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Developmental Practices of Intake Manifold for Compression and Spark Ignition Engines

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ABSTRACT: A detailed developmental practices theoretical and experimentally investigated by various researchers during 2016-2011 years are presented in this review paper. Intake manifold box was optimized using Frontier TM software using different pressur conditions.

KEYWORDS: intake manifold, compression ignition engine etc.

I. INTRODUCTION

Daniela Siano and Fabio Bozza[1] presented in their technical paper the characteristics of the intake system affect both engine power output and gas-dynamic noise emissions. The latter was particularly true in downsized VVA engines, where a less effective attenuation of the pressure waves was realized, due to the intake line de-throttling at part-load. For this engine architecture, a refined air-box design was hence requested. In this work, the Transmission Loss (TL) of the intake air-box of a commercial VVA engine was numerically computed through a 3D FEM approach. Results are compared with experimental data, showing a very good correlation. The validated model was then coupled to an external optimizer (Mode FRONTIERTM) to increase the TL parameter in a prefixed frequency range. The improvement of the acoustic attenuation was attained through a shape deformation of the inner structure of the base device, taking into account constraints related to the device installation inside the engine bay.

Matthew Maunder et al [2] presented in their technical paper engine sound quality was a key attribute for sporty cars – it powerfully conveys the brand image to the driver/passengers and onlookers, and provides driver involvement by giving instant feedback about how a car was operating. Tighter pass-by noise regulations and the near-universal adoption of turbocharging have tempered the natural sporty engine sound quality that customers demand. In the last two decades, some of the sporty engine sound inside the cabin has been regained using intake sound generator systems that transfer the intake system sound more directly to the vehicle interior. Antonio J. Torregrosa et al [3] presented in their technical paper intake noise has become one of the main concerns in the design of highly-supercharged downsized engines, which are expected to play a significant role in the upcoming years. Apart from the low frequencies associated with engine breathing, in these engines other frequency bands are also relevant which are related to the turbocharger operation, and which may radiate from the high-pressure side from the compressor outlet to the charge air cooler. Medium frequencies may be controlled with the use of different typologies of resonators, but these are not so effective for relatively high frequencies. In this paper, the potential of the use of multi-layer porous materials to control those high frequencies was explored. The material sheets are located in the side chamber of an otherwise conventional resonator, thus providing a compact, lightweight and convenient arrangement.

Mateos Kassa et al [4] presented in their technical paper leverages experimental data from an inline 6-cylinder heavy-duty dual fuel engine equipped with a fully-flexible variable intake valve actuation system to study cylinder-to-cylinder variations in power production. The engine was operated with late intake valve closure timings in a dual-fuel combustion mode featuring a port-injection and a direct-injection fueling system. Both dual fuel implementation and late intake valve closing (IVC) timings have been shown to improve thermal efficiency. However, experimental data from this study reveal that when late IVC timings are used on a multi-cylinder dual fuel engine a significant variation in power production across cylinders results and as such, leads to efficiency losses.Ashwini Agarwal et al [5] presented in their technical paper the development of a low cost auxiliary power unit (APU) for the range extender application utilising a well optimised production automotive two cylinder gasoline engine. The 624 cc production engine was further optimised given the project constraints of low cost changes to suit a range extender application.Stephanie Stockar et al [6] presented in their technical paper engine downsizing and boosting, coupled with variable valve actuation, have become an industry standard for reducing CO2 emissions in current production vehicles. Because of the increasing complexity and number of degrees of freedom, the design of control algorithms for the air path system actuators has become a difficult and time consuming process, often involving extensive calibration on engine dynamometers. One possibility to cut the control development time and significantly reduce the time required to bring novel technologies into production was using Software-in-the-Loop (SIL) methods. In the case of the engine air path control problem, SIL simulation tools typically rely on mean-value models, which are not able to predict wave propagation effects in the engine intake and exhaust system. On the other hand, one-dimensional wave action models are characterized by significant complexity and high computation times, preventing their application to SIL and control system verification.

Massimo Masi et al [7] presented in their technical paper the design of intake manifolds and valve ports in internal combustion engines was a fundamental aspect of obtaining high volumetric efficiency and originating in-cylinder flows of proper intensity. CFD calculations using the RANS approach may support steady-state flow measurements in the design of intake manifolds, valve passages, and combustion chambers. On the other hand, the geometrical complexity of these engine parts hardly allows to mesh them by means of fully hexahedral grids and the accuracy of computations was strongly compromised. The paper presents the results of an experimental and numerical study performed on the head of a motorbike high-speed spark ignition engine. The work aims at investigating the reliability of CFD RANS computations performed on polyhedral grids of different size and assessing the mesh size required for accurate computations on such a type of grid.

Farouq Meddahi et al [8] presented in their technical paper compressor models play a major role as they define the boost pressure in the intake manifold. These models have to be suitable for real-time applications such as control and diagnosis and for that, they need to be both accurate and computationally inexpensive. However, the models available in the literature usually fulfill only one of these two competing requirements. On the one hand, physics-based models are often too complex to be evaluated on line. On the other hand, data-based models generally suffer insufficient extrapolation features. To combine the merits of these two types of models, this work presents an extended approach to compressor modeling with respect to thermo- and aerodynamic losses. The resulting model surpasses the extrapolation properties of data-based models and facilitates the generation of extended lookup tables.Leonid Tartakovsky et al [9] presented in their technical paper an interaction process of a single fuel drop and a fuel jet with the impingement surface. Ultrasonic (US) oscillation of the latter was applied to prevent fuel film formation. Diesel fuel was chosen for our experiments because it causes more problems of mixture formation in SI engines. In the series of experiments with a single drop, effects of the drop size, ultrasound performance and a type of the impingement surface on the drop behavior were studied using a high-speed photography. In experiments with a fuel jet the phenomena of fuel film formation and size distribution of the impinging and reflected droplets were studied using a high-speed photography and PDPA/LDV technique.

Dileep Namdeorao Malkhede and Hemant Khalane[10] presented in their technical paper the effect of intake length on volumetric efficiency for wider range of engine speeds. For this purpose 1-D thermodynamic engine model of a single cylinder 611cc standard CFR engine capable of predicting pressure waves in the intake was developed. For validation, pressure waves were predicted at two different locations on intake manifold and compared against test data. This model was used to predict volumetric efficiency for different intake lengths and engine speeds. Volumetric efficiency was found to be a function of both engine speed and intake length, more so at higher engine speeds. Frequency analysis of intake pressure waves during suction stroke and intake valve closed phase was carried out separately.

Takamoto Furuichi, Takashige Nagao, Hisanori Yokura, Ryuichirou Abe, Shigemitsu Fukatsu [11] presented in their technical paper two newly developed technologies of optimizing impurity diffusion concentration for silicon semiconductor material and controlling internal stress of the top SiN (Silicon Nitride) layer on a membrane of a silicon substrate to apply them to the manufacturing process of MEMS (Micro Electro Mechanical Systems) type air-flow sensor chips. Until today, in MEMS-type airflow sensors, poly-crystalline silicon (poly-Si) and platinum were widely used as a resistor material of key functional elements on a membrane of air-flow-rate measurement portion. The functional resistors on the membrane are required to monitor high temperatures of about 300 °C and to perform the self-heating operations at that temperature range because of the suppression of contaminant deposition by means of evaporation or incineration.

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Kazuyoshi Shimatani [12] Various sensors including throttle position sensors (TPS), manifold pressure sensors (MPS), crank angle sensors, engine temperature sensors, and oxygen sensors are mounted in electronically controlled fuel injection (FI) systems to accurately regulate the air-fuel ratio according to the operating state and operating environment. Among these vehicle-mounted sensors, TPS has functions for detecting a fully-closed throttle and estimating intake air volume by the amount of throttle opening. Currently, we have conducted a study on transferring TPS functions into the MPS (manifold pressure sensor) in order to eliminate the TPS. Here we report on detecting a fully-closed throttle for achieving fuel cut control (FCC) and idle speed control (ISC) in fuel injection systems. We contrived a means for fully-closed throttle detection during ISC and controlling changes in the bypass opening during FCC in order to accurately judge each fully-closed throttle state via the manifold pressure.D. Saravanan, Anish Gokhale, N. Karthikeyan [13] presented in their technical paper the Torque from an engine was a very critical parameter which controls the drivability of the vehicle, better torque availability at Partially Open Throttle (POT) condition improves drivability at city driving condition and better torque at Wide Open Throttle (WOT) condition improves cruising at highway driving condition, conventionally engine produces better torque at one particular operating condition leaving poor drivability at others. The Torque characteristics of an engine depends upon the volumetric efficiency of the engine. The volumetric efficiency of a naturally aspirated engine can be improved by tuning the intake manifold. With an overall improvement in volumetric efficiency throughout the engine operating conditions better torque curve can be achieved, which facilitates improved drivability.

Saravanan D, Anish Gokhale, Karthikeyan N[14] presented in their technical paper the demand of Torque from an engine was highly variable, good torque at lower engine speeds improve drivability at city driving condition and good torque at higher engine speeds improves cruising at highway driving, conventionally engine produces better torque at one particular speed leaving poor drivability at others. The Torque characteristics of an engine depends upon the volumetric efficiency of the engine, volumetric efficiency of a naturally aspirated engine can be improved by tuning the intake manifold. For improving volumetric efficiency, several technologies were developed, among that Dual Intake Manifold system is one where the flow of charge is channelized between longer and shorter flow path depending on the engine operating speed. Application of conventional Dual Intake Manifold system is limited due to increased cost, complexity in assembly and need for an external power source for actuation.

Johannes Reß, Christian Bohn, Frank Märzke, Ralf Meinecke, Michael Schollmeyer, Robert Frase[15] presented in their technical paper an improved model-based two-degree of freedom control system for the intake manifold pressure in passenger car diesel engines is described in this paper. The aim of this control system is to track the air charge setpoint rapidly and precisely. To achieve this, an inverse model of the intake manifold dynamics is included in the feedforward control path. The system parameters which are necessary to calculate the inverse model are setpoints from other control loops in the gas system. These generated setpoint values allow for decoupling of the individual control loops in the gas system as far as possible. The parallel linear feedback controller is designed to further improve the accuracy of the control system. The calculated feedforward control signal and the feedback control variable additively generate the effective opened area of the intake throttle valve.

Jensen Samuel, Prasad NS, Kumarasamy Annamalai[16] presented in their technical paper the results of a study on the effect of using a continuously variable length intake runner (intake manifold) on Turbocharged multi-cylinder diesel engines. While there was a large amount of data available for naturally aspirated engines, no reliable source was found for the effect of varying the length of intake runner for Turbocharged engines. This study was done for relatively low-speed off-highway diesel engines. The study is based on the results of one-dimensional engine models simulated in AVL BOOSTTM engine simulation software. A simplified engine model has been used for the single

cylinder naturally aspirated engine, to demonstrate the effects of varying intake runner effective length. The multi cylinder study was based on validated model of a 12 cylinder 1000hp turbocharged diesel engine. It has been found that multi-cylinder turbocharged diesel engines are more responsive to intake runner length variations than naturally aspirated engines.

Shun-ichi Akama, Yasunori Murayama, Shigeho Sakoda [17] presented in their technical paper deals with reduced-order modeling of intake air dynamics in single-cylinder four-stroke naturally-aspirated spark-ignited engines without surge tanks. It provides an approximate calculation method for embedded micro computers to estimate intake manifold pressures in real time. The calculation method is also applicable to multi-cylinder engines with individual throttle bodies since the engines can be equated with parallelization of the single-cylinder engines. In this paper, we illustrate the intake air dynamics, describe a method to estimate the intake manifold pressures, and show experimental results of the method.

Bo-Chiuan Chen, Yuh-Yih Wu, Hsien-Chi Tsai [18] presented in their technical paper for vehicles with intake manifold absolute pressure (MAP) sensor, the intake air mass was obtained using speed-density method. Since the analog MAP signal will contain high frequency noise with uncertain amplitude, the MAP value obtained in the engine management system using angle based sampling will result in MAP value variation even for engine steady-state operation. In order to properly obtain a MAP value under nonlinear time-varying characteristics, a MAP estimation method based on a closed-loop model is proposed. First, an adaptive two-input single-output intake manifold model is constructed. The Recursive Least Square technique is utilized to on-line identify the intake manifold model with throttle opening angle and engine speed as inputs. The identified intake manifold model is then employed to estimate the MAP using the Kalman Filter.

I. Coutinho, A. Pereira, C. Sanches, M. Mottin[19] presented in their technical paper the internal combustion engine air intake manifold was subjected to continuous dynamic excitation due to unbalanced firing sequence and alternated movement of the pistons. An elastic anchoring for the intake manifold of Iveco's new bus was developed based on two criteria: 1. increase the natural frequency of the system to avoid coupling with engine's NEF 6 idle input and 2. minimize the vibration transmitted to the chassis. In order to solve this duality an optimization algorithm was used to fit cushion stiffness to both requirements. The system behavior is evaluated virtually in frequency domain through FRFs and its modal mode shapes and natural frequencies eigenvectors and eigenvalues) extracted with Lanczos method.Fernando Ortenzi, Emiliana Vesco[20] presented in their technical paper analyzes the 1D boundary multi-pipe junctions calculations using the Method of Characteristics (MOC). Sonic flows can be encountered in the exhaust manifolds of internal combustion engines (especially racing engines) and in the model a check if the flow is sonic or not have been made. Flows with more than one manifold have flow toward the junction, need an equivalent "Datum" manifold, with an airflow as the sum of all flows, an averaged area and stagnation enthalpy has been defined in order to calculate the pressure loss when crossing the junction. The pressure loss terms have been calculated as function of the flow-ratio of the gas flowing to the manifold to the total incoming flow and the pipe angle.

Stephanie Stockar, Marcello Canova, Yann Guezennec, Augusto Della Torre, Gianluca Montenegro, Angelo Onorati[21] presented in their technical paper first-principles gas dynamic models predicting the mass, energy and momentum transport in the engine air path system with high accuracy and low computation effort are extremely important today for performance prediction, optimization and cylinder charge estimation and control. This paper presents a comparative study of two different modeling approaches to predict the one-dimensional unsteady compressible flow in the engine air path system. The first approach is based on a quasi-3D finite volume method, which relies on a geometrical reconstruction of the calculation domain using networks of zero-dimensional elements. The second approach is based on a model-order reduction procedure that projects the nonlinear hyperbolic partial differential equations describing the 1D unsteady flow in engine manifolds onto a predefined basis.

Mayank Mittal, Harold Schock, Ravi Vedula, Ahmed Naguib [22] presented in their technical paper an experimental study has been conducted to quantify the velocity and pressure inside an idealized intake manifold of a motored internal combustion engine assembly. The aim of this work is to provide the real-time boundary conditions for more accurate multi-dimensional numerical simulations of complex in-cylinder flows in an internal combustion engine as well as the resultant in-cylinder flow patterns. The geometry of the intake manifold is simplified for this purpose. A hot-wire anemometer and a piezoresistive absolute pressure transducer are used to measure the velocity and pressure, respectively, over a plane inside the circular section of the intake manifold. In addition, pressure measurements are performed over an elliptical section near the intake port. Phase-averaged velocity and pressure profiles are then calculated from the instantaneous measurements. Experiments were performed at 900 and 1200 rpm engine speeds with wide open throttle.

Claire Maxey, Vickey Kalaskar, Dongil Kang, Andre Boehman[23] presented in their technical paper the performance and emissions of a 4 cylinder 2.5L light-duty diesel engine with methane fumigation in the intake air manifold was studied to simulate a dual fuel conversion kit. Because the engine control unit was optimized to work with only the diesel injection into the cylinder, the addition of methane to the intake disrupts this optimization. The energy from the diesel fuel is replaced with that from the methane by holding the engine load and speed constant as methane is added to the intake air. The pilot injection is fixed and the main injection is varied in increments over 12 crank angle degrees at these conditions to determine the timing that reduces each of the emissions while maintaining combustion performance

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as measured by the brake thermal efficiency. It is shown that with higher substitution the unburned hydrocarbon (UHC) emissions can increase by up to twenty times. Hyunjun Lee, Yeongseop Park, Seungwoo Hong, Minkwang Lee, Myoungho Sunwoo[24] presented in their technical paper an exhaust gas recirculation (EGR) rate estimation algorithm for a turbocharged diesel engine. Accurate estimation of the EGR rate is important for precise air system control of a diesel engine. In order to estimate the EGR rate accurately, we developed an adaptive observer using a model reference identification scheme (MRIS). A linear parameter varying model for the intake manifold pressure dynamics was derived as the reference model for the adaptive observer. The intake and exhaust temperature models are developed through an empirical approach. The MRIS was used to design an update rule for the adaptive observer. Convergence of the proposed observer is proven by using the Lyapunov stability criterion. Tuan Le Anh, Khanh Nguyen Duc, Huong Tran Thi Thu, Tai Cao Van[25] presented in their technical paper the effect of HHO gas addition on engine performance and emission characteristics. HHO gas was produced by the electrolysis process of distilled water and stored in a high pressure tank before injected into the intake manifold. The experimental study was carried out on a 97 cc SI engine equipped with two injection systems (HHO gas and addition air) on the intake manifold. The tests were divided into two cases: hybrid HHO/gasoline and HHO/gasoline with addition air from second injection.

Alfonso Dimeo, Guilherme Alegre, Gregorio Modeo, Nazario Bellato, Thomas Moura[26] presented in their technical paper numerical methodology to estimate the acoustic vibration of an Intake Manifold component and how to use that methodology to reduce noise radiation. Vibroacoustic analysis for different Intake Manifold are going to be presented, showing results and how they are managed to match customer targets

Sergio Villalva, Guilherme Alegre, Thomas Moura, Fernando Windlin, Andre Savioli, Paulo Motta[27] presented in their technical paper in the current Brazilian air intake manifold area, most of the small car applications use the reinforced polyamide PA 6.6 GF30 as base material. The glass fiber (30%) guarantees the required mechanical resistance, necessary once the manifold is assembled on the engine and is subjected to considerable vibration levels. Air intake manifolds were developed using a new chemically recycled material recuperated from yarn production process, called Technyl ECO, which represents a reduction of 4.3 kg of CO_2 equivalent per 1 kg of polyamide produced. This material can replace the current one, once it has the same formulation (PA 6.6 GF30) and similar mechanical resistance. Moreover, it represents a cost saving up to 10% in the raw material. The air intake manifolds injected with the recycled material were subjected to the mechanical validation tests under severe conditions of accelerated aging at temperature of 140°C and thermal shock with abrupt temperature change from -40°C to 120°C.

Olivier Grondin, Jonathan Chauvin, Laurent Fontvieille[28] presented in their technical paper a method to detect an intake manifold leakage for a Diesel engine with a dual loop EGR system. The intake manifold leak has a strong impact on the engine performances by changing the intake manifold burned gas ratio. This fault is analyzed according to the control structure used and also according to the EGR operating mode. The paper proposes a diagnosis algorithm to detect the intake manifold leak in sequential or simultaneous use of the two EGR paths. The sensors considered are the mass air flow meter, the intake manifold pressure sensor, the exhaust equivalence ratio sensor and the differential pressure sensor (across the HP EGR valve). The diagnosis is based on a criteria that uses the redundancy between these sensors and air system models or estimators. The diagnosis threshold depends on the engine operating conditions as well as the sensor or model dispersions.

Pierre-Olivier Santacreu, Laurent Faivre, Antoine Acher[29] presented in their technical paper stainless steel grades are now widely used for automotive exhaust systems, driven by the need to increase their durability and to reduce their weight. Exhaust Manifolds are subjected to more severe conditions and peak gas temperatures of 1000°C could be reached in new downsized gasoline engines. Also, longer guaranties are now required. This evolution is a direct consequence of the effort to decrease automotive pollutant emissions with new environmental regulations throughout the world. The paper will deal with the thermal-mechanical fatigue (TMF) damage prediction of fabricated automotive exhaust manifold fixed to the engine. A dedicated lifespan prediction approach was created based on elasto-viscoplastic behavior and damage models identification from different thermal-mechanical tests.

James Taylor, David Gurney, Paul Freeland, Rene Dingelstadt, Jürgen Stehlig, Veit Bruggesser [30] presented in their technical paper downsizing of the spark ignition engine was accepted as a key contributor to reducing fuel consumption. Turbocharged engines are becoming commonplace in passenger vehicles, replacing naturally aspirated larger capacity engines. However, turbocharged engines have typically suffered from “lag” during transient operation. This perceived effect is a combination of the low speed steady state torque and a slower rate to reach maximum torque

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during a load step. In order to increase customer acceptance of downsized concepts it is vital that the low speed torque and transient response are optimized.

Variable Length Intake Manifolds (VLIM) have long been an established method of improving the full load performance of naturally aspirated engines. The manifold length being "tuned" to provide a high-pressure pulse at intake valve closing to maximize cylinder filling and deliver improved performance. Arvindkumar Ka ; Adhithiyan Nb ;Darsak V Sc; Dinesh Cd [31] presented in their technical paper the design and manufacture of an intake system for a 600cc YAMAHA ZF engine. Intake system have a major effect on a vehicle's engine performance, noise and pollutants. Differences in engine outputs and applications require different designs of intake-air manifolds in order to achieve the best volumetric efficiency and thus the best engine performance. As a result, the geometry of the intake system has been redesigned to result in reduced weight by using FIBER REINFORCED POLYMERS (due to lower material density and lack of welds, thermal, heat aging, fatigue, impact, creep, stress and chemical resistance), improved charge distribution, and increased torque through a wide RPM range when compared to its traditionally-manufactured aluminum counterpart.The flow in the internal combustion (IC) engine intake manifold determines the flow in the cylinder prior and during the combustion. Consequently, intake-air manifolds have a major effect on engine's performances and emission pollutants. In order to achieve the best volumetric and thermal efficiency, the design of intake manifolds presents a very important objective for engines manufacturers. In this paper, the flow characteristics of air-fuel mixture flowing in various designs of manifold of IVECO 6 cylinder heavy-duty engine are studied. This engine operates with bi-fuel LPG (liquefied petroleum gas)-gasoline technology. The proposed paper aims to present a three dimensional unsteady CFD (Computational Fluid Dynamics) analysis of the flow inside the two manifold shapes. The mass flow rate of the in-cylinder charge, the velocity and the turbulent kinetic energy are investigated in order to develop a thorough understanding of the in-cylinder flow and identify the optimal manifold. The cyclic dynamic in-cylinder flow results show that the second intake manifold shape present the optimal configuration for engine charging. The comparison between simulation results and those from the literature showed a good concordance.R. Thamaraikanan, M. Anish, B. Kanimozhi, T. George, V. George Koshy,[32] presented in their technical paper a computational study of flow distribution in an intake manifold under steady state turbulence conditions in the current project work an intake manifold for 3-cylinder engine was modeled and analyzed numerically for evaluating the fluid flow. In this process, the geometric model was created with approximate dimensions (by using curves and points) in ANSA a pre-processing tool and the analysis was carried out using STAR CCM+ which was a solver and post-processing tool port in the cylinder head (s). Simeon ILIEV [33] presented in their technical paper development and application of heat transfer model to the intake manifold of four stroke direct injection diesel engine. One-dimensional (1D) gas dynamics was used to describe the flow and heat transfer in the components of the engine model. The engine model has been simulated with variable engine speed from 500 to 4500 rpm with increment of 500 rpm.

II. CONCLUSIONS

1.The high cost of these systems was more recently driving a move towards electronic Active Sound Design with systems delivering artificial synthetic sound through loudspeakers.

2. NOx emissions decrease for all engine conditions, up to 53% using methane fumigation in the intake air manifold.

3.The engine model has been simulated with variable engine speed from 500 to 4500 rpm with increment of 500 rpm.

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