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## ABSTRACT

Both static and dynamic behaviour of different mechanical speed governors, as well as, the overall engine-governor system have been investigated. The study shows the effect of various design parameters of the governors on the performance of diesel engine control systems and provides the necessary guide to make the effective compromises so that the governor can be properly designed and selected for a certain engine under a particular application. Computer programs based on the mathematical formulations of the behaviour of different system components were constructed and used to predict the steady-state and transient behaviour of different engine control systems. Simulations of different diesel engines with a certain governor , as well as , simulations of different mechanical governors with a certain diesel engine were made.

Both experimental and theoretical results confirm that the governor characteristics can be altered in several ways to meet a certain opertional requirement ; either by changing the governor weights or by changing the governor springs.

To achieve the optimum performance from a diesel engine control system , the governor parameters must be changed , as

# العوامل المختلفة المؤثرة على اداء المنظمات الميكانيكيه بمحركات الديزل


ملخص البحـــــث :

بحث نظرى وعملى قد أجرى لتحديد العوامل المؤثرة على أداء المنظمات الميكانيكيـــــــــــة بمحركـات الديزل .

فى الجزء النظرى من هذا العملتم بحث أسلوب الأداءالأستاتيكى والديناميكـــى للمنظمات ذات التأثير المباشر والغير مباشر لأكثـــــر المنظمـــــات الميكانيكيـــــة أستخداما فى محركـات الديـــــزل . وقـــــد تـــــم عمل برامج لكل من هذه المنظمات على الحاســـــب الآلـــــى مع دراســـــة الأداء عند أستخدام منظـــم معيـــن لعـــــدد مـــــن المحركـات وكـــذلك عنـــــد أســـــتخدام منظمات منـــع محرك واحـــــد لتحـــديد أســـــلوب تقييـــــم أداء وأختيـــار المنظـــــم المناســـــب للمحـــــرك .

فى الجزء العملى تم اجـــــراء تجارب عمليـــة لدراســـــة مدى أســـتجابة المنظـــــم الميكانيكـــــى ذات التأثير المباشـــــر لتغييـــــر أكثـــــر العوامـــل تأثيرا .

وأنتهـــــى البحـــــث الى أن كـــل مـــــن النتائـــــج النظـــرية والعمليـــــة تتفـــق علـــــى أن يمكـــــن بتعديـــــل خصائص أداء المنظـــــم ليفـــى متطـــــلبات التشـــــغيل المختلفـــــة لمحـــــرك الديـــــزل عـــــن طـــــريق تغييـــــر كتـــــل المنظـــــم أو تغيـــــر خصائـــــص يايات المنظـــــم المختلفـــه .

وأيضـا لتحقيق الاداء الامثـــل لأنظومـــة التحكـــم فى الســـــرعة يجـــــب تغيير أكثـــــر العوامـــــل تأثيرا طبقـــــا للظـــــروف التـــــى تحـــــدد أدنـــــى قيمـــــة لتكامـــل معيـــــار الاداء للانظومـــه . فى المنظمـــــات الميكانيكيـــــة ذات التأثيـــــر المباشـــــر يمكـــــن تخفيض قيمـــــة الارتفـــاع اللحظـــــى للســـــرعـــة عـــــن طـــــريق تخفيـــــض قيـــم أزمنـــــة التعـــــوق لكـــل مـــــن المنظم والاحتكاك اللزج وكذلـك تخفيـــــض قيـــم درجـــــة عـــــدم الانتظام للمنظم والاحتكاك الجاف .

لكن عدم كفاية قيمة درجة عدم الانتظام للمنظم يمكن تسبب عدم الاستقرار فى تشغيل أنظومة التحكم فى السرعة لمحرك الديزل .

فى المنظمات الميكانيكية ذات التأثير غير المباشر يمكن أيضا تخفيض قيمه الارتفاع اللحظى للسرعة عن طريق تخفيض أزمنة التعوق لكل وحدتى السيرفو والتغذيه العكسية .

فعلى سبيل المثال يمكن تخفيض قيمة الارتفاع اللحظى للسرعة بنسبة ٦ ر ١٠٪ أو ١٠٪ بتخفيض قيمة زمن التعوق للمنظم أوقيمة زمن التعوق للسيرفو بنسبه ٢٥٪ على الترتيب .

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# NOMENCLATURE

## Nomenclature

| | |
|---|---|
| A | Cross sectional area |
| a | Fulcrum lever length |
| B | Governor serviceability coefficient |
| b | Length ; pre-strain ; width |
| bg | Gear pump width |
| C | Spring index ; ratio ; discharge coefficient |
| D | Mean diameter ; radius of gyration |
| d | Diameter ; spring wire diameter |
| E | Energy ; restroing force |
| e | Error ; distance |
| F | Centrifugal force |
| f | Spring deflection |
| G | Moduls of rigidity ; engine flywheel mass |
| g | Gravity acceleration |
| H | Stroke |
| h | Fuel rack travel |
| i | Number of engine cylinders ; number of turns |
| J | Reduced moment of inertia |
| K | Stability factor |
| Ke | Cofficient of self regulation |
| m | Mass of governor weights |

| | |
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| mr | Fuel rack mass |
| Ne | Effective engine power |
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| Poil | Oil working pressure |
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| Px | Pressure deviation |
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| Rn | Governor serviceabilty |
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| S | Engine piston stroke ; lag coefficient |
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| Ti | Anti torque , dash-pot time constant |
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| X | Deviation of the fuel rack travel |
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| Yi | Deviation of the dash-pot plunger travel |
| Ypi | Deviation of PI-element travel |
| Ys | Deviation of the servo piston travel |
| yi | Coordinates of C.G of the governor components |
| Z | Governor sleeve travel |
| Z1 | Number of rotating gear teeth |
| Z2 | Number of driven gear teeth |
| Zpi | PI-element travel |
| Zr | Number of the governor weights |

Subscribts

| | |
|---|---|
| ac | accumulator |
| cv | control valve |
| d | dash-pot |
| d.p | dash-pot plunger |
| e | engine |
| g | gear |
| gov | governor |
| k | viscous friction |
| o | rated state |
| pi | PI-element |
| s | servo piston |

Greek

| | |
|---|---|
| $\alpha$ | amplitude of the oscillator |
| $\alpha_{gov}$ | pre-strain deviation of the governor speeder spring |
| $\gamma$ | specific weight ; phase angle |
| $\Delta$ | increment |
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Note

All dimensions are in S.I. units

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AIN SHAMS UNIVERSITY
FACUITY OF ENGINEERING

# INFLUENCE OF VARIOUS DESIGN PARAMETERS ON THE PERFORMANCE OF MECHANICAL GOVERNORS IN DIESEL ENGINES

BY
ENG.MOHAMED EL SAYED GOMAA SAMRAH

" A Thesis submitted in partial fulfilment of the requirements ofthe degree of master of science in mechanical engineering"

Supervised by
professor Dr . A . H . Bawady
professor Dr . F . A . Tolbah
Dr . Abdul Aziz Morgan

Cairo - 1990

## EXAMINERS COMMITTEE

The undersigned certify that they have read and recommend to the faculty of Engineering , Ain Shams University for acceptance a thesis entitled " INFLUENCE OF VARIOUS DESIGN PARAMETERS ON THE PERFORMANCE OF MECHANICAL GOVERNORS IN DIESEL ENGINES " , submitted by ENG. MOHAMED EL SAYED GOMAA SAMRAH , in partial fulfilment of the requirements for the degree of Master of Science in Mechanical Engineering.

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Professor of Mechanical Engineering
Faculty of Engineering , Ain Shams University.

3- Professor Dr. AHMED HASSAN BAWADY
Professor of Mechanical Engineering ,
Faculty of Engineering , Ain Shams University.

TO MY PARENTS WHO GAVE AND ARE STILL GIVING

WITHOUT ASKING ANY THING IN RETURN

## ABSTRACT

Both static and dynamic behaviour of different mechanical speed governors, as well as, the overall engine-governor system have been investigated. The study shows the effect of various design parameters of the governors on the performance of diesel engine control systems and provides the necessary guide to make the effective compromises so that the governor can be properly designed and selected for a certain engine under a particular application. Computer programs based on the mathematical formulations of the behaviour of different system components were constructed and used to predict the steady-state and transient behaviour of different engine control systems. Simulations of different diesel engines with a certain governor , as well as , simulations of different mechanical governors with a certain diesel engine were made.

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# CHAPTER ONE

# CHAPTER (I)

## 1. Introduction

Depending on the operating conditions ,the diesel engine should meet specific requirements. Under stationary conditions the engine should maintain assigned speed mode regardless of the load. In case of a diesel engine driving an electric generator at a fixed frequency , the fuel supply must be controlled so as to prevent the variation in the engine speed during load fluctuations. In the same way , the automotive engines must neither stall when idling nor exceed the maximum speed prescribed by the engine manufacturer , since the overspeed is very dangerous to the engine components. This necessitates the use of a speed governor. All diesel engine fuel injection pumps operate in conjunction with a governor , which maintains the value of the controlled variable at a specified level. Consequently ,the governors must be properly designed to meet operational requirements of the engines.

The work reported in this thesis was intended to examine the effect of various design parameters on the performance of mechanical governors . This study is to provide the necessary guide to make the effective compromises so that the governors

can be properly designed to meet their requirements.

## 1.1 Review of the previous work

The speed governing system has been studied theoretically and experimentally with various governors. The speed governor is one of partial automation of the diesel engine which has been studied to improve the governing system performance.

Historical review of the speed governing system is given in Appendix (II). The following is a brief description of the recent literature survey .

S.Nagashima [38] studied the relationship between servo time constant of the IHI speed governor and the momentary speed rise,as well as, the response of speed control with two servomotors. The study showed that the speed governing system can be improved by taking a smaller value for the servomotor time constant and increasing the servomotor working speed.

S.Nagashima's report gave also the speed governing system equation with Watt's speed governor to study the system stability. The system consisted of marine generator driven by steam turbine with Watt's governor . He found that the system characteristic related to deviation of the angular velocity was not stable according to Hurwitz's stability method and concluded that the Watt's speed governor can not be used for a generator driven by prime mover .

H.Peter and L. David [41] explored the governor characteristics for engines in tractors and other off high way applications. These do not have to meet stringent emission regulations and therefore , do not need precise control of timing and maximum fuel. Their static study showed that the governing characteristics depend on characteristic and design dimension of the fuel system to determine the fuel control.

A.S. Khachign [43] studied some of the static and dynamic characteristics for the engine control system with quantitative control using direct - action controler. That study showed that the governing system characteristics depend on the design of the control organ and its drive ,as well as, load inertia and its time constant.

S.S.Shamsi [29] studied experimentally and theoretically the influence of four design variables , namely , the engine and turbocharger moments of inertia , the electromechanical governor time constant and the limit on fuel injection pump rack on the transient performance of the turbocharged diesel engine. The study showed that significant improvements in the transient performance of the turbocharged diesel engine could be achieved by changing three of these variables without affecting its steady performance. For example , a

reduction in the fuel rack travel increased the engine speed droop and recovery time , while a reduction in the governor time constant reduced the speed droop and recovery time.

An increase in the engine moment of inertia reduced the engine speed droop ,while the recovery time increased.

The fourth design parameter , namely , the turbocharger moment of inertia needed to be reduced to achieve improved engine transient performance , but that was not possible without a turbocharger rematch unless some super light materials were developed and used in rotor construction.

G. Hutarew and A. schmid [13] studied experimentally the influence of the control characteristics for different diesel engine governors on their frequency responses.

The study showed that dynamic tests can be carried out on any type of governors with sufficient accuracy. The results of dynamic tests may include all influences of the governor variables which cannot be described by differential equations.

They studied the influence of some governor parameters , namely, temporary feedback and flexible coupling by means of root locus techniques . This study showed that the above parameters affect the system stability.

K. Minoruand [42] made a theoretical investigation on the unfavorable surge phenomenon. The study showed that the

surge phenomenon is due to the poor characteristics of the speed governing systems.

G.E.Parker and D.C. Garvey [39] studied the hunting phenomenon in diesel engine governors and their responses to this disturbance . The hunting occurs during the alternate speeding up and slowing down of the engine . The process may be repeated and consequently oscillations may be set up . If the frequency of fluctuations in engine speed coincides with the natural frequency of oscillation of the governor , then , due to resonance , the amplitude of oscillations becomes very high. Consequently ,the governor tends to intensify the speed variation instead of controlling it . The study showed that the hunting tendency may be reduced by reducing the friction of moving parts between the centrifugal masses and the fuel rack .

M. Wuhrer [13] studied experimentally the influence of Coulomb friction and oscillating masses on the fuel bar . The study showed that all oscillating masses increase the amplitude of the fuel bar oscillation . This effect was observed especially at low frequencies in the case of governors provided with additional masses and with governors actuating double pump units . The Coulomb friction increases the insensitivity of the governor and its inaccuracy and it

reduces the amplitude of the fuel bar oscillation.

These effects also increase the adjusted permanent speed droop. The Coulomb friction can be reduced by vibrations due to the fuel injection pump. The deadband of the governor became smaller by increasing the injection and also with double pump units.

## 2.3 Problem formulation

It can be seen from the previous literature that the three requirements of stability ,accuracy and speed response of the automatic control system of a diesel engine must be met . This may not always be easy because the requirements tend to be incompatible ; compromises between them must be made . As mentioned , there are many types of governors which can be used to control the speed of a diesel engine . See Appendix (III).The wide variety of these governor types makes the suitable choice of the proper governor to a particular engine for a certain application quite difficult. Also, the characteristics of the governor depend on the design and dimensions of its components .

Therefore , it was necessary to study the subject of the static and dynamic behaviour of mechanical governors , as well as , the overall engine - governor control system in some more detail . The main aim is to provide the necessary

guide to make the effective compromises so that the mechanical governors can be properly designed and selected for a certain engine application.

## 2.4 Present work

In this present work ,the influence of various design parameters of the governor on the performance of engine control system with three different mechanical governors are studied . This was to achieve economical and optimum combinations of the design changes to meet the operational requirements . Both the theoretical and experimental plan of work are explained below .

### 2.4.1 Theoretical work

The present theoretical work has progressed according to the following scheme :

1- Theoretical computer programs based on the mathematical formulations of the behaviour of different speed governing system components developed by the previous investigators have been constructed . These mathematical formulations result in final differential equations which describe the behaviour of different systems under transient operation. The solutions of these differential equations are used as a design tool to achieve economical and optimal combination of design parameters to meet operational requirements in steady

and transient modes.

2- Study behaviour of different diesel engines with a certain mechanical governor,as well as,different mechanical governors with a certain engine .

3- Determination of optimum governor variables .

Static and dynamic studies dealt with in this work have been carried out on three different mechanical governors.

The R-11M type was such a precision speed governor , the BOSCH-RQ (500/1700) type was such a limiting speed governor and the R-23 type was such a proportional plus integral governor.

2.4.2 Experimental work

The experimental work was set out to investigate the effect of main design parameters obtained from the theoretical work on the mechanical governor time response.

For the purpose of confirmation the computer programs which were constructed ,both the experimental and theoretical results have been compared.

The scope of the present text is arranged as follows :

Chapter Two deals with the mathematical models of three control systems.

A full description of the experimental test rigs is given in chapter Three.

Chapter Four includes the theoretical and experimental results and their discussion.

Finally , the main conclusions and suggestions for further work are presented in chapter Five.

# CHAPTER TWO

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