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**Transient One-Dimensional Fluid Flow
in High Pressure Applications for
Diesel-Fuel**

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Abstract

Future emission laws like *EURO VI*, *JPNLT*, *US 10* and *US T4* require to increase the efficiency of diesel engines. Shaping the rate of diesel fuel injected into a cylinder during one combustion cycle has great influence on emission of *CO*, *NO_x* and *sooty particles*. In order to determine an optimal rate shaping, knowledge of the thermodynamic behavior of diesel and of the pressure waves in the components of the injection system is needed.

Here we deduce a simulation model, that calculates transient one-dimensional flow of diesel fuel. The model consists of three components, which are all based on the equations of state for liquid diesel fuel. The flow in the pipes is considered one-dimensional and inviscid. Thus the Euler equations are solved numerically using Roe's method. In a volume the kinetic energy can be neglected and the changes of internal energy are calculated by a mass and energy balance considering the in and outflow masses and their enthalpy and the change of volume with time, as well. A throttle will be described by a pressure loss coefficient. Changes of temperature due to the Joule-Thomson effect are also taken into account. Equations of state for liquid diesel Fuel have been derived from measured data for density and isobaric heat capacity. The equation of state is tested by comparing the predicted values for the speed of sound with measured data reported in the literature. To proof the ability of the simulation tool to resolve shock and rarefaction waves as well as contact discontinuities, the results for a shock tube test are shown. Further the change of density and temperature during compression and expansion in a piston pump is shown. Also the results for two volumes with different initial conditions, connected by a throttle in one test case and connected by a pipe in another test case, show different transient behavior. This work shall help simulating transient one dimensional flow of liquid diesel fuel in modern diesel injection systems, having operating pressures of up to 2500 bar and operating temperatures from 260 K to 393 K.

Kurzdarstellung

Künftige Abgasnormen wie *EURO VI*, *JPNLT*, *US10* und *US T4* erfordern eine Steigerung der Effizienz von Dieselmotoren. Der Verlauf der Einspritzrate des Dieselkraftstoffes während eines Brennzyklus spielt eine entscheidende Rolle für die Emission von CO , NO_x und *Russpartikeln*. Um optimale Einspritzverlaufs- Formung zu bestimmen, bedarf es sowohl einer genauen Kenntnis der thermodynamischen Eigenschaften des Dieselkraftstoffes, als auch der sich ausbreitenden Wellen in den einzelnen Komponenten.

Hier wird eine Simulationsmodell abgeleitet, das instationäre eindimensionale Strömungsvorgänge von Dieselkraftstoff berechnet. Das Modell besteht aus drei Komponenten, deren gemeinsame Grundlage eine Zustandsgleichung für flüssigen Dieselkraftstoff ist. Die Strömung in den Rohrleitungen wird eindimensional und reibungsfrei angenommen. Daher werden die Euler Gleichungen numerisch, mittels der Methode von Roe, gelöst. In einem Vorratsbehälter (Volumen) können die kinetischen Energien vernachlässigt und die Änderungen der inneren Energie mittels Massen- und Energiebilanz berechnet werden, unter Berücksichtigung von ein- und ausströmender Masse und Enthalpie, sowie der zeitlichen Änderung des Gesamtvolumens. Drosseln werden durch Druckverlustbeiwerte beschrieben. Außerdem werden Änderungen der Temperatur aufgrund des Joule-Thomson Effekts berücksichtigt. Die benötigten Zustandsgleichungen für flüssigen Diesel Kraftstoff werden aus Messungen von Dichte und isobarer Wärmekapazität hergeleitet. Um diese Zustandsgleichung zu testen, wurden daraus berechnete Werte für die Schallgeschwindigkeit mit Werten aus der Literatur verglichen. Um das Simulationsmodell auf die Fähigkeit Druckwellen, Verdünnungsfächer und Kontaktunstetigkeiten auflösen zu können zu überprüfen, werden die Ergebnisse eines Stoßrohrproblems gezeigt. Weiters werden die Änderungen von Dichte und Temperatur während der Kompression und Expansion in einer Kolbenpumpe gezeigt. Außerdem wurden zwei verschiedene Kombinationen von Komponenten ausgetestet. Zwei Volumina mit unterschiedlichen Anfangsbedingungen werden in einem Test mit einer Drossel und in einem anderen Test mit einer Leitung verbunden. Der zeitliche Verlauf der daraus resultierenden Ausgleichsvorgänge wird gezeigt.

Die Arbeit soll helfen instationäre eindimensionale Strömungsvorgänge von flüssigem Diesel in modernen Einspritzsystemen, mit Betriebsdrücken bis zu 2500 bar und Temperaturen zwischen $-10^\circ C$ und $120^\circ C$, zu simulieren.

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