MULTIDISCIPLINARY DESIGN OPTIMIZATION FOR MULTI PURPOSE DESIGN OF TRUCK

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Abstract

Multidisciplinary Design Optimization (MDO) problem are often encountered in many industrial areas and aspect. MDO refers to the optimization of systems of subsystem (disciplines). The optimization of the full system is often reduced to hierarchy of optimizations at subsystem and system levels. Multidisciplinary Design Optimization is a body of methods and techniques for performing the above optimization so as to balance the design considerations at the system and detail levels.

This paper will be presents an application of MDO for multi purpose design of truck, case study in Toyota Dyna. That body of truck can be used for some purpose, example for fluid tanker, mixer truck, bulk and box truck and other purpose. The successful design requires harmonization of a number of objectives and constraint. However, dimensionality of such optimization and the complexity and expense of the underlying analysis suggest a decomposition approach to enable concurrent execution of smaller and more manageable task. We identify that the fundamental approach to modeling the design depend on lumped mass, vehicle fixed coordinate system, motion variable, earth fixed coordinate system, euler angles, and force. The master problem for multi purpose design of body truck is to maximize the contain capacity, with design variable are length, wide and high of the body. The sub problem are minimize the centrifugal force, roll threshold and suspension.

The result of this paper will be giving the optimum condition of the body dimension and helpful the design to reduce time for design. Finally, quality of product will be increase, reducing cost and thereby being competitive.

Key word: Multidisciplinary, Design, Optimization, Optimum, Vehicle, Truck

1. INTRODUCTION

The market of heavy vehicle –medium truck- in the several years has been increased in Indonesia. This phenomena are depend on the economic performance, the easier foundation from bank, and the recovered from monetary crisis in Indonesia. There are a lot of MERK and type in multi purpose truck. For example, Toyota Dyna have five variant -115ST, 115 ET, 125 LT, 125HT, 140GT- for 3.700 cc – 4.600 cc class. The customers can be choose the type or model depend on need and purpose. The body of truck can be change to the other purpose vehicle, for example mixer truck, box truck, power gate lifter truck, oil or fluid vehicle and etc. (see figure 1). The design and development process of a car body is a very complex process, as various functional requirements have to be considered. To design the body of truck we must pay attention the specification of truck, regulation, dimension, technical aspect, and vehicle stability. That is complicated to accommodate all aspect, but as designer we must observe all of design aspect. The design of large and complex system requires making appropriate compromises to achieve balance among many coupled objectives such as high performance, safety, simple operation and low cost. The effect of this problem, designer needed more time to design the body of the truck.

The difficulties associated with conceptual design are (i) conceptual design is characterized by a low level system and (ii) the relationships among design objectives and the conceptual design parameters are often not well modeled or understood. This results in probably inefficient final design.

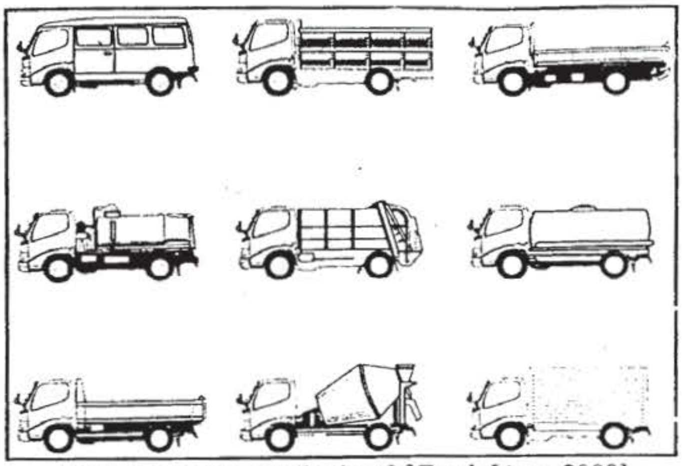

Fig 1. Multi Purpose Design Of Truck [Auto 2000]

2. MULTIDISCIPLINARY DESIGN OPTIMIZATION

2.1 MDO as a Strategy in The Design Process.

Multidisciplinary design optimization is a useful and challenging activity in many disciplines. It provides decision makers with tools for producing better decisions while saving time in the decision process. Nowadays, a multitude of new constructions and their corresponding designs require much closer attention because more than one main criterion corresponding the aspect [2]. The following aspects show the necessity of introducing optimization procedures into the practical design phase:

1. Increasing the quality and quantity of products and plants and at the same time reducing cost and thereby being competitive.
2. Fulfilling the permanently increasing specification demands as well as considering reliability and safety, observing severe pollution regulations and saving energy and raw materials.
3. Introducing inevitable rationalization measures in development and design offices in order to save more time for the staff to work creatively.

Most multidisciplinary design optimization strategies require a complete formulation of the problem; that is, the objective function, the constraint equations, and the bounds on the decision variables need to be clearly defined in mathematical terms [2]. When using a conventional optimization package a decision maker has to select from different methods available for multidisciplinary optimization to suit the problem domain. In general, the following aspects have to be considered in selecting the appropriate procedure for the problem at hand - type of decision variables, number of objectives, nature of objective functions and constraints, availability of gradients of objectives functions and constraint functions -. Thus, considerable experiences and mathematical background is expected from the decision maker in selecting the best possible optimization procedure.

2.2 Optimization Problems

Consider the general nonlinear constrained optimization problem mathematically as follows [3]:

Minimize/maximize:	$F(X)$	objective function	(1)
Subject to:			
$g_j(X) \leq 0$	$j = 1,m$	inequality constraint	(2)
$h_k(X) = 0$	$k = 1,l$	equality constraint	(3)
$X_i^l \leq X_i \leq X_i^u$	$i = 1,n$	Side constraint	(4)

The vector **X** is referred to as the vector of design variables.

Most optimization algorithms require that an initial set of design variables, X^0, be specified. Beginning from this starting point, the design is update iteratively. Probably the most common form of this iterative procedure is given by [3];

$$X^q = X^{q-1} + \alpha^* S^q \qquad (5)$$

Where q is the iteration number and S is a vector search direction in the design space. The scalar quantity α^* defines the distance that we wish to move direction S.

In the application of optimization techniques to design problems of practical interest, it is seldom possible to ensure that the absolute optimum design will be found subject to the constraint. This may be because multiple solutions to the optimization problem exist or simply.

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3. VEHICLE STABILITY

3.1 The Principles to Vehicles

These same principles apply to our vehicles and, while they can't be eliminated, they can be controlled [4].

Speed

The effect of speed on cornering stability, braking distance and impact forces increases at the square of the speed increase. This means, for example, that cornering forces don't just double when the vehicle speed doubles, they increase by four times.

This effect is highlighted in Figure 3. The arrow in the left-most illustration represents the overturning force acting on a truck in 30 kilometers per hour (km/h) corner. If the same truck is driven through the same corner at 60km/h, the overturning forces will be four times higher (2 x 2 = 4, speed squared effect), represented by the arrow in the middle illustration. If the truck is now driven through the corner at 90km/h the overturning forces will be nine times higher (3 x 3 = 9, speed squared effect) than at 30km/h, as in the third illustration. This speed squared effect has a dramatic impact on vehicle stability and controllability.

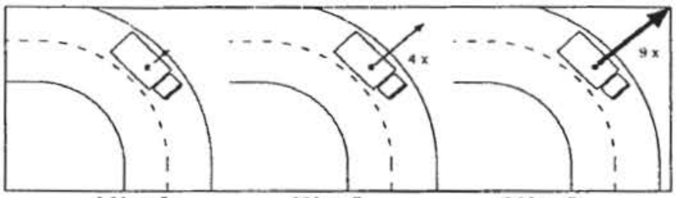

Figure 2. Speed squared effect on cornering forces [4]

Gravity

Gravity creates a force that, in simple terms, attracts everything towards the centre of the earth. Every object affected by gravity has a centre of gravity (CG): the point around which the object is balanced in all directions (Figure 3). The higher of CG are more unstable the object (such as a truck). The closer to the ground, the more stable the object.

In vehicle terms, if a load is not centered across its width, the stability will be reduced when cornering. If the load is not balanced correctly along its length, wheel lockup during braking becomes more likely.

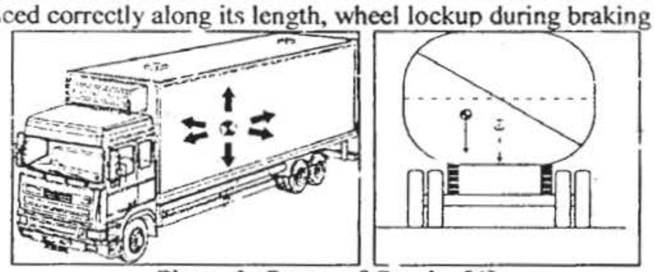

Figure 3. Center of Gravity [4]

Kinetic Energy

Kinetic energy is the energy contained in a moving object. The heavier and/or faster the object, the more energy it will contain. The effects of kinetic energy increase at the square of the speed and have a major influence on all motor vehicles in three particular situations: braking, cornering and impact.

Friction

Friction is the resistance to motion that occurs when one body or surface moves across another. On a vehicle the most common points of friction are the brakes, the tyre contact with the road, air resistance and engine and transmission components. Friction creates heat. Vehicle braking systems produce large amounts of heat, but the secret to a good braking system is its ability to dissipate, or remove, that heat quickly. The faster a vehicle is traveling, or the heavier it is, the more heat the brakes generate in bringing the vehicle to a stop.

Centrifugal force (overturning or side force)

Centrifugal force causes passengers to slide across the seat when cornering at high speeds and happens when a moving object, such as a vehicle, changes direction.

The weight of a vehicle means that when traveling in a straight line it will Endeavour to continue in that direction, even when the driver turns the steering wheel. Changing direction causes the vehicle's

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weight to move to the outside of the turn which, unless the driver controls its speed, can lead to rollover or sliding out potential to do a great deal of damage over a greater area for the same reason.

Static roll threshold (SRT)

SRT describes the maximum amount of lateral (sideways) acceleration a heavy vehicle can handle without rolling over. This depends on the vehicle's speed and the tightness of the turn. The centrifugal (side) force created by the lateral acceleration will push a part of the vehicle's weight to the outside of the curve when the driver turns the steering wheel.

Side force tipping truck over = weight of truck x lateral acceleration (a). (5)

Vertical force = weight truck (W) x acceleration on the road (g) (6)

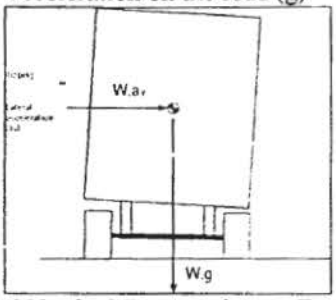

Figure 4. Side force and Vertical Force acting on Truck During Concerning

4. IMPLEMENTATION AND DISCUSSION

The conceptual design multi purpose truck has highly coupled and significant data exchange and iterations are often required among discipline and disciplinary tool as shown in figure 5 bellow:

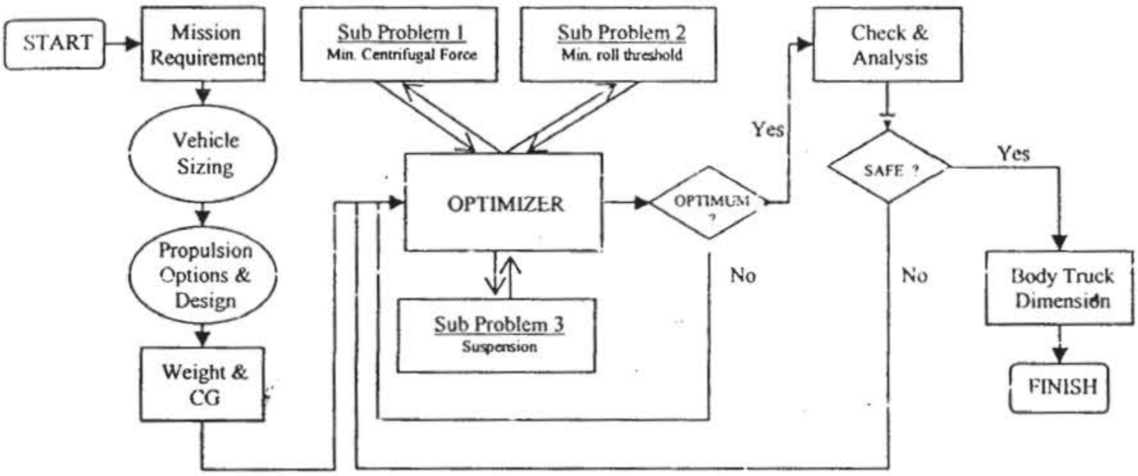

Figure 5. Schematic Diagram

4.1 Geometry Definition

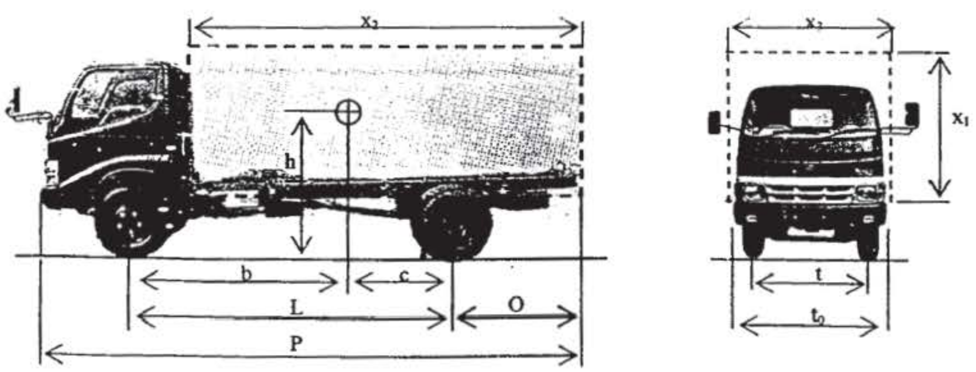

Figure 6. Dimension of Truck [AUTO 2000]

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x_1	= height of body truck	b	= distance from front axle to CG
x_2	= length of body truck	M	= mass of the vehicle
x_3	= wide of body truck	c	= distance from rear axle to CG
t	= front tire distance	V	= speed
t_o	= outer distance	P	= total length of truck
L	= wheel base	C	= capacity
O	= overhange		

4.2 Implementation

We will give one example of implementation multidisciplinary design optimization for box body of truck.

Master Problem :

Maximize contain capacity:

$$F(X) = x_1 . x_2 . x_3 - C$$

Subject to :

- $x_2 < 3.040$ mm (for 4 wheel)
- $x_2 < 4.285$ mm (for 6 wheel)
- $x_3 - t_0 < 100$ mm
- $O < 0.625$ L

Independent variable (depend on type of truck)

- Front tire distance
- Wheel base
- Distance from front axle to CG
- Mass of the vehicle
- Distance from rear axle to CG
- High of truck
- Total length of truck

Sub Problem 1

Minimize : Centrifugal Force

Subject to :

- Maximum speed
- Load capacity

Sub Problem 2

Minimize : roll threshold

Subject to :

-Maximum lateral acceleration

- Max weight of truck

Independent Variable:

- Gravitational Force

Sub Problem 3

Minimize : suspension load

Subject to :

-Max weight of truck

Independent Variable:

- Gravitational Force

5. CONCLUSION

The result of this study, using the multidisciplinary design optimization the sizing and weight estimation in loop process gives optimum dimension. The optimum depend on dimension of type of body truck and contain capacity. The study shows that calculating and analysis for dimension and weight estimation in conceptual design does not need more time.

6. ACKNOWLEDGEMENT

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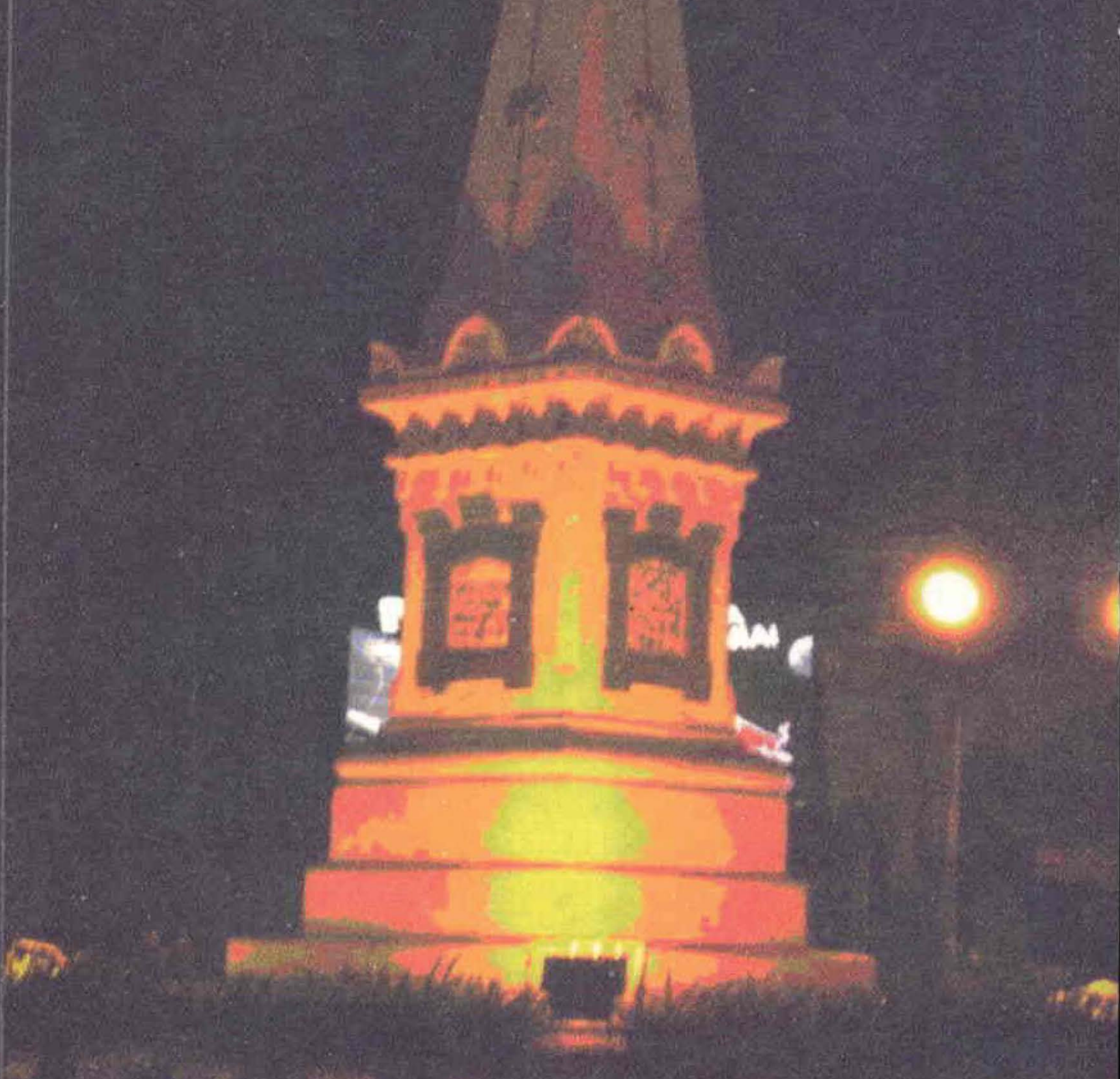

December 13 and 14, 2006
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FOREWORD

One of the results in the first seminar on Product Design & Development 2005 that was held in Yogyakarta on December 20 – 21, 2005, the Department of Mechanical and Industrial Engineering Gadjah Mada University has decided to establish this seminar becomes an annual event. The theme of this year seminar that is held on December 13-14, 2006 is "Frontiers in Product Design & Development". The aim of the seminar is to bring all industrial practitioners, researchers, educational staff members, students, enterpreneurs, etc. to be able to communicate each other and to share their experiences. The synergy of all potencies above is necessary to maximize the ability of international industrial competitiveness in design and development of product. This includes the ability to create new products with competitive cost and innovative design. These products do not mean that they come from nothing, but they also cover improvement of existing products, utilization of products for various applications, or functional diversification and complementary of product equipment.

The 44 selected papers from universities, research institutions, industries, and other institutions from different countries, such as Indonesia, Malaysia, Japan, New Zealand are presented in this seminar. The papers cover various aspects of Product Design & Development including:

- Design for Manufacturing
- Management of Product Design and Development
- Teaching Materials in Product Design and Development
- Material Development
- New Product of Manufacture Industry and Others
- Rapid Prototype, Ergonomy
- CAD/CAM
- Forecasting and Optimization

We would thank all authors who have done the best to present their papers and share their experiences. We also appreciate to all reviewers for their great contribution. Finally, we hope that the seminar will give a great contribution in improving the field of Product Design & Development from any aspects.

December, 2006
Dr. Khasani
Chairperson of International Seminar on
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