

## DEVELOPMENT OF A SEPARABLE CAR SEAT TYPE MULTI FUNCTIONAL STROLLER BY OPTIMIZATION

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### ABSTRACT

In this paper, optimization of a separable car seat type multi functional stroller based on minimizing total weight, subject to the limits on the structural performance measures. The effects of dimensional imperfections of the members on the minimum weight design of a structure. Design sensitivity coefficients of objective function and constraints are computed and supplied to the optimization algorithm. In this Research Paper the components of the separable car seat type multi functional stroller and its cross sectional imperfection are discussed. This paper illustrated with design concept considering the cases with multiple loading options and some means of deterministic analysis. The achieved optimum solutions for designs with admissible tolerances show significant differences in structural weight. In case of these the proper analytical approaches were given by showing the stresses, deformations and weight. Problems are presented to study the performance of the proposed optimization technique as well as the methodology based on approximation optimization concepts.

**Keywords:** Optimization, Sensitivity, Optimization-algorithm, Deterministic Analysis, Structural Weight.

### 1. INTRODUCTION

Structural shape optimization aims to find an optimum shape, defined by a set of design variables, in order to minimize an objective function while satisfying a set of design constraints. Over the past decades, the scope of structural shape optimization has widened considerably. Optimization is to enhance the weight minimizing of structures remains an active area of research.

Intense global competition in the automotive industry has driven automakers to propel the evolution of optimization methods for design applications. The urgent need to improve product performance, shorten design cycles, reduce cost, and meet increasingly stringent government regulations is the main driving force. The performance of an automobile can be improved in a cost-effective manner by integrating optimization techniques in the design process. In the past decade, the automotive industry has extensively used optimization techniques for component design. As a result, almost any structural part of an automobile can now be optimized using such techniques. Examples of optimization of small parts such as mirrors, steering knuckles, rocker panels, mounting brackets, pillars, seat frames, trunk reinforcements, suspension rings and tie rods or large parts such as engine blocks, chassis and whole car bodies, are abundant in the published literature. For instance, Chen et al. [1] performed the shape optimization of the gas tank. White and Webb [2] used shape optimization method to determine the optimum air cleaner shape and rib design for low shell noise. Chen and Usman [3] present

an application of topology optimization for seam weld reduction of an instrument panel. Leiva et al. [4] utilized sizing optimization method to identify optimum location of automobile welds.

Traditional methods for shape optimization are based on the assumption that the geometry of the structure is defined by the shape of its boundary, and that an optimal design can be found by varying the shape of an existing initial design. Even if at first glance such an approach seems very general, this formulation cannot by itself remove existing boundaries or add new boundaries to the design.

The main difficulties encountered in shape optimization are [5], the continuously changing of the model, since it is difficult to ensure that the accuracy of the analysis remains adequate throughout the design process, and the expense involves in to obtain good sensitivity derivatives with respect to shape design variables than with respect other variables (e.g. sizing variables).

The investigation presented in this paper aims to develop a fully automated shape and material layout optimization system for Car Seat type stroller structures. In last year's some research groups had combined successfully these technologies, but the design domain (ground structure) where topology optimization is formulated has always been supposed to be constant in the course of the process, as proposed for instance by Maute and Ramm [6].

This paper will propose an integrated procedure where GDO and shape optimizations are combined in

automation. Shape and GDO optimization steps are alternated during the process, where the Stroller geometry and sizing variables are optimized sequentially (see Fig. 1). This procedure allows predicting the optimum shape of the structure, but also the optimum material distribution on the model. This formulation involves a variable designing domain for the topology optimization problem, since the shape of the shell mid-plane where the material is distributed changes during the process. The presented method will enhance the exploration of better designs for carrying the applied loads, and provide the designer with a tool which would help to conceive the best configuration of the element considered in each situation.

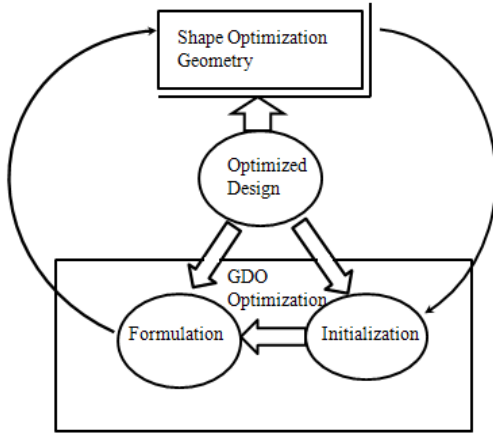


Fig 1. Combined Shape and GDO optimization

The objective of this paper is to present a methodology for Development of a Separable Car seat type by optimizing a Multi Functional Stroller. First, the traditional GDO-based method of optimization using sensitivity analysis is explained. Then the alternative method of optimality criteria is presented. It will be shown that the complex task of shape optimization of nonlinear structures can efficiently be performed by the optimality criteria method. It will also be proved that by this process the structure for the stroller what we get is more efficient and light.

## 2. ADAPTIVE REFORMULATION OF OPTIMIZATION PROBLEMS

A typical design optimization problem for this process can be defined as follows:

$$\text{Minimize } \varphi(b) \text{ Subject to } \psi_i(b) \leq \psi_i^u \text{ and } b_j^l \leq b_j \leq b_j^u \quad (1)$$

Where  $\varphi(b)$  is the objective function;  $b$  is the vector of design variables captured in CAD solid models;  $\psi_i(b)$  is the  $i^{\text{th}}$  structural performance measure with its corresponding upper bound;  $\psi_i^u$ ; and  $b_j^l$  and  $b_j^u$  are lower and upper bounds of the  $j^{\text{th}}$  design variables, respectively.

### 2.1 Goal driven non-linear constrained optimization

Assuming that the objective and constraints are sufficiently smooth functions of the optimization variables  $s$ , the solution of the above constrained optimization problem is characterized by a stationary point of the following Lagrange function:

$$L(s, \beta, \gamma, v) = f(s) + h(s)^t \beta + g(s)^t \gamma \quad (2)$$

where  $\eta$  and  $\gamma$  are vectors of Lagrange multipliers. The Karush–Kuhn–Tucker (KKT) conditions are the first order necessary conditions for a local extremum:

$$\nabla L = \nabla f(s) + \nabla g(s)^t \beta + \nabla h(s)^t \gamma = 0 \quad (3)$$

where  $\nabla(\cdot)$  is the gradient operator with respect to the optimization variables  $s$ . In structural optimization, for example, the objective  $f$  and the constraints  $h$  and  $g$  are typically functions of certain optimization criteria, such as mass, strain energy or stress, which are in turn explicit or implicit functions of the optimization variables  $s$ .

At the optimum,  $\nabla L$  vanishes. For non-optimal designs the norm of the residual together with the norm of the constraint violations can be used to measure the quality of the intermediate result.

### 2.2 Shape optimization

Shape optimization methods provide a powerful tool for challenging design problems in form finding of shell structures. These methods allow to determine the optimum shape of variable contour edges, which define the geometry of the shell mid plane. There are a large number of possible formulations of shape optimization problems.

One may choose to minimize weight, stress, compliance, displacement or any other property that can be derived with the output from a finite element analysis module. In the present study, we formulate the problem as the minimization of the compliance for a fixed volume of material.

In order to incorporate the constraints described above, the penalty method is used. In this method the fitness of an individual design is increased when constraints are violated. Then Eq. (4) can be written in the following way:

$$g_i = W + \lambda |\Delta \sigma|^2 + \mu |\Delta V p|^2 + \eta H_1(g_c, 0) + \xi H_2(g_s, 0) \quad (7)$$

where  $g$  is the penalized weight,  $i$  the structured index,  $|\Delta \sigma|$  the allowed stress minus acting stress,  $|\Delta V p|$  the allowed control-points coordinate minus actual control-points coordinate,  $H_1(g_c, 0)$  the function that measure the elements shape distortion. If there exist some singular or negative Jacobians  $g_c = aW$ , otherwise  $g_c = 0$  and  $H_2(g_s, 0)$  the function that measure the violation of side constraints. If one or several side constraints are violated  $g_s = \gamma W$ , otherwise  $g_s = 0$ .

The parameters  $\lambda$ ,  $\mu$ ,  $\eta$ ,  $\xi$ ,  $\sigma$ ,  $\gamma$  are adjusted by trial and, in this paper, they have been evaluated in such a way that a 10% of violation in every constraint increases the original weight by about of 10%.

### 3. GEOMETRY BASED MODELING

The solid modeling system used herein is based on geometric element modeling. This type of modeling is based on three main aspects [7]: problem formulation through geometry, geometry representation and geometry manipulation.

The formulation of the shape optimization problem by using the geometry is depicted in Fig. 2. The process begins using solid design elements to define the problem

geometry. Then, the mesh control information is defined on the boundary as well as the problem-specific attributes, such as material properties, loads, boundary conditions, etc., are assigned to the model.



Fig 2. Modeling process

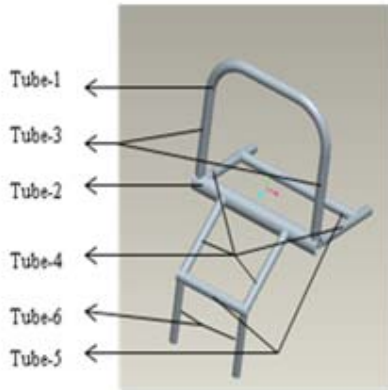


Fig 3. Geometric entities

#### 4. NUMERICAL SIMULATION IMPLEMENTATION

The implementation part is basically consists of 3 parts. These 3 parts are very important for the stroller optimization cases. Three parts are:

1. Space size determination
2. Determination of optimized design criteria by GDO optimization
3. Weight minimization by the Shape optimization

##### 4.1 Space Size Determination

Table 1: Space size dimension of different cars:

Type	Length (mm)	Width (mm)	Height (mm)
1	520	310	330
2	480	300	300
3	560	300	320
4	500	310	310
5	530	320	300
Optimum	518	308	312

#### 4.2 Optimized Design Criterion By GDO

For the optimization by GDO process we consider two criteria for the selection of force

(a) Give the movement force to the stroller.

(b) Give the force to the stroller main edges by the baby. In case of this condition I used the weight of baby considering that the baby is 2 or 2.5 yrs old. The weight of the baby is 6-8.5 kg. So I used the forced as 60N.

Optimization history of tube selections:

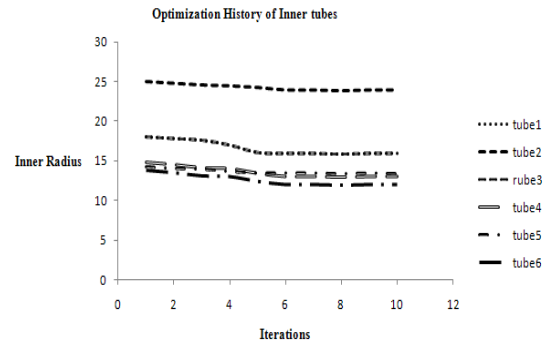


Fig 4. Optimized radius selection (Inner tube)

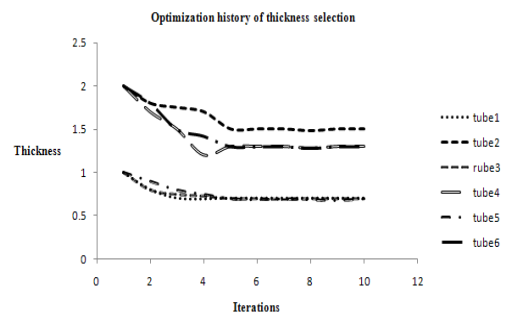


Fig 5. Optimized thickness selection

Sensitivity analysis for selecting the tube radius of optimal value:

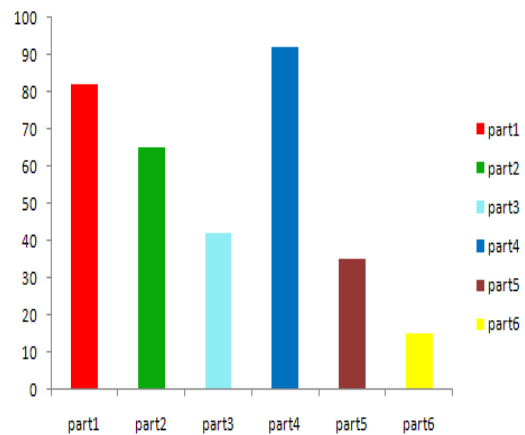


Fig 6. Sensitivity analysis for tube radius selection

Table 2: Optimum dimension of tube inner and outer radius and thickness

Tube	Inner (mm)	Thickness (mm)	Outer (mm)
1	16	0.7	16.7
2	24	1.5	25.5
3	16	0.7	16.7
4	13	1.3	14.3
5	13.5	1.7	15.2
6	12	1.3	13.3

Table 3: Weight minimization from initial condition to GDO optimization

Tube	Initial Dimensions		
	Inner Radius (mm)	Outer Radius (mm)	Thickness (mm)
1	15	17	2
2	15	17	2
3	15	17	2
4	15	17	2
5	15	17	2
6	15	17	2

Optimal dimensions			Weight Reduction (%)
Inner Radius (mm)	Outer Radius (mm)	Thickness (mm)	
16	16.7	0.7	12
24	25.5	1.5	31
16	16.7	0.7	9
13	14.3	1.3	17
13.5	15.2	1.7	20
12	13.3	1.3	13

#### 4.3 Weight Minization By Shape Optimization

Here in the selection of Shape optimization first application of the modeling in the program. Then applied all the conditions and finally by 10% reduction of weight will get the optimized weight of the stroller.



Fig 7. Geometry dimensions, boundary and load conditions for the stroller



Fig 8. Final optimized shape and optimal weight of the stroller

Table 4: Shape optimization data for 10% reduction of weight for the optimal structure

Type	Mass (Kg)	Target Reduction (%)	Support Type
Original	0.580		
Optimal	0.522	10	Fixed

## 5. RESULTS

It is found that in case of our procedure we obtained the optimal dimensions for stroller by the GDO process and optimized mass and final shape by the Shape optimization process. Typical results are shown in Fig. 7, Fig. 8 & Table 4. In fig. 7 it shows the optimized dimensions of the tubes strollers and the modeling and fig. 8 it shows the final shape given by the shape optimization and Table 4 gives the specific optimized result by reducing the original weight by 10%.

## 6. CONCLUSION

A new methodology for shape optimization of a separable car seat type stroller has been developed. Two optimality criteria have been proposed and combined with a geometrically nonlinear analysis. The method changes the shape of the structure so that the average optimized weight (or variation for the case of thickness optimization) for all design variables become uniform. It has been shown that this method converges to the optimum shape in less number of iterations compared to the standard gradient-based methods of optimization. It is concluded that the complex task of shape optimization of nonlinear structures can efficiently be performed by the proposed methodology.

An integrated approach for three-dimensional shape optimal design using genetic algorithms and mesh parameterization has been presented. The definition of geometry through shape geometric entities provides a great versatility for the characterization and control of the body shape. Also, the use of GDO and Shape optimization as optimization technique increases the performance of the developed tool due to its great advantages as compared with traditional optimization techniques.

The use of this combined optimization tool provides

an alternative, effective and realizable way to solve this kind of problem and their encourages its application to more complex three-dimensional shape optimization problems.

More studies are currently conducted by the authors to determine the performance of the proposed algorithm in the design of large scale structures, and also how to consider and modify the imperfection during shape optimization. The results of such studies will be reported in the near future.

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