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A review of optimization of Automobile structures

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Abstract

This paper presents an overview of the optimization and some closely related subjects in the automobile industry. An historical review of the optimization is given. The optimization techniques and the software related to optimization are reviewed. In the end some applications are also listed out.

Keywords

Automobile structure, Optimization Techniques

1. Introduction

Optimization defined as the process of finding the conditions that give the minimum or maximum value of a function, where the function represents the effort required or the desired benefit. Optimization is the act of obtaining the best result under the given circumstances. It is useful for design, construction and maintenance of engineering systems involve decision making both at the managerial and the technological level. The Goals of optimization are to minimize the effort required or to maximize the desired benefit. Successful optimization requires availability of appropriate analysis models and knowledge of the capabilities and limitations of the mathematical optimization techniques. In engineering, most optimization problems are multi-objective in their nature. In a problem with multiple objectives, it is generally impossible to obtain a ranking of all of the alternative solutions, without using further rules or assumptions. In this situation, the decision of the better solution may become subjective, or must rely on additional information, such as the importance of each objective [19].

2. Review History

- Newton (1660s) and G. W. von Leibniz (1670s) create mathematical analysis that forms the basis of calculus of variations. Some separate finite optimization problems are also considered.
- The first optimization algorithms are presented. K.T.W.Weierstrass, J.Steiner, W. R.Hamilton and C.G.J.Jacobi further develop calculus of variations in 19thcentury.
- 1917 H. Hancock publishes the first text book on optimization, Theory of Minima and Maxima.
- 1951 H. Markowitz presents his portfolio theory that is based on quadratic optimization. In 1990 Markowitz receives the Nobel memorial prize in economics.
- 1954 L.R. Ford's and D.R. Fulkerson's research on network problems is a starting point of research on combinatorial optimization.
- 1957 R. Bellman presents the optimality principle.
- 80s as computers become more efficient, heuristic algorithms for global optimization and large scale problems begin to gain popularity.
- 90s the use of interior point methods expands to semi definite optimization.

3. Optimization Techniques

Classical Optimization Techniques
The classical optimization techniques are useful in finding the optimum solution or unconstrained maxima or minima of continuous and differentiable functions. These are analytical methods and make use of differential calculus in locating the optimum solution. The classical methods have limited scope in practical applications as some of them involve objective functions which are not continuous and/or different. Yet, the study of these classical techniques of optimization form a basis for developing most of the numerical techniques that have evolved into advanced techniques more suitable to today's practical problems. These methods assume that the function is differentiable design variables and the derivatives are continuous. There are three main types of problems can be handled by the classical optimization techniques single variable functions, multivariable functions with no constraints, multivariable functions with both equality and inequality constraints.

Numerical Methods of Optimization
Linear programming: studies the case in which the objective function *f* is linear and the set A is specified

using only linear equalities and inequalities. (A is the design variable space)

Integer programming: studies linear programs in which some or all variables are constrained to take on integer values.

Quadratic programming: allows the objective function to have quadratic terms, while the set A must be specified with linear equalities and inequalities

Nonlinear programming: studies the general case in which the objective function or the constraints or both contain nonlinear parts.

Stochastic programming: studies the case in which some of the constraints depend on random variables.

Dynamic programming: studies the case in which the optimization strategy is based on splitting the problem into smaller sub-problems.

Combinatorial optimization: is concerned with problems where the set of feasible solutions is discrete or can be reduced to a discrete

Infinite-dimensional optimization: studies the case when the set of feasible solutions is a subset of an infinite-dimensional space, such as one a space of functions.

Constraint satisfaction: studies the case in which the objective function *f* is constant (this is used in artificial intelligence, particularly in automated reasoning).

Advanced Optimization Techniques

Hill climbing: it is a graph search algorithm where the current path is extended with a successor node which is closer to the solution than the end of the current path. In simple hill climbing, the first closer node is chosen whereas in steepest ascent hill climbing all successors are compared and the closest to the solution is chosen. Both forms fail if there is no close mode. This may happen if there are local maxima in the search space which are not solutions Hill climbing is used widely in artificial intelligence fields, for reaching a goal state from a starting node. Choice of next node/ starting node can be varied to give a number of related algorithms.

4. Optimization Methods

Some of the algorithms developed for optimization are:

- Gradient based algorithm
- Heuristic based algorithm
- Deterministic algorithm
- Stochastic algorithm
- Evolutionary algorithms this includes genetic algorithms. evolution strategy, evolutionary programming and genetic programming.

5. Literature Review

In July 2011,by Kutay yilmazcoban and Yasar kahraman has worked on truck chassis structural thickness optimization with the help of finite element technique the conclude that thinner chassis profiles can be reliable used in the truck chassis section with the help of structural finite element analysis. The total displacements are in thickness of 6mm: 0.6483mm, thickness of 5mm: 0.8098mm and the thickness of 4mm: 1.126mm. The displacement values are less than expected. If the truck loaded with 16t (that is the capacity of this chassis), thickness of 4mm chassis, is bending just about 1mm [5].

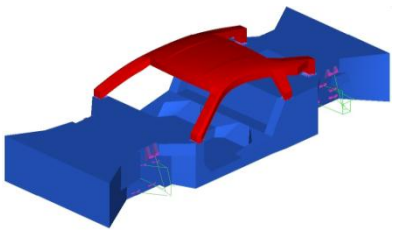
In July 2000, I.Rajendran and S.Vijayarangan has worked on the subject of 'Optimal design of a composite leaf spring using genetic algorithms'. They describe that the leaf springs are optimized by making use of genetic algorithms with a powerful non-traditional optimization method. They also found that the use of violation parameter is much easier than penalty parameter for the to unconstrained optimization problem and optimization using genetic algorithms has contributed to a reduction of 8% of the steel spring weight [12].

Table 1: Comparison [1, 2, 3, 4, 5, 13, 14, 15]

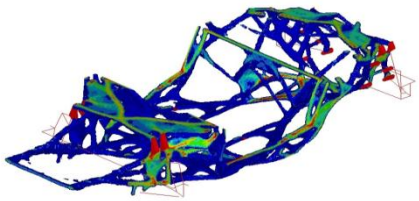
Author	Year	Method	Application
Chien HSING li,Hong Shun Chiou,Yun Yuan Chang	2002	Finite element analysis	Design of gear system
Ian R.Chittick	2008	Asymmetric sub optimization	Aero structural optimization
Jing Heng Wen	2008	Ansys software	Optimization Design for Multiple loads
Lacs Lanzi	2008	Iterative global approximation	Structural optimizations
J.M.Biradar,B.V.Vijay,Kailash Jat	2008	Genetic Algorithms	Sizing Automotive Optimization
D.M.Chauhan,S.B.Soni,A.M.Gohil	2010	Ansys (APDL)	Hydraulic Modular Trailer Frame

Oja Kurdi	2010	Finite element analysis	Stress distribution on heavy duty truck chassis
R Martinez-Val	2010	Parametric analysis	Plan form and cruise condition of a transport flying wing
E Acar	2010	Radial basis functions	Automobile crashworthiness
Waffa Mahdi Salih	2011	Finite element analysis and Stochastic design improvement	Robust design of suspension arm
Kutay Yilmazcoban	2011	Finite element analysis	Truck chassis structural thickness optimization
Marco Cavazzuti	2011	Topology optimization	Automotive chassis

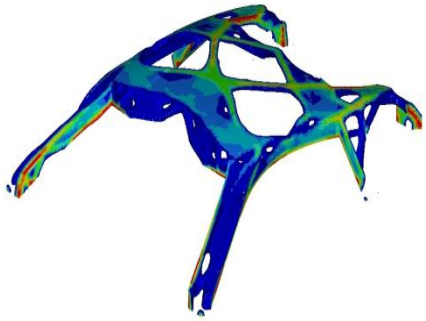
In 2011, Marco Cavazzuti, Dario Costi, Andrea Baldini and Patrizio Moruzzi has worked on a chassis topology optimization. They find weight reduction is a major problem in car industry concern due to safety.



[Figure 1] Design Space



[Figure 2] Optimum Chassis Configuration



[Figure 3] Optimum Roof Configuration

They used a trial and error approach for the design of the car. The weight was reduced 12% [17].

6. Engineering applications of optimization

- Design of structural units in construction, machinery, and in space vehicles.
- Maximizing benefit/minimizing product costs in various manufacturing and construction processes.
- Optimal path finding in road networks/freight handling processes.
- Optimal production planning, controlling and scheduling.
- Optimal Allocation of resources or services among several activities to maximize the benefit.
- Radiotherapy for cancer treatment: optimized narrow X-RAY beam that delivers a specified radiation does to a tumour that minimizes radiation exposure in surrounding healthy issue.
- Global optimization in computational biology.
- Operation research: Design production schedules that harness personnel .Raw materials and transportation systems in a way that optimizes productivity and profit.
- Design telecommunications networks: Capacity is added in a way that maximizes the expected future network performance while meeting budgetary limitations.
- Predict traffic flow in congested road network: Each driver is choose the fastest route between his or her origin and destination. The resulting flow pattern from these individual decision is that all routes actually used will take the same time to travel.[20]

7. Software used for optimization

OptiSLang is one of the most efficient software tools for tasks regarding sensitivity analysis, optimization, reliability evaluation and robustness evaluation. OptiSLang is successfully applied for fatigue-related optimization and robustness problems in a wide range of industrial sectors including automotive, electronics and consumer products.

ANSYS was listed on the NASDAQ stock exchange in 1996. In late 2011, Investor's Business Daily ranked ANSYS as one of only six technology businesses worldwide to receive the highest possible score on its Smart Select Composite Ratings. ANSYS has been recognized as a strong performer by a number of other sources as well. The organization reinvests 15 percent of its revenues each year into research to continually refine the software.

Nexus is software for process integration. It is designed to solve multi-disciplinary and multi-objective optimization problems via a flowchart representation validated on the fly. Nexus is developed by iChrome Ltd., a British engineering and Software Company that is specializes mainly in mathematical optimization and finite element structural analysis. Version 1.1.06 of Nexus was released in September 2011 and runs on Windows or Linux.

SNOPT (for 'Sparse Nonlinear OPTimizer') is a software package for solving large-scale optimization problems written by Philip Gill, Walter Murray and Michael Saunders. It is especially effective for nonlinear problems whose functions and gradients are expensive to evaluate. The functions should be smooth but need not be convex.

8. Conclusion

In this paper, the history and literature are discussed. The techniques and the method of optimization are described. There are different types of software are listed which is very important in the present optimization process. Optimization process is very effective in the automobile structures. The optimization process is cost saving, reduce weight of the structure. Optimization is the act of obtaining the best result under the given circumstances. The Goals of optimization are to minimize the effort required or to maximize the desired benefit.

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