UNIVERSITI TEKNIKAL MALAYSIA MELAKA

UTEM FV MALAYSIA RACING CAR SUSPENSION OPTIMIZATION USING GEOMETRICAL OPTIMIZATION

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Engineering Technology (Type your Department's course here) (Hons.)

by

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor Degree of Mechanical Engineering Technology (Automotive Technology) with Honours The member of the supervisory is as follow:

……………………………….

(**MUHAMMAD ZAIDAN BIN ABDUL MANAF**)

ABSTRACT

The title of this project is “ UTeM FV Malaysia racing car suspension optimization using geometrical optimization ”. A suspension system for UTeM FV Malaysia racing car will be model by MotionView software using multibody dynamic method. In the vehicle suspension design the optimal suspension should fulfil the following basic requirements: the ride comfort, reduction of dynamic road-tyre forces, and reduction of relative motions between the vehicle bodies. In this project, push rod double wishbone suspension system is used and then analyse the suspension system using kinematic and compliance method. This analysis is done to study the movement of each components in UTeM FV Malaysia racing car suspension and optimize the suspension geometry (kinematic) and shock absorber characteristic (compliance) using geometrical optimization. MotionView analyze data for vehicle dynamics of resulting design and provide the information about the comparison of analyzing data for vehicle dynamics and suspension performance. The optimization method helps to find the optimum locations of the hard points efficiently. For each iteration in the process of optimization, prediction uncertainty is considered and the multi objective optimization method is applied to optimize all the performance indexes simultaneously. It is shown that the proposed optimization method is effective while being applied in the kinematic performance optimization of a push rod double wishbone suspension system. Several optimization techniques were made to optimize the parameters .The study will cover on both front and rear suspension system. As known Suspension system give our car stability, steering control and improve comfort. The suspension allows the wheels to move up and down independently from the rest of the car. That will keep the wheels on the road when hit bumps.

ABSTRAK

Tajuk projek ini adalah "pengoptimuman suspensi kereta lumba UTeM FV Malaysia dengan menggunakan pengoptimuman geometri". Sistem suspensi untuk kereta lumba UTeM FV Malaysia dimodelkan oleh perisian MotionView dengan menggunakan kaedah dinamik multibodi. Dalam mereka bentuk suspensi kenderaan yang optimum perlu memenuhi syarat-syarat asas berikut: keselesaan perjalanan, pengurangan daya dinamik jalan-tayar, dan pengurangan gerakan relatif antara badan-badan kenderaan. Dalam projek ini, rod sistem suspensi wishbone digunakan dan kemudian menganalisis sistem suspensi yang menggunakan kaedah kinematik dan pematuhan. Analisis ini dilakukan untuk mengkaji pergerakan setiap komponen di UTeM FV Malaysia suspensi kereta lumba dan mengoptimumkan geometri penggantungan (kinematik) dan kejutan penyerap ciri (pematuhan) menggunakan pengoptimuman geometri. MotionView menganalisis data untuk dinamik kenderaan yang disebabkan reka bentuk dan menyediakan maklumat tentang perbandingan menganalisis data untuk dinamik kenderaan dan prestasi suspensi. Kaedah pengoptimuman membantu untuk mencari lokasi yang optimum. Bagi setiap lelaran dalam proses pengoptimuman, ramalan ketidakpastian dianggap dan kaedah pengoptimuman objektif berbilang digunakan untuk mengoptimumkan semua indeks prestasi pada masa yang sama. Ia menunjukkan bahawa kaedah pengoptimuman yang dicadangkan adalah berkesan ketika sedang digunakan dalam pengoptimuman prestasi kinematik pada rod sistem suspensi wishbone. Beberapa teknik pengoptimuman dibuat untuk mengoptimumkan parameter kajian. Kajian ini akan merangkumi kedua-dua sistem suspensi depan dan belakang. Sistem suspensi dikenali untuk memberikan kestabilan pada kereta, mengemudi kawalan dan meningkatkan keselesaan. Suspensi ini membolehkan roda untuk bergerak ke atas dan ke bawah secara bebas dari seluruh kereta. Yang akan membuat roda di jalan raya apabila melanggar sesuatu.

DEDICATIONS

To my beloved parents

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First, I am really grateful to Allah S.W.T because the strength that He give to me. I finally can have finished my Bachelor Degree Project without any problem or delay. I am also very grateful to Allah S.W.T for granting me strength and wisdom to overcome the problems to accomplish this project.

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CHAPTER 1

INTRODUCTION

1.0 Introduction

Suspension is the framework that comprises of tires, tire air, springs, safeguards and linkages that unites a vehicle to it wheels. This will permits relative movement between that segments. Three principle elements of suspension frameworks, it is critical for the suspension to keep the street wheel in contact on the grounds that all ground powers following up on the vehicle do as such through the contact patches of tires, will impact to the vehicle's street taking care of and braking for good dynamic security and driving joy, and keeping vehicle tenants agreeable and a ride quality sensibly very much detached from street clamor, knocks, and vibrations. These objectives are for the most part at chances, so this tuning of suspension will includes discovering the right trade off. This suspension likewise shields the load and vehicle from harm. The configuration of back and front suspension arrangement of an auto may be not quite the same as one another.

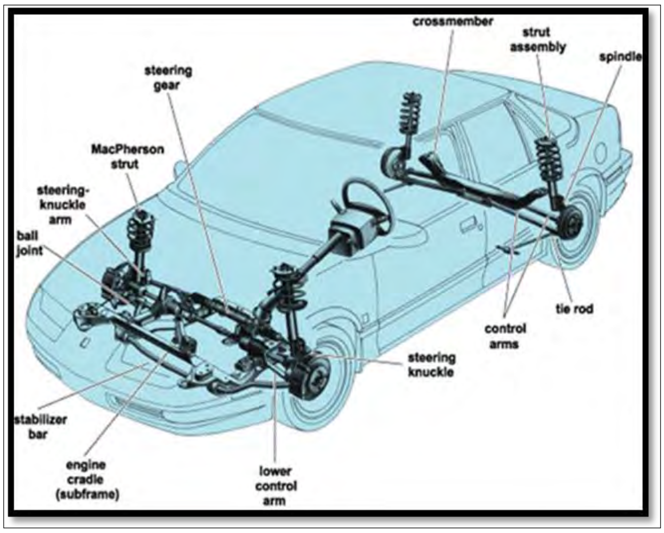

Figure 1: Full vehicle suspension hard point

There have a wide range of sorts of suspension relying upon vehicle model. Its motivation is give a superior driving solace and to diminish the impact of knocks. The motivation behind the suspension framework is to seclude the vehicle from street vibrations which would somehow or another will be exchanged to the travelers. Additionally it keep the tires in contact with the street surface. An essential suspension framework comprises of arms, bars, springs, axles, safeguards, rotating appendages and some more. The spring is adaptable part of the suspension and it writes are loop springs, torsion bars and leaf springs. Current traveler for the most part utilize light loop spring. Business vehicles have heavier springs than traveler vehicles, and have leaf springs at the back and curl springs at the front.

Strong, axles interface the wheels on each side of vehicle. The development of a wheel on one side of the vehicle is exchanged to the wheel on the other side. By utilizing free suspension, the wheels can move autonomously of one another, then it will lessens body development. This will keep the other wheel from influenced by development of the wheel on the inverse side. This will diminishes body development.

Safeguards hose spring motions by give power on oil through little gaps. The oil will warms up, then ingests the vitality of movement. At that point warmth exchanged through the safeguard to the air. At the point when vehicle hits a deterrent, the extent of response power will relies on upon how much unsprung mass at every wheel. Unsprung mass incorporates the tires, brake and gatherings wheels. Vehicle ride and taking care of will enhanced if unsprung mass is low.

1.1 Problem Statement

Generaly, suspension system will improve comfort, car stability and steering control . The suspension allows the wheels to move down and up independently. This will keep the wheels on the road when hit bumps. To model UTeM FV car suspension. Before this, in FV car suspension development there is no suspension optimization. Optimize the suspension design by using suitable optimization method such as RMAS by using HyperWork software. Conventional single body method, which based on 14 D.O.F mathematical model using MATLAB or any other numerical computing software were enable to predict dynamics response as good as multibody dynamics (MBD) approach. This not accurate because the previous method in dynamic response is using mathematical model (14 D.O.F). Finite Element Analysis (FEA) which commonly use in CAE design only capable for structure analysis but incapable to measure the dynamics performance of suspension systems. This because the dynamics performance of suspension system is unknown. But by using MBD method, before fabrication we can get the suspension performance .

1.2 Objective

In light of the title " UTeM FV malaysia racing car suspension optimization using geometrical optimization ", the targets to be accomplish are as beneath :

1). To model the push rod double wishbone suspension system for UTeM FV Malaysia racing car using Multibody Dynamics (MBD) method.

2). To find the correlation between the suspension parameter.

3). To optimize the suspension geometry (kinematic) and shock absorber characteristic (compliance) using geometrical optimization.

1.3 Scope

The scope of this project are to select the vehicle level requirement using motion view. Other scope is location of hard point by control the static settings and the kinematic of the suspension that can be done graphically by CAD and kinematics software.

The loads and geometry are use to design design shock absorbers characteristics and spring rate by using K&C analysis. The design of structure for loads and geometry for each components will used to design the spindle and arms. Then, motion view will analyze data and will provide the information about comparison of analyzing data for suspension performance and vehicle dynamics.

Then, by using HyperWorks software, a kinematics and compliance analysis will be run to study the movement of each component in UTeM FV Malaysia racing car suspension. Then the optimization of the suspension geometry (kinematic) and shock absorber characteristic (compliance) geometrical optimization will be done using HyperWorks Motion View.

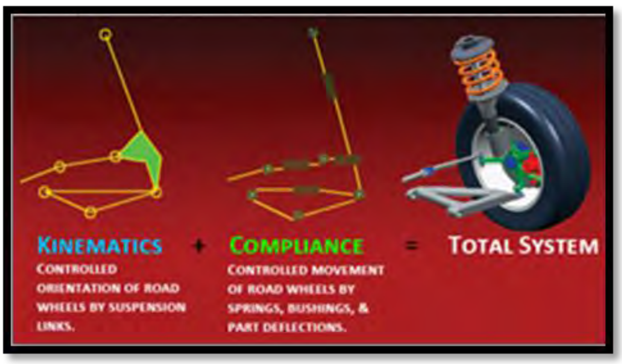

Figure 1: Kinematic and Compliance

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This chapter presents a literature review that identified with the vehicle suspension outline for ideal suspension that satisfy the fundamental necessities. The prerequisite is the lessening of relative movements between the vehicle bodies, reduction of dynamic road-tyre forces and ride comfort.

2.1 Suspension System

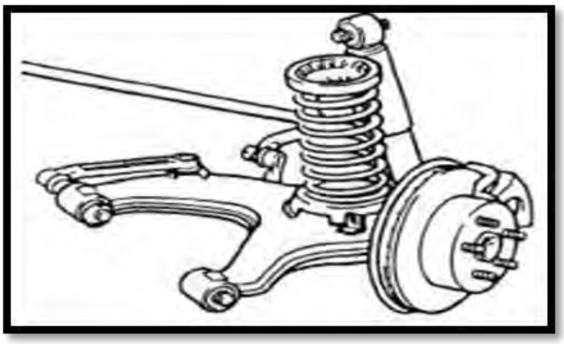

Figure 3: Suspension system

Suspension is the arrangement of linkages, springs and shock absorber that join a vehicle to its haggles relative movement. Suspension frameworks have reason for adding to the vehicle's street holding/taking care of. Additionally to keep vehicle inhabitants agreeable that very much segregated from vibrations, knocks and street clamor.

2.2 Macpherson Suspension

The McPherson strut suspension, fabricated in 1940s by Earl Steele Macpherson, utilized on the 1949 by Ford Vedette (Gilles). It is a generally new suspension arrangement. It comprises of a telescopic strut and lower control arm that appended to the assortment of vehicle and to the wheel bearer (upright). The essential spring and damper are co-direct with the strut's line of interpretation. This design give a couple favorable circumstances. Gillespie say that its natural L-shape helps with the bundling of transverse motors. In like manner, as Daniels says, its three mounting focuses can be broadly dispersed, will permitting this design to be productive. Daniels additionally takes note of that camber edge change with suspension travel is little. (Andersen et al., 2007)

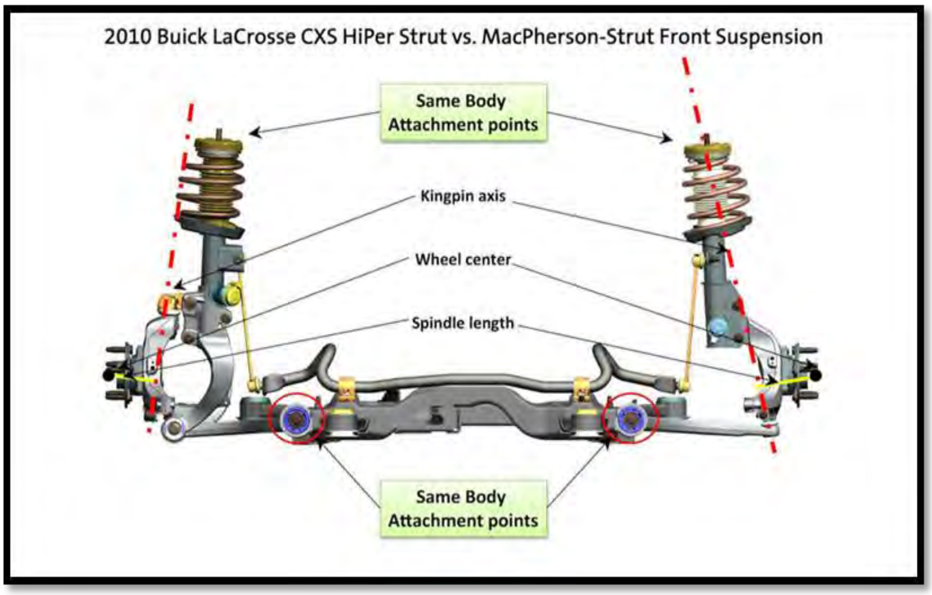

Figure 4 : MacPherson SuspensionHard Point

2.3 Wishbone Suspension

In the suspension frameworks, it have different sorts of the suspensions like wishbone or twofold wishbone suspensions. For A-sort control arm, it joins the wheel center to the vehicle outline that taking into consideration a full scope of movement while it keeping up legitimate suspension arrangement. Suspension commotion or misalignment, controlling wheel shimmy and uneven tire wear are the fundamental driver of the disappointment of the lower suspension arm. The greater part of the cases the disappointments are calamitous in nature. So the auxiliary trustworthiness of the suspension arm is significant from configuration perspective both in static and element conditions. (Darge, Shilwant, &Patil, 2014)

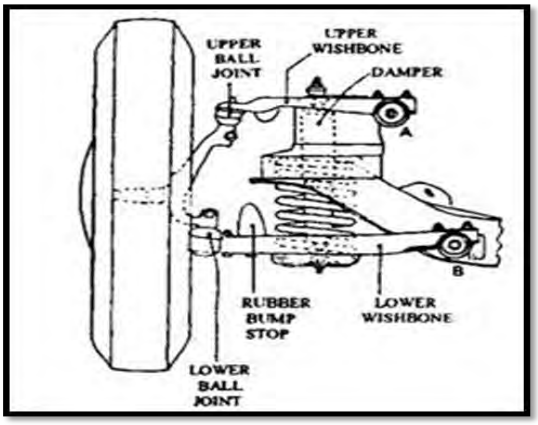

Figure 5: Wishbone Suspension

2.4 Suspension Kinematics And Compliance (K&C)

The suspension K&C attributes have straight forwardly impacts on riding exhibitions and vehicle taking care of. This get to be extraordinary significance in vehicle improvement. With mechanical adaptability and shrub vulnerability, it is exceptionally hard to foresee affectability of hard focuses areas in the kinematic execution of a suspension framework in light of the fact that it profoundly nonlinear and coupled. A streamlining strategy may be valuable to give direction through the configuration process. As of late concentrated on ideal configuration for car suspension frameworks in view of unwavering quality investigations for upgrading kinematics and consistence attributes; they performed dependability improvement with the single-circle single-variable strategy by utilizing the outcomes from a deterministic streamlining as beginning qualities. (Yang et al., 2014)

2.5 Design And Performance Of Suspension

Vehicle suspension configuration and execution issues has been contemplated utilizing straightforward auto models, for example, two degrees-of-flexibility (d.o.f.) or seven d.o.f. full auto models. The suspension outline approachs depend on expository techniques where a straight vehicle model is explored by understanding direct conventional differential mathematical statements. The execution capacities is spoken to by move capacities in Laplace and/or Fourier areas are thought to be identified with tire strengths and taking care of criteria ride solace. Next to that, the examination of nonlinear suspension attributes must be founded on numerical routines looked at than scientific techniques.

2.6 Passive And Semi-Active Suspension

A broad writing study is initially performed on the subject of semi-dynamic and detached suspension frameworks. The measure of productions on suspension frameworks is extremely constrained and suspension ideas connected in vehicle suspensions are likewise respected. From this, few detached and semi dynamic suspension ideas are chosen in this venture. The exhibitions as far as driver solace of the chose suspension ideas are looked at. In this manner a 4 level of-flexibility quarter-vehicle model was utilized to portray the flow in vertical heading with motor suspension, pivot suspension and lodge suspension.

In the past the numerical streamlining of a detached lodge suspension has been performed by Besse join, as a major aspect of the numerical improvement of the aggregate suspension arrangement of a truck/semi-trailer, including motor and suspensions hub. However, to model and streamlining methods utilized as a part of this exploration likewise be important while in regards to optional suspension frameworks. Consequently, distinctive nonlinear quarter vehicle models are proposed. At the point when concentrating on the dynamic tire powers, three primary centered is for the cow pivot, the drive hub with leaf spring and drive hub with air spring. (Maddaiah, Ratnam, Kumar, Kumar, & Student, 2013)

2.7 Multi-Body Dynamic

A multibody dynamic (MBD) framework comprises of unbending bodies that are associated with one another by joints that confine their relative movement. The examination of how instrument frameworks move affected by powers is the primary center investigation of MBD.

Multi body motion (MBD) will includes the reenactment of mechanical frameworks as either element or kinematic investigations. It will figure instrument movement, for example, strengths inside of the system. These strengths will be nourished into a limited component investigation (FEA) as exact information stacking.

Kinematic investigation including moderate moving parts where dormancy impacts and mass and is utilized to guarantee the coveted movement is accomplished or to make freedom envelopes to bundle different segments around. Dynamic investigation will considers mass and inactivity impacts. It can be utilized for those with damping impacts, for example, a car suspension framework.

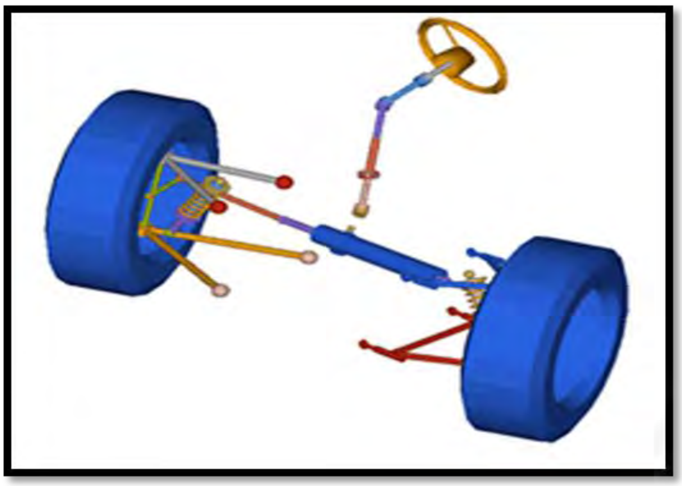

Figure 6 : Multi-body dynamics

2.8 Optimization

Customary configuration procedures are natural and depend on the originators experience and information of the issue being explained. At the point when new issues are to be comprehended, or significantly better arrangements are to be gotten, the whole issue space should be investigated. In this manner, routine configuration procedures should be enlarged with optimization driven-outline forms that can deliberately investigate the whole plan space. Streamlining driven-configuration is the utilization of numerical methods to offer architects some assistance with realizing an outline that augments the configuration objective(s) while fulfilling assembling and other physical requirements. This procedure is formal and mechanized. At the point when appropriately actualized it permits designers to concentrate on discovering the right answer for their issue.

The optimization issue is scientifically communicated as as :

$$
\begin{aligned}
&\text{Minimize :} && f(\mathbf{x}) = f(x_1, x_2, \ldots, x_n) && \\
&\text{Subject to :} && g_j(\mathbf{x}) \le 0 && j = 1, \ldots, m \\
& && h_k(\mathbf{x}) = 0 && k = 1, \ldots, m_h \\
& && x_i^L \le x_i \le x_i^U && i = 1, \ldots, n
\end{aligned}
$$

Figure 7 : A Typical Formulation for Optimization Problems

There are three stages in characterizing an optimization issue.

I. Identify outline variables : These are framework parameters, for example, hard-point, damping properties, geometrical measurements and configuration shape can be changed to enhance the framework execution.

II. Identify objective function(s) : System execution measures that must be minimized (expanded, for example, removal, cost and mass.

III. Identify imperative capacities : System prerequisites that must be fulfilled for the outline to be possible, for example, necessities on hassles and removals. These capacities ought to additionally be elements of the outline variables (g(x) and h(x).

For vehicle suspension outline for the ideal suspension ought to satisfy the accompanying fundamental prerequisites :

I. Ride comfort

II. Reduction of dynamic road-tyre force

III. Reduction of relative motions between the vehicle bodies

2.9 Optimization Method

Method		Continuous	Discrete	Linear	Nonlinear	Single Objective	Multi Objective	Deterministic	Probabilistic	Accuracy	Efficiency	Global	Comments
ARSM		✓	✓	✓	✓	✓		✓		★	★★★		Default method for single objective problems.
GRSM	SOO	✓	✓	✓	✓	✓		✓		★★★	★★	✓	GRSM is the default method for multi objective problems and it is also the preferred method when the number of design variables is large. It can start optimizing with just a few numbers of points independent of the number of design variables.
	MOO	✓	✓	✓	✓		✓	✓		★★★	★★★	✓	
SQP		✓		✓	✓	✓		✓		★★★	★★		Use SQP if the simulation is affordable or if you have a good fit.
MFD		✓		✓	✓	✓		✓		★★	★★		MFD may work more efficiently for problems with a large number of constraints.
GA		✓	✓	✓	✓	✓		✓		★★	★	✓	This method is significantly more expensive. Use GA if the simulation is affordable or if you have a good fit.
HMMO		✓	✓	✓	✓	✓	✓	✓		★★★	★★	✓	Use this method if the maximum allowable evaluations are very large.
MOGA		✓	✓	✓	✓		✓	✓		★★	★	✓	This method is significantly more expensive. Use MOGA if the simulation is affordable or if you have a good fit.
SORA		✓		✓	✓	✓			✓	★★★	★		Use SORA if the simulation is affordable or if you have a good fit.
SORA-ARSM		✓		✓	✓	✓			✓	★	★★★		SORA-ARSM is more efficient than SORA, but not as accurate. It is not recommended to use SORA-ARSM with a fit.
SLA		✓		✓	✓	✓			✓	★★	★★		This method is a good substitution to SORA.
USER													

Figure 8 : Method in optimization

2.10 Adaptive Response Surface Method (ARSM)

Adaptive response surface method (ARSM) will work when reaction surfaces and adaptively was self building and turn out to be new assessments are accessible. Straight relapse polynomial turn out to be first reaction surfaces. It will discovered the ideal surfaces and will acceptance it. In the event that the reaction qualities originate from the reaction surface and the careful reproduction are not all that nearby, then ARSM will upgrades the surface. It included new assessment to finds the ideal in this overhauled surface. ARSM will rehashes this circle until it meets merging criteria.

The flowchart show the ARSM process.

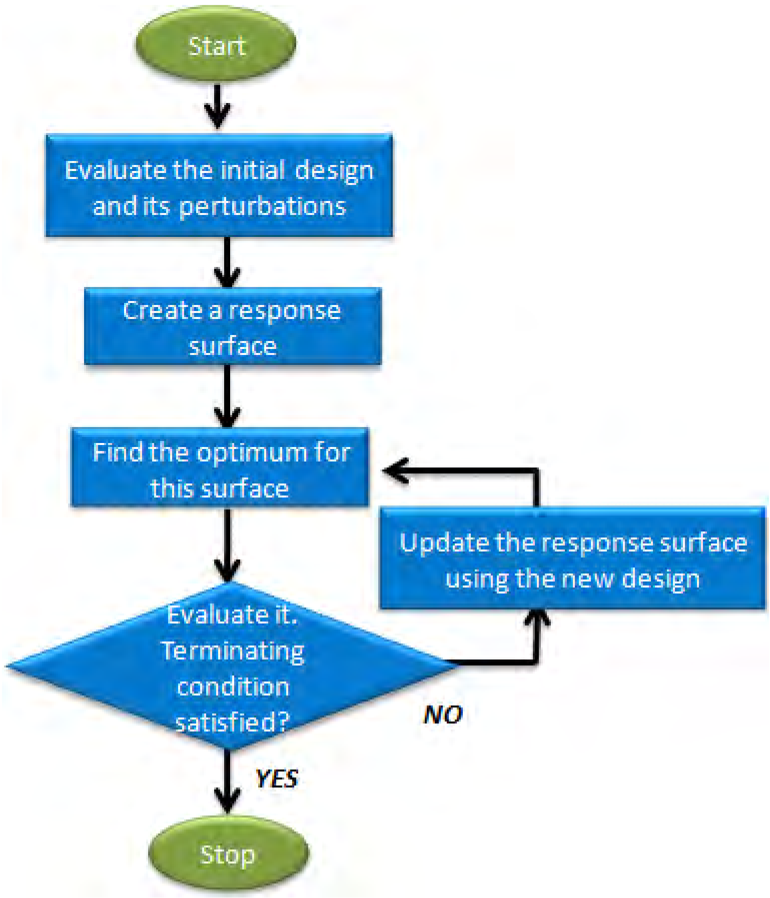

Figure 9 : Adaptive response surface method (ARSM)