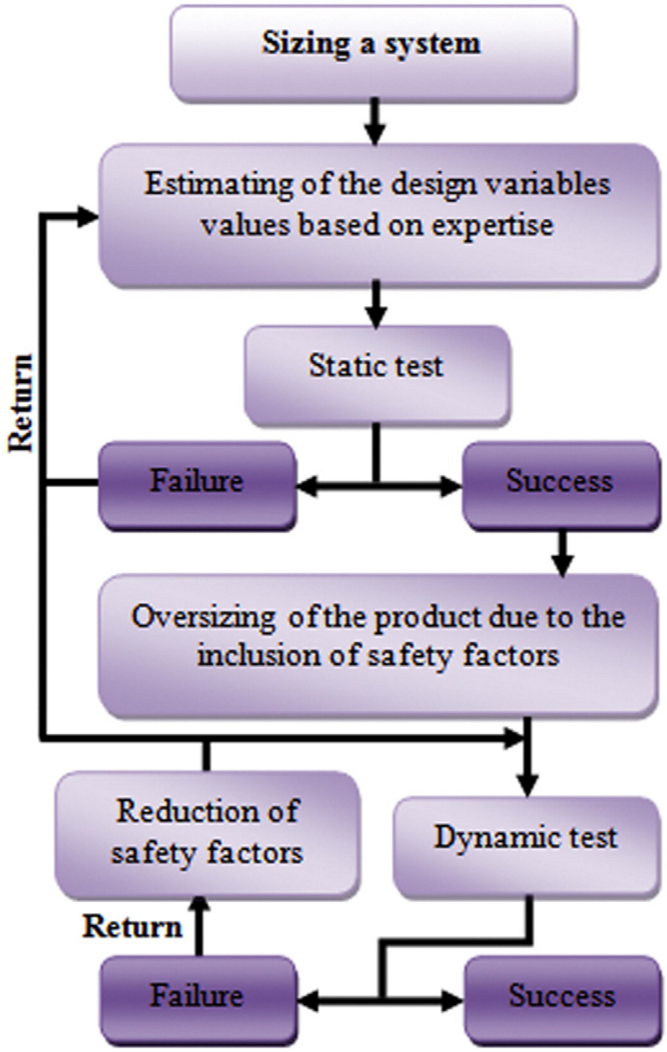

Fig. 1. Conventional method for a system dimensioning.