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CRANKSHAFT MECHANISM WITH OFFSET FOR THE COMBUSTION ENGINE

P. Brabec[*], R. Voženílek[**], B. Menič[***]

Abstract: *The paper deals with crankshaft mechanism with offset. The size of the offset has a positive influence on course of normal (lateral) force on a piston, which means the possibility of reducing passive resistances of a combustion engine, and therefore, possibly, to achieve lower fuel consumption and less amount of produced emissions. Selected results of forces calculation of one variant of such modified crank mechanism are shown in this paper.*

Keywords: Simulation, Offset, Crankshaft, Friction loss, Fuel consumption, CO_2 production.

1. Introduction

Emission limits, in particular CO_2 limits, have been constantly decreasing at regular intervals. Therefore, the pressure on manufacturers of car driving units continually increases so that they must invest a large amount of their financial resources especially in reducing adverse exhaled gases and fuel consumption of vehicles. The limits planned for the year 2020, when they should be restricted again, are close to a physical limit of maximum efficiency of a combustion engine. For reason of fulfilling these legislative limits, the automobile manufacturers must search for a way of reducing produced emissions. This explicitly includes increasing the overall efficiency of a conventional combustion engine, in hybridization of vehicle drive, eventually using electromobiles instead of classic vehicle drive. (Schöppe et al, 2013)

One possible way of fuel consumption reduction is reducing passive resistances in the driving unit (combustion engine). In Fig. 1 (left) can see an example of the distribution of the friction losses. The biggest share of the remaining friction comes from the piston group. This high friction share is mainly caused by pre-tightened and loaded piston rings and by the lateral piston force under running conditions. (Schöppe et al, 2013) (Basshuysen, Schäfer, 2002) The course of friction losses is dependent on the operating temperature (i.e. temperatures of the components and the oil and cooling). The reasons for this are, first the change in viscosity of the lubricant and, second, the change in the clearances in the various friction pairs. If the temperature is low, the friction losses are higher (doubled compared with an engine in the favourable temperature). Furthermore, we can say that the friction losses also increase with increasing rpm. (Schwaderlapp et al, 2000) With increasing rpm, the load influence decreases and the diesel engine, compared to a spark ignition engine, has higher losses. (Páv, 2016)

2. An asset of the piston pin offset

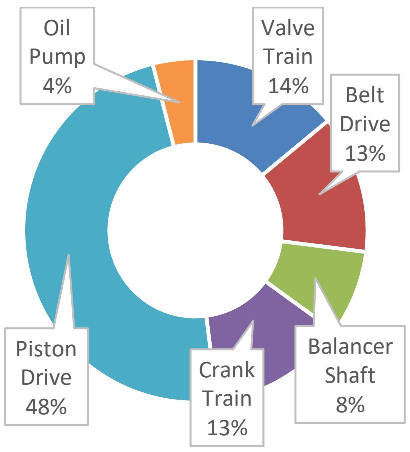
A so called piston pin offset has been used for a long time, which means that the piston (piston pin) is placed outside the cylinder axe. This measure serves, in particular, to decrease the engine noise level as it minimizes the piston tilting in the top dead centre. In the area of the top dead centre, the lateral force changes

[*] Ing. Pavel Brabec, Ph.D.: Technical University of Liberec, Studentská 2; 461 17, Liberec 1; CZ, pavel.brabec@tul.cz

[**] Ing. Robert Voženílek, Ph.D.: Technical University of Liberec, Studentská 2; 461 17, Liberec 1; CZ, robert.vozenilek@tul.cz

[***] Boris Menič: Univerza v Ljubljani, Fakulteta za strojništvo, Aškerčeva cesta 6; 1000 Ljubljana; SLO, boris.menic@gmail.com

its orientation and the piston is – by the action of this force – tilted onto the opposite side of the cylinder. The tilting is accompanied by noise. Due to the piston pin offset, the piston is tilted onto the opposite side of the cylinder even before reaching the top dead centre, which means even before the pressure increase. A piston pin offset can be used to affect the secondary motion of the piston, and therefore the formation of a lubricating film on the piston skirt. The greatest potential of the thrust-side (TS) piston pin offset for reducing friction mean effective pressure can be detected at low load and high speed. The Fig. 1 (right) shows the friction power losses of the four piston pin offset variants that were tested, comparing different speeds. The variant with a piston pin offset of 0.5 mm toward the thrust side (TS) always exhibits the least friction power loss, regardless of the speed. A change in the piston pin offset in the direction of the thrust side, or in direction of the antithrust side, causes an increase in friction power loss. (MAHLE GmbH, 2016) – Note: the thrust side = TS; antithrust side = ATS



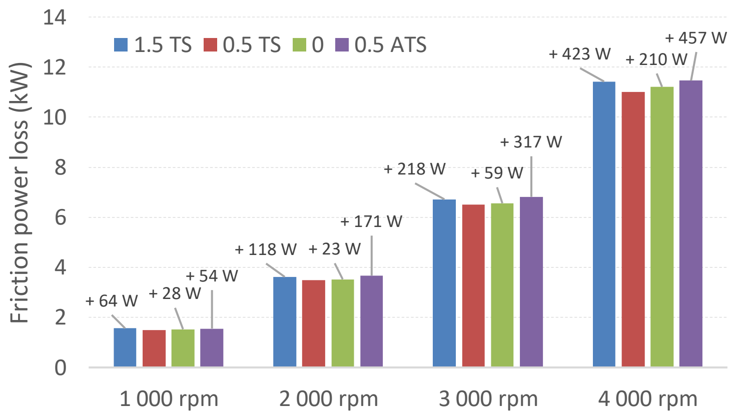
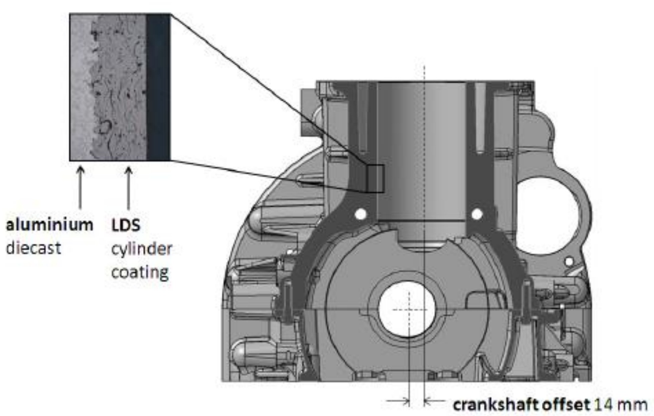


Fig. 1: Distribution of friction losses (Solfrank, 2012) and friction power losses for four different piston pin offsets, at different speeds and IMEP = 10 bar, engine temperature 100°C (MAHLE GmbH, 2016).

Another possibility of how to influence the size of the lateral force acting on the piston is the crankshaft offset. This was used for example by BMW and its new, modern, 2.0L, spark ignition engine. The crank shaft bearing exhibits 14 mm offset relative to the cylinder axis, reducing, on the one hand, the lateral piston force during the combustion cycle and, on the other hand, offering thermodynamic advantages. (Steinparzer et al, 2011) The all-aluminium crankcase is designed as bedplate concept with partition on the centre of the crank shaft. Both components are diecastings made of alloy AISi9Cu3. Cast steel bearing inserts are integrated in the bedplate in order to reinforce the structure. Here, the cylinder bore coating was applied for the first time by means of electric arc wire spraying (EAWS) under series conditions. At this process an iron alloy that is very thin in comparison to cast iron liners, is sprayed onto the pre-treated bore by means of an electric arc. The engine uses the two balancing shafts (refer the Fig. 2) for excellent running smoothness by means of mass balancing with height offset and additional measures for reduction of rotational irregularities.



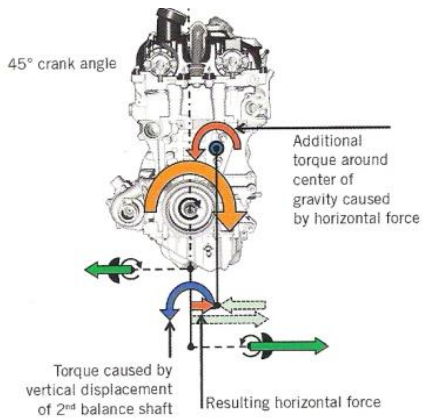


Fig. 2: The sample of cross-section crankcase with EAWS cylinder liner and two balancing shafts with asymmetric, height-offset imbalance masses (method of operation) from BMW (Steinparzer et al, 2011).

Similar and more detailed results for the crankshaft offset are shown in the publication (Yan Hongwei et al, 2015). The authors use there AVL Glide software for analysing the piston dynamics. The paper contains five different values of the crankshaft offset and it shows the influence on the secondary piston movements, transverse velocity and acceleration of the piston, impact energy and friction losses. There is also an interesting graph of dependence of friction losses and impact energy on the offset of crankshaft mechanism ratio (refer the Fig. 3). When comparing for example the -14.5 mm offset to the zero offset, the impact energy markedly decreases (by 44.7 %) but the friction losses of the piston increase by about 17.5 %. Along with the positive increase of the crankshaft offset, the friction losses decrease, and the impact energy increases significantly up to the value of the zero offset, then gradually decreases. When the offset is +14.5 mm, the friction losses are around 10.1 % smaller, and the impact energy also decreased by around 4.1 % compared to the zero offset. It means that due to the positive crankshaft offset we are capable to decrease both the friction losses and the piston impact effects.

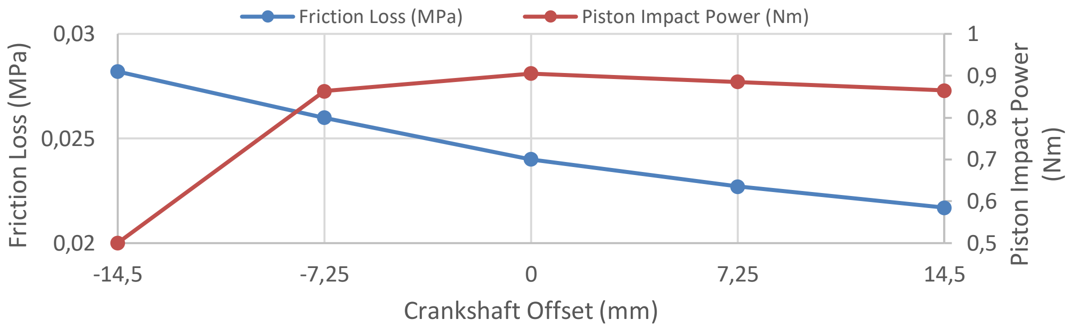
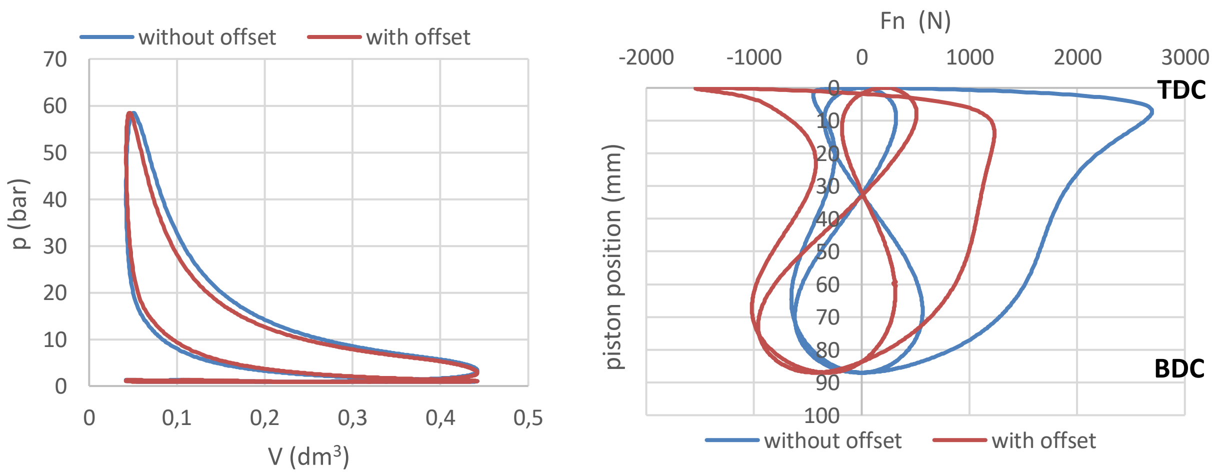


Fig. 3: The curve of piston skirt friction loss and maximum piston impact energy under different crankshaft offset (Yan Hongwei et al, 2015).

3. A simplified calculation of lateral force size acting on the piston, comparing results for crankshaft mechanism with and without the offset

For comparing the resultant lateral forces acting on the piston, a simple simulation model was created, where force of gas pressure (above the piston) and inertia forces (primarily from oscillating mass) were taken into consideration; therefore, it was necessary to specify the piston acceleration. The influence of the crankshaft offset was set for the same parameters (that means for identical size of crankshaft mechanism and for the same course of combustion pressure). Due to the same size (volume) of the combustion engine cylinder, only the radius size of the crankshaft was changed. In the following graphs (Fig. 4), there are illustrations of crankshaft without offset, and with positive offset of 14 mm. Minor changes caused by the offset appeared among others with current position, and piston speed and acceleration; these also influenced the curve of the p-V diagram. The largest influence was observed at the resultant lateral force acting on the piston. The extreme was about 2.2× bigger for the variant without offset. The disadvantage of the variant with offset is a lower value of the resulting torque in the area of maximum combustion pressure (therefore also the average/measurable value).



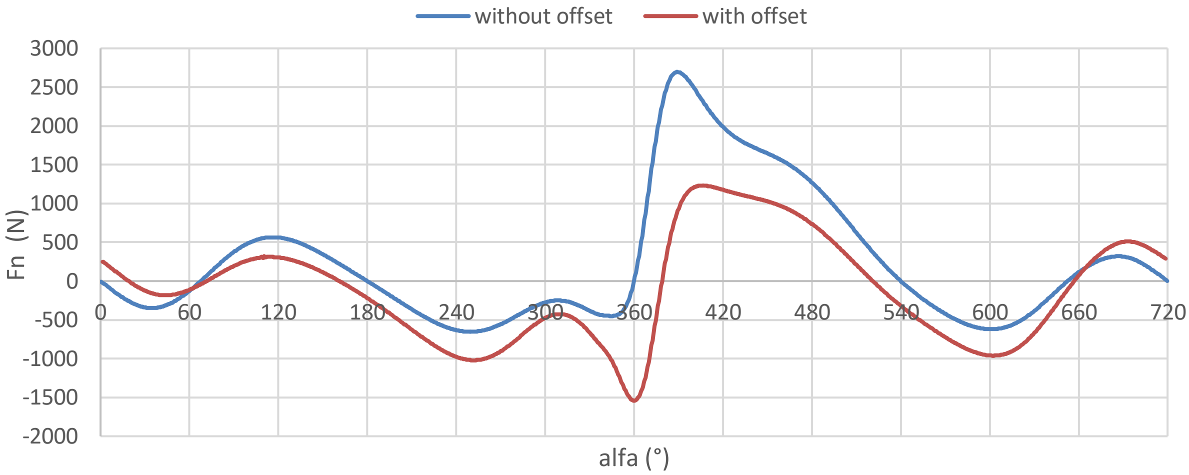


Fig. 4: The dependence of working pressure above piston on actual cylinder volume and the change of the lateral force acting on the piston for crankshaft without offset and with positive offset of 14 mm

4. Conclusion

According to the literature and due to the acquired results we can say that the positive crankshaft offset decreases both the lateral force acting on the piston, i. e. friction losses, and also the piston impact energy. Moreover, with increase of the crankshaft offset, also the stroke of engine (size of cylinder) can extend. Above shows, for crankshaft offset selection, we should consider its influence on the piston secondary motions, piston impact energy, the piston skirt friction loss and other components dimensions. Generally, the selection of crankshaft is the larger positive offset. (Yan Hongwei et al, 2015)

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