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


By

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# ABSTRACT


| | |
|---|---|
| **Title:** | **Effect of the Tailpipe Entry Geometry on a Two-Stroke Engine's Performance Prediction** |
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It is 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 steps down while at the tail pipe entry it changes from stepping down to constant area. At this point a vena contracta can form that effects 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.

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 Afbloeipyp se Geometrie op die Voorspelling van die Werkverrigting van 'n Tweeslagenjin**

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Dit is standaard praktyk in die een-dimensionele gasdinamiese simulasies van hoë werkverrigting tweeslag enjins om die ingang van uitlaatstelsel se afbloeipyp 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 afbloeipyp 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 simulasies te verbeter, is die varieërende oppervlak-algoritme by die afbloeipyp se inlaat vervang met 'n weerstandsalgoritme wat 'n vloeiweerstandskoeëfisiënt insluit en wat toelaat vir 'n verhoging in entropie na die weerstand. Die vloeiweerstandskoeëfisiënt 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 massavloeie by 'n reeks afbloeipyp ingangsgeometrië te meet by 'n reeks drukke wat die drukverhoudings, soos wat in werklike enjins voorkom, te meet. Uit die massavloei resultate kan die vloeiweerstandskoeëfisiënt vir 'n reeks druk- en oppervlakverhoudings en trukaatskegel ingeslote hoeke, bereken word en in 'n matriks gerangskik word om vloeiweerstandskoeëfisiënt-kontoerkaarte te vorm. Die kontoerkaarte is in die sagteware geïnkorporeer en getoets.

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

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## NOMENCLATURE

### List of Symbols

| | |
|---|---|
| $A$ | Area |
| $Ar$ | Area Ratio |
| $a$ | Sonic Velocity |
| $Cd$ | Coefficient of Discharge |
| $Cp$ | 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 |
| $\mathrm{Pr}$ | Pressure Ratio |
| $R$ | Gas Constant |
| $T$ | Temperature |
| $\delta E$ | Change in Internal Energy |
| $\delta m$ | Change in Mass |
| $\delta Q$ | Heat Transferred |
| $\delta W$ | Work |
| $\gamma$ | Ratio of Specific Heats |
| $\theta$ | Included Angle of the Reverse Cone |
| $\rho$ | 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-Einfelt |
| LW | Lax-Wendroff |
| MoC | Method of Characteristics |
| EngMod2T | Acronym for The two-stroke engine simulation software |