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Design sheet of a single cylinder pilot injection gas engine

For the efficient use of renewable fuels further development with research engines like the pilot injection gas engine are necessary. Based on a six-cylinder Scania diesel engine, a design sheet for a single cylinder research engine with fluctuating torque compensation and first-order mass compensation was developed.

Keywords

Research engine, pilot injection gas engine, mass compensation, fluctuating torque compensation, test bench, biogas, block heating station

Abstract

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A six cylinder Scania engine was used as basis for the design of a single cylinder dual fuel combustion test engine. The single cylinder incorporates a combination of fluctuating torque and mass compensation. The dual fuel engine works for both biogas and vegetable oils. The injection of a small amount of vegetable oil initiates the combustion process.

The utilization of energy from biogas to generate electrical power can be accomplished with either gas turbines or internal combustion engines. Two different types of internal combustion engines are normally used: the gas-otto-cycle engine and the pilot injection gas engine.

Pilot injection process

The pilot injection gas engine requires pre-ignition-oil and an ignitable fuel gas - air mixture. Vegetable oil is used for initial combustion whereas biogas is used as the main fuel once ignition has occurred. The biogas-air-mixture is transferred from the inlet tract to the combustion chamber and is compressed there. The vegetable oil is injected into the combustion chamber by means of a conventional fuel injection system. The compressed biogas-air-mixture is ignited by the self-ignition of this small amount of vegetable oil.

Generally, combustion processes of internal combustion engines are tailored to suit the type of fuel used. A consistent and stable engine performance can only be maintained by using a high and steady quality of the fuel. There is no mandatory quality standard for biogas fuel. The composition of biogas and its energy content are depending on process-related variations.

The complete design

Pilot ignition gas engines have a high degree of efficiency. For example, at the pilot ignition gas engine, model ES 32505 from Schnell Zündstrahlmotoren AG & Co. KG, an electrical efficiency of about 41,5% was measured at rated load [1]. Schnell Zündstrahlmotoren uses Scania-diesel-industrial-engines for their block heating stations. The results of the development of the combustion process can be transferred to the serial product because the single cylinder research engine is derived from such an engine. A single cylinder engine prevents interactions with other cylinders thus avoiding erroneous results. The single cylinder engine features easy accessibility and high flexibility to facilitate the integration of measurement techniques and the component development.

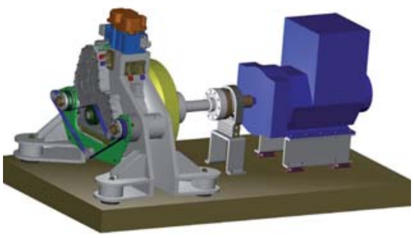
During operation on the test bed, there is a high transfer of mass and gas forces to the crankcase. The water- and oil-circulation systems need to be highly variable for system research. The cooling water system in the cylinder and in the cylinder head is divided in two independent circulation systems. Oil supplied to the piston cooling nozzle is decoupled from the main supply line, to vary the cooling capacity at the piston.

Figure 1 shows the complete design of the single cylinder research engine as well as the generator used as electrodynamic brake. In between are the transmission and the torque measurement equipment. The power transmission of the drive section consists of a connection shaft and flexible discs, which provide a shock-absorbing effect and compensate small shaft offsets. The safety clutch protects the engine from overloading.

Oscillating and rotating mass compensation

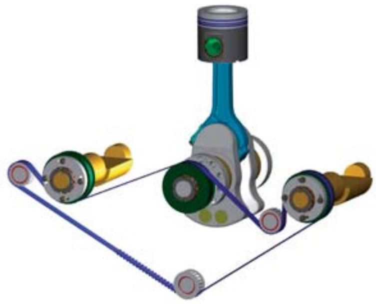
In order to visualize the combustion chamber, a high resolution and high speed camera is planned. High engine smoothness is necessary to obtain usable recordings of the combustion chamber. This can be achieved by utilizing 100% rotating mass com-

Fig. 1



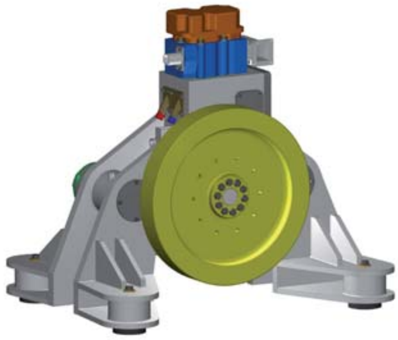
Design of the single cylinder engine including the generator

Fig. 3



Design of first-order mass compensation using a belt drive

Fig. 5



Rear view of the single cylinder engine including the flywheel

pensation, plus a first-order oscillating mass compensation. By separating the driving mechanism forces and performing the resultant calculations, it is possible to design the rotating and oscillating mass compensation.

The rotating mass forces are revolving and outward looking circular forces at the crankpin. They are constant with constant engine speed. 50% of the centrifugal forces of serial engines are balanced by the dimensions of the crank webs. To balance the centrifugal forces up to 100% would require more and not available space in the crank case. Therefore high density tungsten counterweights are inserted in the crank webs.

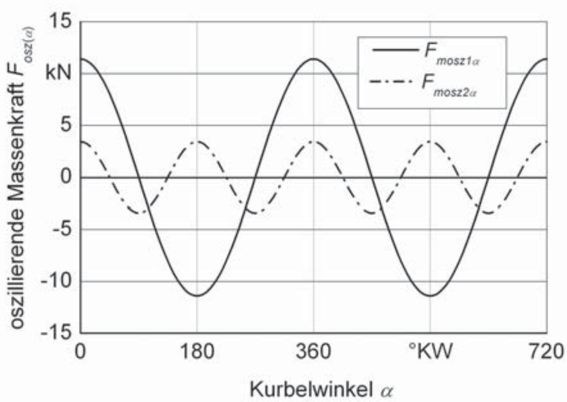
The oscillating masses are generating the oscillating mass force, which acts in direction of the cylinder axis. This force depends on the crank angle and changes periodically with the acceleration of the piston. The first order mass force changes periodically according to the revolution of the crankshaft. The second order mass force depends on the doubled crank angle and has twice the frequency of the first order mass force, figure 2. The amplitude of the first order mass force is much higher than the one of the second order mass force. For single cylinder engines the compensation of the first order mass force is normally sufficient. In this design sheet it is realized by two counter-rotating shafts with one balance weight each. The resulting harmonic fluctuating force of the counterweights has the same absolute value, but opposite in direction, as the oscillating force of the crankshaft drive. The countershafts are driven by a gearwheel directly mounted on the crankshaft. The positive power transmission and the counter-rotating countershafts are realized by a double toothed belt guided by an idler pulley and a tensioner. The counterweights are designed as half cylinders, figure 3.

Power balancing

An electrical generator is used as machine. It requires a constant torque with constant speed. The rotary force varies depending on the crank angle and cause undesirable fluctuations of the angular velocity and the torque of the combustion engine, figure 4. The addition of a flywheel can reduce the fluctuations in engine speed.

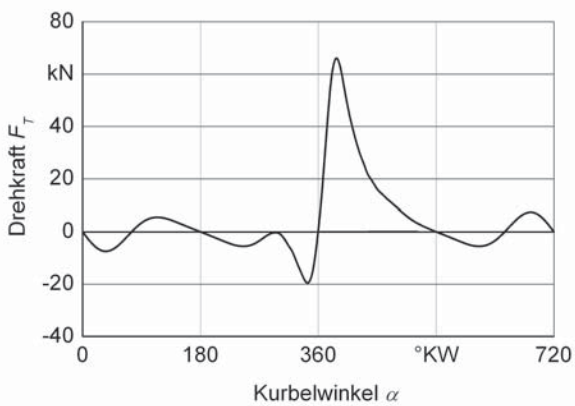
The dimensioning of the flywheel enables the power balancing, figure 5. The flywheel has an adequate moment of inertia to

Fig. 2



First-order and second-order mass force of the single cylinder engine

Fig. 4



Resulting force of rotation FT

maintain the desired constant speed of the engine. Prerequisite is the diagram of the rotary force, resulting from the superposition of the gas forces and the oscillating mass forces. The gas forces depending on the crank angle are derived from pressure measurements in the combustion chamber.

Outlook

The slightly investigated pilot injection gas engine is predicted as having an enormous potential due to its high degree of efficiency. Based on this research engine, a solid and serial production-oriented development of the pilot injection gas engine will be put into practice by Schnell Zündstrahlmotoren. The development program will be mainly focused on improving the efficiency, the thermal characteristics and the exhaust emission characteristics.

Abstract

Main objective of the use of the single cylinder research engine is the development of the combustion process. The compensation of oscillating and rotating mass forces realizes the desired smoothness of running for the installation of measurement techniques. The power balancing enables the necessary smoothness of running for a stable generator operation.

Literature

[1] DLG Prüfbericht Nr.5540F. Deutsche Landwirtschafts-Gesellschaft e.V., http://www.dlg.org/de/landwirtschaft/testzentrum/pruefberichte/bioenergie.html, 20.10.2008.

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