

ABSTRACT

EFFECT OF THE TAILPIPE ENTRY GEOMETRY ON A TWO-STROKE ENGINE'S PERFORMANCE PREDICTION

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Degree: Master in Engineering (Mechanical)

The standard practice in one-dimensional gasdynamic simulations of high performance two-stroke engines to model the exhaust tail pipe entry as an area change using an algorithm similar to the area change of the reverse cone. In the reverse cone the area continually drops down while at the tail pipe entry it changes from slopping down to constant area. At this point a shock can form that affects the flow resistance of the tail pipe.

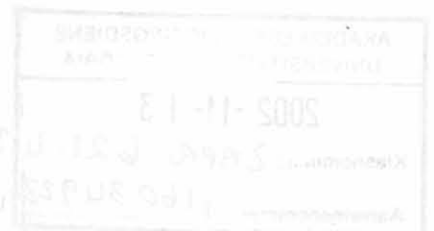
In an effort to improve the accuracy of the gasdynamic simulations the area change algorithm at the tail pipe entry was replaced with a restriction algorithm that incorporates a coefficient of discharge and allows an increase in entropy on the expansion side. The coefficient of discharge is defined as the actual measured mass flow divided by the mass flow predicted by the restriction algorithm.
By
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An experimental set up was designed and constructed to measure mass flow for a variety of tail pipe entry geometries at a range of pressures covering the pressure range encountered in a real engine. From the mass flow results the coefficients of discharge for a range of pressure and area ratios and reverse cone angles could be calculated and arranged into a matrix form.
Presented in partial fulfilment of the requirements for the degree

MASTER OF ENGINEERING

In the Faculty of Engineering,
University of Pretoria
Pretoria

December 2000



SAMEVATTING

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In an effort to improve the accuracy of the gasdynamic simulations the area change algorithm at the tail pipe entry was replaced with a restriction algorithm that incorporates a coefficient of discharge and allows an increase in entropy on the expansion side. The coefficient of discharge is defined as the actual measured mass flow divided by the mass flow predicted by the restriction algorithm.

An experimental set up was designed and constructed to measure mass flows for a variety of tail pipe entry geometries at a range of pressures covering the pressure ratios encountered in a real engine. From the mass flow results the coefficients of discharge for a range of pressure and area ratios and reverse cone angles could be calculated and arranged into matrix form to define Cd-maps. The Cd-maps were incorporated into the simulation software and tested to ensure that it functioned correctly.

Finally, the simulation results with and without the Cd-maps were compared to measured results and it was shown that incorporating this refinement improves the accuracy of the simulation results on the "over run" part of the power curve. This is the part of the power curve after maximum power and very important in the development of high performance two-stroke engines. These maps can be used for all future simulations on any engine size that uses the same tail pipe geometry.

SAMEVATTING

Titel: Die Invloed van die Afbloeiyp se Geometrie op die Voorspelling van die Werkverrigting van 'n Tweeslagenjin

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Dit is standaard praktyk in die een-dimensionele gasdinamiese simulaties van hoë werkverrigting tweeslag enjins om die ingang van uitlaatstelsel se afbloeiyp as 'n area verandering te modelleer deur dieselfde algoritme te gebruik as wat vir die modellering van die trukaatskegel gebruik word. In werklikheid verskil die twee deurdat die trukaats kegel se deursnit oppervlakte kontinu verklein, terwyl die deursnit oppervlakte van die afbloeiyp se ingang verander van 'n afnemende waarde na 'n konstante waarde. By dié punt kan 'n vloeivernouing ontstaan wat die vloei weerstand kan beïnvloed.

In 'n poging om die akkuraatheid van die gasdinamiese simulaties te verbeter, is die varieërende oppervlak-algoritme by die afbloeiyp se inlaat vervang met 'n weerstandsalgoritme wat 'n vloeiveerstandskoeëfisiënt insluit en wat toelaat vir 'n verhoging in entropie na die weerstand. Die vloeiveerstandskoeëfisiënt word gedefiniëer as die verhouding tussen die gemete massavloei en die voorspelde massavloei soos voorspel deur die weerstandsalgoritme.

'n Eksperimentele opstelling is ontwerp en gebou om massavloei by 'n reeks afbloeiyp ingangsgeometrië te meet by 'n reeks drukke wat die drukverhoudings, soos wat in werklike enjins voorkom, te meet. Uit die massavloei resultate kan die vloeiveerstandskoeëfisiënt vir 'n reeks druk- en oppervlakverhoudings en trukaatskegel ingeslote hoeke, bereken word en in 'n matriks gerangskik word om vloeiveerstandskoeëfisiënt-kontoerkaarte te vorm. Die kontoerkaarte is in die sagteware geïnkorporeer en getoets.

Ten slotte is die simulatie resultate met en sonder die kontoerkaarte met gemete resultate vergelyk en dit is gevind dat die verfyning die akkuraatheid van die simulatie verbeter by die gedeelte van die drywingskromme na maksimum drywing. Hierdie gedeelte van die drywingskromme is baie belangrik by hoë werkverrigting tweeslag enjins. Die kontoerkaarte maak nou deel uit van die simulatie sagteware en is van toepassing op alle enjins wat die tipe uitlaatstelsel gebruik.

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| 0 | Reference Conditions | |
| 1 | Values for Pipe 1 | |
| 2 | Values for Pipe 2 | |
| 1 | Incident | |
| m | Mesh | |
| r | Reflected | |
| 1 | Throat | |
| eff | Effective Value in Throat | |

NOMENCLATURE

List of Symbols

| | |
|------------|------------------------------------|
| A | Area |
| A_r | Area Ratio |
| a | Sonic Velocity |
| C_d | Coefficient of Discharge |
| C_p | Specific Heat at Constant Pressure |
| c | Particle Velocity |
| d | Diameter |
| F | Function |
| h | Enthalpy |
| l | Length |
| M | Mach Number |
| \dot{m} | Mass Flow Rate |
| P | Pressure |
| P_r | Pressure Ratio |
| R | Gas Constant |
| T | Temperature |
| δE | Change in Internal Energy |
| δm | Change in Mass |
| δQ | Heat Transferred |
| δW | Work |
| γ | Ratio of Specific Heats |
| θ | Included Angle of the Reverse Cone |
| ρ | Density |

Subscripts

| | |
|------|---------------------------|
| 0 | Reference Conditions |
| 1 | Values for Pipe 1 |
| 2 | Values for Pipe 2 |
| i | Incident |
| m | Mesh |
| r | Reflected |
| t | Throat |
| teff | Effective Value in Throat |

Definitions

$$G5 = \frac{2}{\gamma - 1}$$

$$G6 = \frac{\gamma + 1}{\gamma - 1}$$

$$G7 = \frac{2\gamma}{\gamma - 1}$$

$$X = \left(\frac{P}{P_0} \right)^{\frac{1}{G7}}$$

Abbreviation

| | |
|----------|---|
| FCT | Flux Corrected Transport |
| GPB | Gordon P Blair |
| HLLE | Harten-Lax-Van Leer-Einfeldt |
| LW | Lax-Wendroff |
| MoC | Method of Characteristics |
| EngMod2T | Acronym for The two-stroke engine simulation software |



Figure 1.1: Schematic of Two-Stroke Engine

It is standard practice to model the tailpipe entry using the same formulation as used for the reverse cone. By using a more sophisticated model combined with a measured coefficient of discharge it is hoped that the accuracy of the simulation can be improved. The engine simulation software, EngMod2T will be used for the evaluation. (Refer to Appendix I for a more detailed description of EngMod2T) This software was written to simulate the performance characteristics of a high speed, high output two-stroke spark ignition internal combustion engine. It simulates the tailpipe duct flows using one-dimensional gasdynamics and follows the current trend by modelling the tailpipe entrance as an area change. By modelling it as an orifice with an experimentally determined discharge coefficient it is hoped to improve the accuracy of the simulation software.