# VEHICLE MONITORING FOR PREVENTION OF ROAD ACCIDENTS

*A Dissertation*

*Submitted in partial fulfillment of requirement for the award*

*of the degree*

*of*

**MASTER OF TECHNOLOGY**

*in*

**SYSTEMS AND CONTROL**

**Submitted by**

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# CANDIDATE’S DECLARATION

I hereby declare that the work which is presented here, entitled, **Vehicle Monitoring for Prevention of Road Accidents**, submitted in partial fulfillment of the requirement for the award of the degree of **Master of Technology** in **Systems And Control** at **Department of Electrical Engineering, Indian Institute of Technology Roorkee**, is an authentic record of my own work carried out under the supervision and guidance of **Dr. Rajendra Prasad, Professor, Department of Electrical Engineering, Indian Institute of Techonology Roorkee, Roorkee (India).**

I also declare that I have not submitted the matter embodied in this report for award of any other degree.

Date:

Place: Roorkee **(ARIJIT GHOSH)**

# CERTIFICATE

This is to certify that the above statement made by the candidate is correct to the best of my knowledge**.**

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I also had a pleasure of interacting with quite a few students during my TA classes in C++, and I must say that the confidence and single pointed dedication exhibited by some of them inspires me and their simplicity and desire to learn motivates me. I am grateful to the Academic Section of IIT Roorkee which gave me an opportunity to complete my M. Tech by converting it into Part Time status to continue my degree, when I got selected at Indian Oil Corporation Limited as Operation Officer. Finally, my apologies to anyone if I have hurt them through my thoughts, words or deeds and for any inadvertent mistakes which I might have done during the past two years.

Thanks a lot to everyone once again.

Date: Arijit Ghosh

Place: Roorkee

# ABSTRACT

Road Accidents have been occurring on a higher note in the 21st century. Most of them occur due to fact that people are not able to learn from their past mistakes. Road commuters know the traffic rules but it is the laxity in the implementation that accounts for most number of casualties in road mishap. The thesis deals with the study of 2 DOF IMC based Controllers. The signal tracking and disturbance rejection ability makes IMC more robust in itself. Efforts are being made to employ the use of IMC to control vehicle dynamics and ensuring steady control of motors. A paper on the above subject has been forwarded and is under review at IEEE Conference in Modi University of Science & Technology.

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# CHAPTER 1: ROAD RAGE - A PREFACE TO ROAD ACCIDENTS

## 1.1 Introduction

With the advent of industrial revolution in the modern era, there has been an enormous development in the state of affairs of the country. There has been rapid development in the infrastructure, software, hardware, mineral wealth which has proven to be fruitful for the economy of the nation.

One of the major beneficiaries of the industrial revolution is the Automobile Sector. With each day passing by, we are able to find more number of vehicles plying on the streets. India is a developing country which has about 5.4 million km of road network which is humongous in both size and figures. Apart from it, the Indian Government pays thousands of Crores of rupees for ensuring maintenance of roads constructed round the year.

From the allocation of Union Budget 2018 to Ministry of Transport and Highways, the total expenditure is around Rs. 71000 Crores with revenue expenditure amounting to Rs. 11,560 Crores. This revenue expenditure is incurred for maintenance and repairs works. The prime reason for the huge cost incurred is the increase in the number of personal vehicles which have increased the burden on roads. The United Nations in its study conducted by UN Economic and Social Commission for Asia and Pacific says that the GDP of India drops down annually by 3% due to Road Accidents. It is estimated that at an annual rate about 1, 40,000 people are injured on the world’s roads. Loss of life in accidents leads to impose of great burden on the families which they have for families and added expense for them.

Normally road accidents occur due to due to three main aspects which are: humans, type of road and environment. Environment factors include ambient light, weather and gases present in atmosphere which does play a major role in accidents. The type of road differs from place to place depending on the type of terrain. Speed is the major factor which causes accident. Along with speed luminosity, weather and behavior of driver also plays a major role in the occurrence of accidents.

From the website of Ministry of Transport, data has been provided in regard to road accidents that has caused havoc across the world. This is due to the low visibility and high speed of vehicles. The speed of vehicles is usually more in the areas of good luminosity on highways where the driver is skilled. In such cases the chance of road mishap is very unlikely to take place.

An estimate shows that inattentiveness among the drivers is also one of the reasons of road accidents. In the night time visibility of objects greatly reduces which makes it difficult for drivers to determine the distance of incoming vehicle, its size, speed, etc. The visibility also gets affected during winter when the fog is present in the air. It creates a mist in the environment which makes vision blurred cutting down far sighted vision among drivers. It is noticed that during winter’s night driving is not preferred during late hours to avoid the fog.

| STATES IN INDIA | Accidents Cases | Deaths |
|---|---|---|
| **TELANGANA** | 469 | 279 |
| **HARYANA** | 494 | 241 |
| **UTTAR PRADESH** | 283 | 232 |
| **RAJASTHAN** | 617 | 222 |
| **WEST BENGAL** | 480 | 205 |
| **MAHARASHTRA** | 443 | 157 |
| **TAMIL NADU** | 757 | 155 |

Table 1.1: Table showing the number of cases of road accidents reported in Indian States and number of deaths in 2014

The table shown above represents the number of cases of road accidents reported in Indian States and number of deaths in 2014. The source for the data is in the literature obtained from the open government portal. Various methodologies have been proposed for minimizing of road accidents. The engineering technique includes Fuzzy prediction, Regression, internal model control, microcontrollers, DSP, EEG and FPGAs. All the above methods work on different logic but analysis for each is to reach to a similar conclusion.

# CHAPTER 2: INTERNAL MODEL CONTROL (IMC)

## 2.1 Introduction

The philosophy of the Internal Model Control (IMC) is based on the fact of Internal Model principle which clearly states that perfect control of the system can be achieved only if the system encapsulates either implicitly or explicitly, some representation of the process to be controlled. It defines that if the control mechanism has been developed on the exact model of the system, then the perfect control is theoretically possible.

It stands in absolute contrast with the classical control model which fails to explicitly model the controlled system. It has now become a common used method that provides a transparent mode for design and tuning of various types of control. The ability of the Proportional-Integral-Derivative (PID) Controllers in order to comply the demands of major control objectives have led with the large scale acceptance in the control domain. The Internal Model Control (IMC) based controller design is one of the approaches and its equivalent PID method is to be used in control application in industries.

The IMC one degree of freedom controller shows good set point tracking but some disturbance always occurs, in relation to the small time delay. The parameters or coefficients of the original system vary with operating conditions and time; hence it becomes very important to design a control system that shows robustness in its performance. Henceforth in view of the above it is to be confirmed that controller design should emphasis on disturbance rejection rather than set point tracking.

The actual process differs from the model of the process due to the mismatch caused by unknown disturbances in the system. This cause difficulty in the implementation of the open loop system for which a perfect control strategy is required. Henceforth the IMC works in the manner to obtain perfect control. In this thesis an optimum IMC filter to design an IMC based controller for better set point tracking is proposed. The propose controller works on different set of values of the filter coefficients to achieve the desired response. In our study we have obtained the transfer function of the actual process or plant from the dynamic model of vehicle.

The representation of the plant is obtained from the classical reduced order model technique by Pade Approximation and Routh Stability method. We analyze the response of the IMC controller output with respect to the reference input by adjusting the value of tuning filter parameter.

Since all IMC controllers involves some kind of model reduction techniques which takes into account some amount of approximation errors, it is to be noted that this error becomes very significant in terms for the process having time delays.

## 2.2 IMC Theory:

Fig 2.1: Open Loop Control System

For the open loop control system as shown in Fig 2.1, it is to be noted that:

G(s) : Actual process or plant
Q(s) : Controller of process
$G_R(s)$ : Actual model of the plant

$$Q(s) = (G_R)^{-1} \qquad (2.1)$$

If $G(s) = G_R(s)$ , the model is the exactly the same as the actual process.

Output Y(s) = Q(s). G(s) . Set point (multiplication of all three parameters)

= $(1/G_R(s))$ . G (s) . Set Point From equation (2.1)

= Set Point

Hence for this condition the output will be equal to the set point. Thus the open loop system can also give the desired response of the system if the process is exactly known before the design of the controller for the system. In such cases, there is no need of the use of feedback for the system.

A controller is used to control the process G(s). Suppose $G_R(s)$ is the model of the plant and used to control the process. Then by setting the plant to be replica of the process, we will have exact representation of the actual process. This makes it very clear that the actual process will be exactly representing the system. This exactly means that if we have complete knowledge of the process, it will be very easy to have perfect control of the process.

The process of IMC provides compensation for the disturbances and model uncertainty due to the fact that IMC leads to a feedback system. Also IMC controllers must be necessarily be tuned to ensure stability if there is non-identity with model uncertainty.

## 2.3 Structure of IMC:

The basic characteristics of the IMC structure is including the process model which is in parallel with the actual process of the plant.

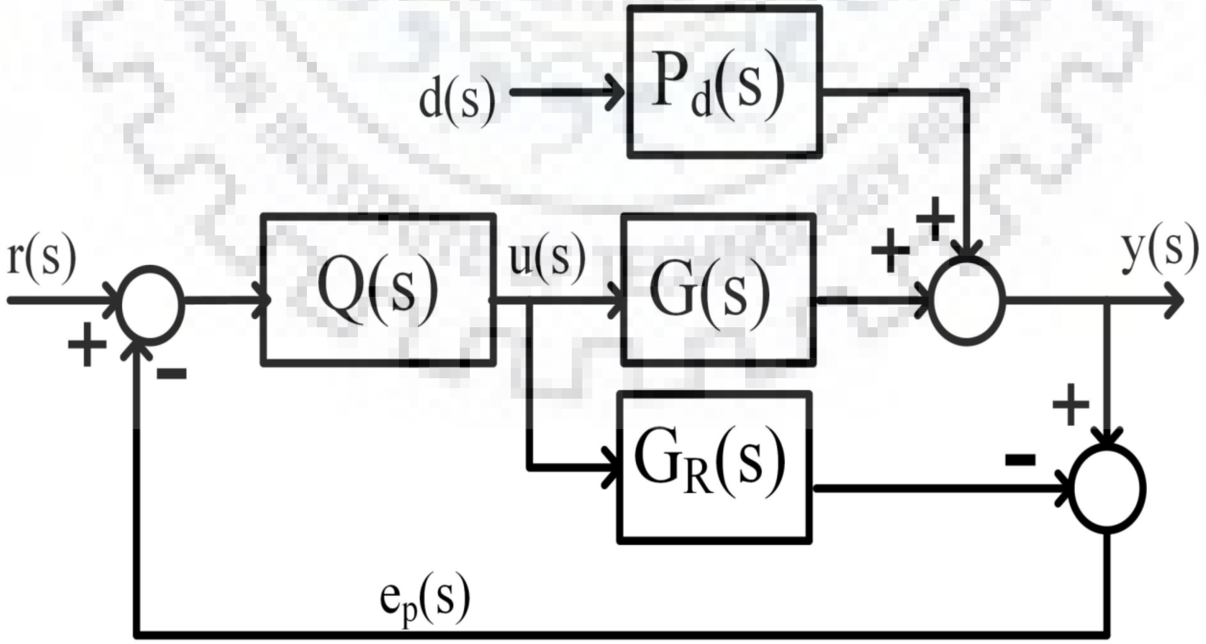

Fig 2.2 Block Diagram of IMC Controller

The various parameters used in the IMC theory have been listed as follows:

Q: IMC Controller
G: Actual Plant
$G_R^*$: Model of plant
r: Set Point
u: Controlled Output
d: Disturbance
$d^*$: Calculate new disturbance

$$d^* = (G - G_R^*) \,.\, u + d \qquad (2.2)$$

Changed set point input:

$$r' = r - d^* = r - (G - G_R^*) \,.\, u + d \qquad (2.3)$$

This relationship is same as that for the open loop system. This if the controller **$G_C$** and the process **$G_P$** is stable the closed loop system is stable. But in practical cases the disturbances and uncertainties do exist and hence actual process or plant cannot be equal to the model of the plant. The error signal e(r) comprises of the model mismatch and the disturbance which is send as modified set point to the controller and is given as:

$$r'(s) = r(s) - d^*(s) \qquad (2.4)$$

The output of the controller is u(s) which is sent to both the process and the model.

$$\begin{aligned} u(s) &= r'(s).\, Q(s) = [r(s) - d^*(s)]\,.Q(s) \\ &= [r(s) - (G_R(s) - G_R^*(s)).u(s) + d(s)].Q(s) \end{aligned}$$

$$u(s) = \frac{((r(s) - d(s)).Q(s)}{1 + (G(s) - G_R(s)).Q(s)} \qquad (2.5)$$

Hence, the close loop transfers function with reference to Fig. 2.2 as shown in the block diagram has been shown below.

$$Y(s)=\frac{Q(s)G(s)R(s)+(1-Q(s)G_M(s))d(s)}{1+(G(s)-G_M(s))Q(s)} \tag{2.6}$$

In order to have good robustness in the system, the effect of disturbance should be reduced. This is achieved by minimizing the model mismatch of the system.

It is to be noted that since the mismatch of the process usually occurs at very high frequency ranges of the system, therefore the implementation of the low pass filter is added. It is used to attenuate the disturbance occurring due to the model mismatch of the system. Thus the internal model controller is usually designed as the inverse if the process model in series with the low pass filter.

In IMC, the model of the process has been factorized into minimum phase part and non minimum phase parts of the transfer function represented by:

$$G_R(s)=G_R^-(s)G_R^+(s) \tag{2.7}$$

Here, $G_R^-(s)$ corresponds to the minimum phase part of the $G_R(s)$

$G_R^+(s)$ corresponds to the non minimum phase part of the $G_R(s)$

The mathematical modeling of IMC Controller Q(s) has been defined as:

$$Q(s)=G_R^{-1}(s)F(s) \tag{2.8}$$

With reference to eqn (2.10), F(s) corresponds to the low pass filter. The function of the filter is to attenuate the high frequencies where there are much greater chances of having plant-model mismatch. The design of the low pass filter has been shown in eqn 2.9.

$$F(s) = (1 + \lambda s)^{-n} \tag{2.9}$$

The filter coefficient $\lambda$ is a tuning parameter which corresponds to the speed of response of the closed loop system. Choosing the value of $\lambda$ parameter is carried out by hit and trial method which is carried out in view of shaping the response of the system.

Another parameter n is defined as the order of filter. The order of filter is chosen in order to make the Q(s) as proper or semi proper function such that it is physically realizable.

Let us suppose the plant model is the exact representation of the process. This means that the actual plant and its model are identical. Also if we consider that the controller Q(s) to be exactly equal to the inverse of the minimum phase part of plant model, some necessary deductions shall be made.

$$G(s) = G_R(s) \tag{2.10}$$

$$Q(s) = (G_R^-(s))^{-1} \tag{2.11}$$

Substituting equation (2.10) and equation (2.11) in the equation (2.6), the resulting equation (2.6) reduces to:

$$Y(s) = G(s)Q(s)R(s) \tag{2.12}$$

This eqn (2.12) clearly states that irrespective of disturbance applied in the system if the conditions in eqn(2.10) and (2.11) is met, the output tends to follow the input. This ensures perfect set point tracking along with disturbance rejection by employing internal model control technique.

It is to be noted that even in case of equation (2.10) does not hold good, then also disturbance rejection can be obtained since the response of the closed loop system to disturbance is nullified. The disturbance rejection capability of IMC block diminishes when step input directly enters through the process without passing through the disturbance block. When disturbance enters the process model, the resulting signal is sluggish and the controller fails to obtain the required control effort.

## 2.4 Features of IMC

1. Feature of Dual Stability: If we suppose that the plant model is perfect such that $G(s) = G_R^{-1}(s)$, where disturbance is not present in the plant, then in such case from eqn 2.6 it is very well clear that the system becomes open loop with closed loop stability of system depending on the stability of G(s) and Q(s).

2. Perfect Control feature: If we assume that $G(s) = G_R^{-1}(s)$ with $Q(s) = (G_R^{-1}(s))^{-1}$, in such case with reference to eqn. (2.6) with G(s) being stable, then system is perfectly controlled with $Y(s)=R(s) \ \forall \ s$ in the range of $(0,\infty)$. Thus the usefulness if IMC implies that it allows an open loop controller to provide perfect closed loop performance.

3. Zero offset features: If the gain of the steady state controller is equal to inverse of the gain of the model, in such case offset free control is obtained for asymptotically constant step or ramp inputs and disturbances.

   With respect to the above mentioned points the IMC provides advantages with respect to the classical feedback controllers only when the plant model is perfect. However all the physical systems are non linear in nature. The choice of selecting an inverse model as a compensator can lead to instability in case of model mismatch.

# CHAPTER 3: IMC - TWO DEGREE OF FREEDOM

## 3.1 Introduction

It is to be noted that in case of practical systems perfect disturbance rejection is not physically attainable. The basic aim of the controller is to obtain set point tracking between the input and output systems along with the ability to disturbance rejection. In the basic model of IMC when the disturbance enters through the process, the response to disturbance rejection becomes more and more sluggish.

This is due to the issue of insufficiency of the controller to provide sustained control action for set point control and disturbance rejection ability simultaneously. The tradeoff between the noise rejection ability and tracking of the desired control trajectory cause the system to allow time lag and delay into the system. To avoid this condition of tradeoff, a single controller of IMC is split into two different controllers

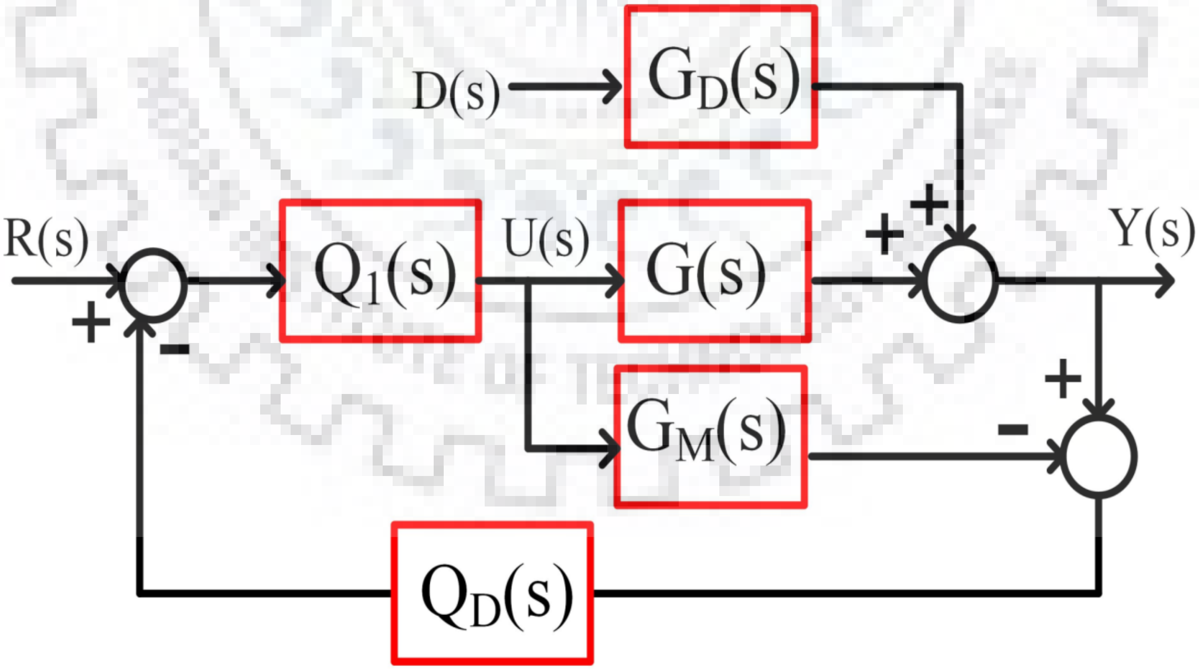

Fig 3.1 Block Diagram of two degree of freedom IMC Controller

From the block diagram it is seen that two separate controllers $Q_1(s)$ and $Q_D(s)$ have been come into existence where both have developed for undertaking different tasks. The disturbance rejection controller $Q_D(s)$ have been appeared in the feedback path and the set point controller $Q_1(s)$ is present in the forward path.

The disturbance rejection capability of IMC block diminishes when step input directly enters the process by not going through the disturbance path.

The design of controller $Q_D$ is provided in the following equation:

$$Q_D = \frac{(1+\sum_{i=1}^{n} a_i s^i)}{(\lambda s+1)^n} \tag{3.1}$$

Here the parameter $\lambda$ is the tuning parameter for the disturbance rejection, n is the number of poles of $G_R$. If we suppose $p_1, p_2, p_3,,\ldots\ldots p_r$ be the number of poles of value of $G_R$ , then coefficient $a_i$ is computed from equation (3.2)

$$(1-G_R\,(s)\,Q(s)\,Q_D(s)\,)|_{s=p1,p2,\ldots..pr,} \text{ for all } i = 1,2,3,\ldots\ldots\ldots r. \tag{3.2}$$

The value of the disturbance rejection parameter $\lambda$ is used to be adjusted in such a manner that the noise amplification criterion should be attained.

This implies that $\dfrac{Q_1 Q_D(j,\omega)}{Q_1 Q_D(0)}$ should be fulfilled for all $\omega$.

Generally the noise amplification factor must be less than 20.

The filter for two degree of freedom IMC has the form:

$$F(s) = \frac{(\psi s^2+\theta s+1)}{(1+\lambda_f s)^x} \tag{3.3}$$

The parameters $\psi$ and $\theta$ are filter coefficient for designing an effective IMC based filter. Depending on the value of x to be set, the controller $Q_D(s)$ has to be designed in order to make it strictly proper.

Here $\theta$ and $\psi$ as the filter coefficients must satisfy some condition for each pole of reduced order model of the system with reference to equation (3.4)

$$\lim_{s \to p_i} \left(1 - T(s)\right) = 0 \quad \forall\, i = 1,2. \tag{3.4}$$

The value of T(s) has been determined as:

$$T(s) = Q_D(s) \, . \, G_R(s) \tag{3.5}$$

Substituting equation (2.7) and equation (3.1) in equation (3.5), we have:

$$T(s) = \frac{G_M^{+}(s)(\psi s^2 + \theta s + 1)}{(\lambda_f s + 1)^x} \tag{3.6}$$

# CHAPTER 4: DYNAMICS IN VEHICLE MOTION

## 4.1 Introduction:

Most of the vehicles in the present era have been automated in the light of rapid globalization. With respect to the advancements in controls like steering wheels, pedals have been grown in the limelight of the demand risen, specialization in automation techniques have also been taken a much heighted approach for the same. It has been owing to the demand of drivers that manual transmission systems have paved the way for the development of the semi automatic and automatic systems.

In the past days most of the cars had manual controls for the purpose of igniting and running the engines. However in the modern control of cars, automated drivers have been present that are not used for the purpose of driving the vehicles directly but have been implemented to control air conditioning systems, navigation system, on board computer, in house entertainment, wind screen wiper and touch panels system. The simulation enables to address the complex problems of the road accidents and provides solution for the large number for dynamic parameters whose values change significantly from time to time. The comparison of different control strategies enables to come with new results and obtain better steady state response of the system.

In order to accurately develop vehicle system, the characteristics from point of view of mechanical design, electronics development and control systems is needed. Heavy trucks and passengers cars have different engines characteristics that are not easy to be developed.

## 4.2 Speed Control Scheme:

Controlling the speed of the vehicle is of the most important issues in the designing of controller. It is to be noted that it is hard to build an accurate model based on the based on the physical characteristic of the car. This is due to the fact that not only the prototype but also tier size, type of engine, weight of the car remains uncertain.

The twin turbo engine of the vehicles consists of two turbo chargers for the implementation of the speed control characteristics. During low energy, when exhaust of engines shall be minimum, then only one turbocharger is active. The speed characteristics of the turbo shall be dealt employing the use of IMC Control. The engine characteristics of the turbo charger deals with Internal Model Control (IMC). IMC shall be employed to control the speed of the engine and effective control for the same.

In order to have a good control and easy operation to the speed control system, control scheme based on the implementation of Internal Model Control (IMC) on the mathematical model of twin turbo engine of heavy duty vehicle has been proposed. In accordance with the actual state of the motor, an ideal model for the inertia based on the non sip wheel has been established. It is based on the dynamic application of the brakes actuation pressure that is used to establish traction control of vehicle. It is required to detect the road tire friction in vehicle dynamics and control.

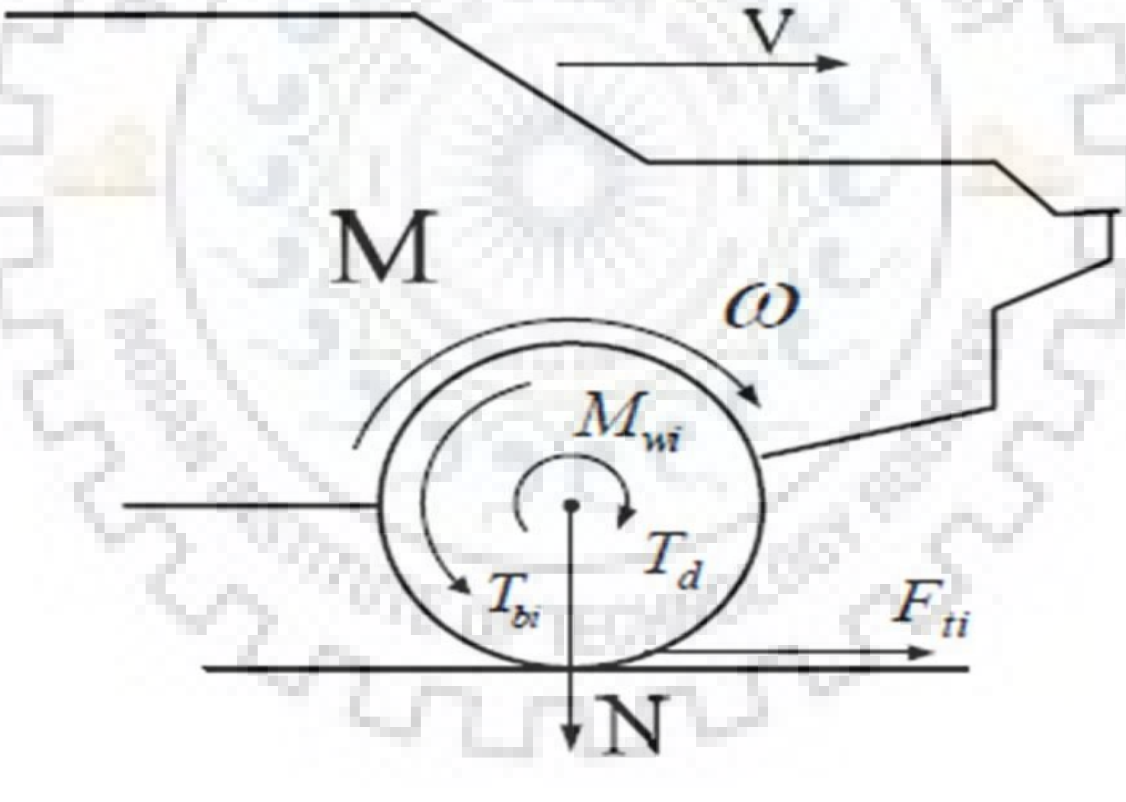

Fig 4.1: Quarter model of vehicle

With respect to the dynamic model of the vehicle as represented in Fig 4.1, consider the set of equations:

$$I \frac{d\omega}{dt} = T - F\,r \qquad (4.1)$$

$$F = M \frac{dv}{dt} \qquad (4.2)$$

$$u = \frac{F}{N} \qquad (4.3)$$

In the above set of equations: I -refers to the moment of Inertia of wheel
F -refers to the friction between the tyre and road
M -refers to the body mass of vehicle
v -refers to the driving speed of vehicle
N -refers to the normal reaction force on the vehicle
$\omega$ -refers to the angular velocity of vehicle

The slip in the wheels of the vehicle can be easily monitored in real time. For moving of the vehicle on the horizontal roads, it is to be noted that speed of the motion of each wheel is taken to be approximately equal. When the control input is applied in the engine through the accelerator pedal, the torque is developed which is converted into rotational motion in the form of angular velocity of the wheels which dries the vehicle forward.

When the vehicle is running, the variation in the friction coefficient and the rate of slip has a mathematical relationship.

$$\frac{du}{ds} = \frac{du}{dt} \cdot \frac{dt}{ds} \qquad (4.4)$$

In accordance with the relationship of adhesion coefficient and slip of vehicles, the relation can be determined:

1. <u>For the accelerating vehicles:</u>

When the wheel is running under the non stable state with the angular speed higher than the optimal speed, then the coefficient of adhesion decreases with time and slip ratio increases with time.

$$\frac{du}{dt} < 0 \;,\; \frac{ds}{dt} > 0 \qquad (4.5)$$

When the wheel is running under the stable state within the optimal speed, then the coefficient of adhesion and slip ratio both increases with time.

$$\lambda_D \;,\; \frac{ds}{dt} > 0 \qquad (4.6)$$

2. <u>For the decelerating vehicles:</u>

When the wheel is running under the non stable state with the angular speed higher than the optimal speed, then the adhesion coefficient decreases with time and slip ratio increases with time.

$$\frac{du}{dt} > 0 \;,\; \frac{ds}{dt} < 0 \qquad (4.7)$$

When the wheel is running in the stable state both the adhesion coefficient and slip ratio decreases with time.

$$\frac{ds}{dt} < 0, \ \frac{du}{dt} < 0 \qquad (4.8)$$

## 4.3 Application of IMC Technique

In the model of twin turbo engine for heavy vehicles control input for guiding the speed of the vehicle is proposed to be given at the steering end. Based on the roughness of the road and uneven trajectory of the path, the disturbance in the form of vibration tends to affect the balance of the vehicle thereby leading to the uncontrolled speed. In the case of providing guided control signal to the steering axle and accelerator pedal, the vehicle should follow the signal unperturbedly in the presence of disturbances.

This employs the implementation of the IMC technique in order to model the response of the vehicle output to manage the dynamics of the system. The mathematical model for the twin turbo engine has been provided in equation (4.9).

$$G(s) = \frac{0.64s^2 + 0.4104s + 0.0783}{s^4 + 1.489s^3 + 0.768s^2 + 0.0954s + 0.0424} \qquad (4.9)$$

In order to model the system in second order, Routh Approximation method is employed for the reduction of higher order system into lower system for the purpose of synthesis and simulation results. It is based on the routh table for the original transfer function.

$$G_R(s) = \frac{0.01353s + 0.1899}{s^2 + 2.714s + 1.48} \qquad (4.10)$$

It is to be noted that the reduced order IMC Model consist of the minimum and non-minimum phase part of the system which has been depicted below

Minimum phase part of the reduced order model:

$$G_R^-(s) = \frac{1}{s^2 + 2.714s + 1.48} \qquad (4.11)$$

Non minimum phase part of the reduced order model:

$$G_R^+(s) = 0.01353s + 0.1899 \qquad (4.12)$$

In order to determine the characteristics of filter, the tuning of filter parameters also owes a challenge to provide by a set of design techniques and tools for implementation for the robust on-line tuned controllers. The filter makes the controller robust, and ensures to minimize errors between the plant and the model at the high frequency ranges. It has been noticed that higher the value of $\lambda$, higher will be the robustness of controller, but the speed of tracking reduces.

The controller for the IMC has been designed with respect to the maintaining output in control with the input signal by varying the filter coefficient.

For IMC one degree of freedom at $\lambda$ = 0. 53112, the design for the controller Q(s) has been designed as:

$$Q(s) = \frac{s^2 + 2.174s + 1.481}{0.01218s^2 + 0.1844s + 0.1899} \qquad (4.13)$$

The study has been further extended to the two degree of freedom IMC Controllers. The designing of set point controller is in line with equation (2.8) and disturbance rejection controller is in line with equation (3.1).

Similarly for IMC two degree of freedom IMC, the value of filter coefficient has been chosen at $\lambda$ = 0.321 and $\lambda_D$ = 0.2681.

The controller Q(s) and $Q_D$(s) has been computed as:

$$Q(s) = \frac{s^2 + 0.164s + 1.881}{0.01218s^2 + 0.1844s + 0.701} \tag{4.14}$$

$$Q_D = \frac{0.4616s^2 + 1.032s + 1}{0.004457s^4 + 0.0703s^3 + 0.4056s^2 + 1.04s + 1} \tag{4.15}$$

Based on the tuning of filter coefficients for 1st order and 2nd order IMC based controllers for the system, the output response of the traction control is provided. The response curve as

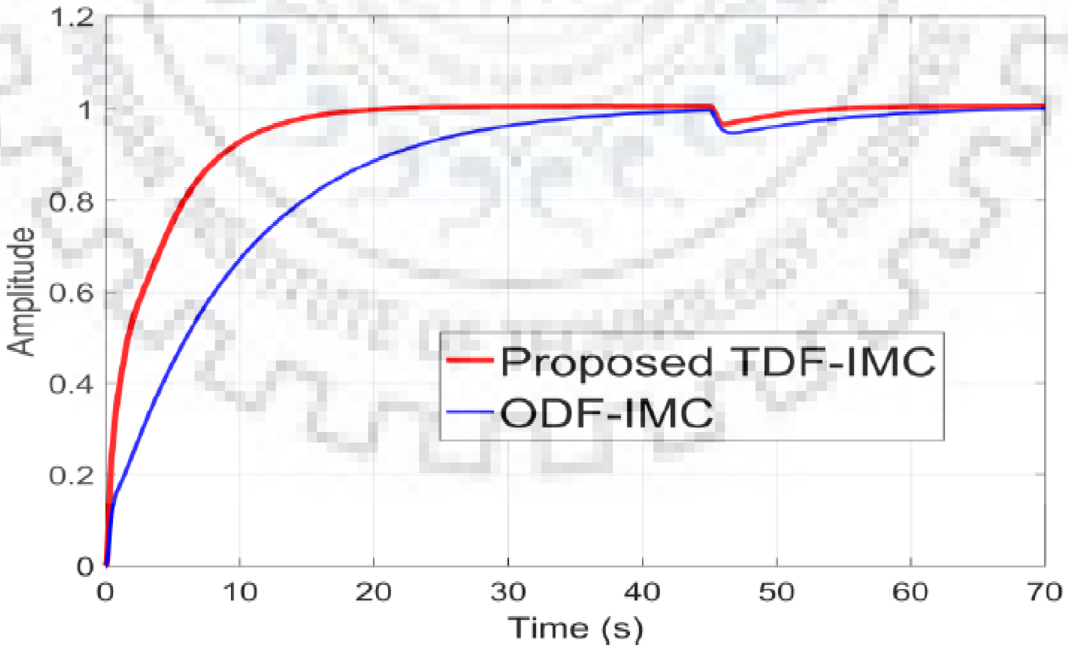

Fig 4.2 Comparison of controlled output between ODF & TDF-IMC Controller

## 4.4 Interpretation of Result

The IMC controller with 2 Degree of Freedom has better signal tracking and disturbance rejection ability. This has made two degree of freedom IMC better and more widely implemented with respect to other conventional control techniques. The one degree of freedom of IMC is similar in action whose control strategy depends on the tuning of PID parameters.

The initial turbulence in the system response is exactly represented by one degree of freedom of IMC controller. This shows the low disturbance rejection ability of IMC ODF controllers with respect to the IMC TDF controllers. It is due to the reason that the basic IMC with two degree freedoms are more efficient in managing set point tracking along with the ability to manage vibration in the system with respect to the environment in the system. It is important to note that unlike IMC controllers which has less parameter to tune, other classical controlling techniques like PID controllers. This has reduced the dependency of the IMC to variation in parameters unlike traditional controlling techniques.

# CHAPTER 5: CONCLUSION & FUTURE SCOPE

IMC has very good tracking ability for both ODF & TDF IMC Controllers. However the response to the disturbance rejection is sluggish in ODF-IMC. A compromise is required for balancing the performance of disturbance rejection and set point tracking which is easily managed by IMC- 2 DOF with help of separate controllers each dedicated for set point tracking and disturbance rejection. IMC is better than classical controllers like PID where only one parameter needs to be tuned, whereas in PID all the different controller parameters are to be tuned.

It can be clearly seen that at T=45 seconds, when the vehicle is in motion, the undulation disturbance has been deliberately added into the model. A unit step disturbance input causes the vehicle to enter into turbulence which is easily controlled by IMC based control action with fast response within a definite time frame. The simulation in the IMC controller in different parameter within a fixed range has proven that IMC has a good ability to change to the environment.

However the response of the system shows that proper tracking using one degree of freedom for IMC is inferior as compared to two degree of freedom IMC Controller. The difference (error) between the input and output response for the signal tracking in one degree of freedom IMC is more significantly higher than the two degree of freedom IMC Controller. According to the simulation results, it shows that the IMC-2 DOF controller is less affected by the disturbance. Therefore the IMC Controller has better capacity of resisting disturbance.

Efforts are being made to stabilize the study the impacts of fractional order based IMC controllers and making use of their advantages in establishing the same. The fractional order control strategy is very much versatile in itself and accurate in its state of working. It gives very robust performance in both nominal as well as varying operational conditions.

It is to be noted that with the rapid development of intelligent traffic system, the development of greater preciseness in speed control has been in the next step to study in depth for the process. The development of soft computing methods like fuzzy logic, neural networks, and genetic algorithm may be implemented. Such techniques are also helpful in the monitoring of actuators that regulate control action to be acting upon the systems.

This forms the scope of further extension of the research work that is proposed to be undertaken in the future.

# SIMULINK FOR MODEL

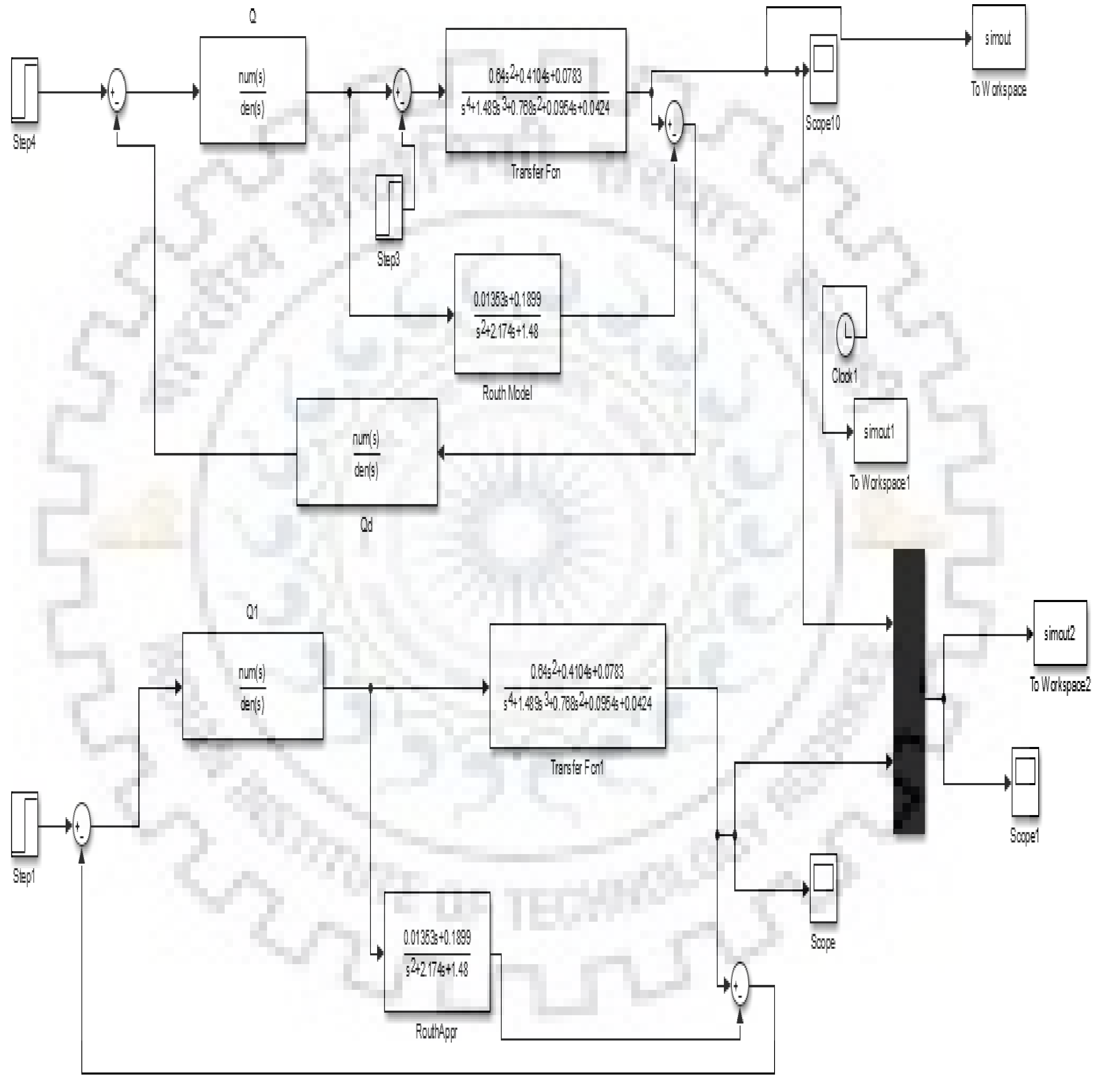

Fig (a): Simulink model showing the comparison between ODF & TDF IMC Controllers

# MATLAB CODES

## For 2 DOF IMC Controllers:

```
syms lambda lambda_f
lambda = 0.33;
lambda_f = 0.26;
P = tf([0.01353 0.1899],[1 2.174 1.481]);
p1 = -0.5618;
p2 = -0.2045;
Q = tf([1 2.17 1.481],[0.01353*lambda 0.01353 +
0.1899*lambda 0.1899]);
psi = (p1*(p2*lambda_f-1)^4 - p2*(p1*lambda_f-1)^4
- p1 + p2)/(p1*p2*(p2-p1));
theta = (p1^2*(p2*lambda_f-1)^4 -
p2^2*(p1*lambda_f-1)^4 - p1^2 + p2^2)/(p1*p2*(p2-
p1));
s = tf('s');
Qd = (psi *s^2 + theta*s + 1)/(lambda_f*s + 1)^4 ;
T= stepinfo(P);
```

**Comments:**

lambda: refers to filter tuning coefficient of set point tracking controller Q
lambda_f: refers to the filter tuning coefficient of disturbance rejection controller Qd
P: refers to the reduced order model by Routh Approximation
p1, p2: refers to poles of reduced order model
Q: refers to set point controller
Qd: refers to disturbance rejection controller
theta, psi: filter coefficients of disturbance rejection controller Qd

## For 1 DOF IMC Controllers:

```
syms lambda
lambda = 0.9;
P = tf([0.01353 0.1899],[1 2.174 1.481]);
Q1 = tf([1 2.174 1.481],[0.01353*lambda 0.01353 +
0.1899*lambda 0.1899]);
s = tf('s');
T= stepinfo(P);
```

**Comments:**

lambda: refers to filter tuning coefficient of set point tracking controller Q1

P: refers to the reduced order model by Routh Approximation

Q1: refers to set point controller

# SUMMARY OF PUBLICATIONS

1) **Title:** Monitoring of Road Accidents- A Review

   **Submitted to:** International Conference of Control, Power, Communication and Computing Technologies

   **Presented on:** 24 March 2018

   **Status:** Accepted and Published in Conference Proceedings

2) **Title:** Analysis of Road Accidents using Regression

   **Submitted to:** 1st International Conference on Secure Cyber Computing and Communication

   **Presented on:** 23 December 2018

   **Status:** Accepted and Published in Conference Proceedings

3) **Title:** IMC Based Simulation for Prevention of Road Accidents

   **Submitted to:** International Conference on Emerging Trends in Communication, Control and Computing (ICONC3)

   **Status:** Under Review

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