THE RESEARCHES ON THE TRIBOLOGICAL PROPERTIES OF ELEMENTS OF THE SEAT INSERT-VALVE-VALVE GUIDE ASSEMBLY

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Abstract

The researches have been carried out, where the object has been the elements of valve trains in the different combustion engines. Those elements have been valve, valve guide and seat insert. The analysed valves have been driven by special camshaft, with the cams of trapezoid shape. The special research stand has been elaborated and its scheme has been presented in the article. The mentioned research stand has been driven by electric motor. The rotational velocity of the camshaft has been controlled and measured. The aim of the researches has been to obtain values of wear for valve, seat insert, valve guide vs. valve lift, and rpm of camshaft. The dynamic parameters have been analyzed for the seat insert – valve – valve guide assembly, experimentally and by simulation either. During researches the values of valve lift, of valve acceleration, of temperature for seat insert and additionally sound level have been measured. The wear of valve, seat insert and valve guide has been measured, basing on their initial and post-research geometry. The results of experimental researches obtained for different materials for valve, valve guide and seat insert have been presented in the article. The simulation model of the analyzed seat insert – valve – valve guide assembly has been elaborated and presented in the article. Such model has been needed to calculate the values of the settle velocity for the analyzed valve. The wear of titanium valve has been a little greater than of the steel valve, the wear of cast iron seat insert mating with steel valve has been much greater than for titanium valve case. The wear of valve guides, made of bronze has been several times less than those of cast iron.

Keywords: *combustion engine, valve timing, lightweight valve, seat insert, valve guide*

1. Introduction

In the majority of combustion engines, valves made of steel are commonly used. But recently the lightweight valves have been more and more often observed in the modern valve train in combustion engine. It has been in camless valve trains and in those with the classical camshafts, either. Components of camless valve trains have got specific tribological properties, sometimes different in comparison to those of camshafts. The head difference has been the shape of valve profile, which has been similar to the trapezoid one. The valve lift and valve duration could be different and could vary during valve cycles.

The researches have been carried out, where the object has been the elements of valve trains in the different combustion engines. Those elements have been valve, valve guide and seat insert. The analysed valves have been driven by special camshaft, with the cams of trapezoid shape. The special research stand has been elaborated and its scheme has been presented in the Fig. 1. The analyzed valves have been made of steel and of TiAl – alloy. The analyzed valve guides have been made of cast iron and of bronze. The analyzed seat inserts have been made of cast iron and of bronze, as well. The valves have mated with their guides and their seat inserts in the conditions of oil absence. The valves have mated with their springs, mounted in the modified injection pump body. The research series have been carried out for constant camshaft rpm.

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The results of experimental researches obtained for different materials for valve, valve guide and seat insert have been presented in the article.

2. Research stand

The mentioned research stand has been connected of the valve 1 mating with its valve guide and its seat insert. The seat inserts are manufactured in the special plate 2. The valve guide has been mounted in the in the modified injection pomp body. The valve has mated with its spring and has been driven by camshaft through the valve lifter. In the case of valve of Rover, the research stand has been equipped with additional set of springs to simulate additional loading from pas force. In the case of valve of KTM, there has been not such additional set of springs. The camshaft has been driven by the electric motor. During researches it has been measured the sound level, the valve lift and acceleration, the rotational velocity of camshaft and the temperature of seat insert.

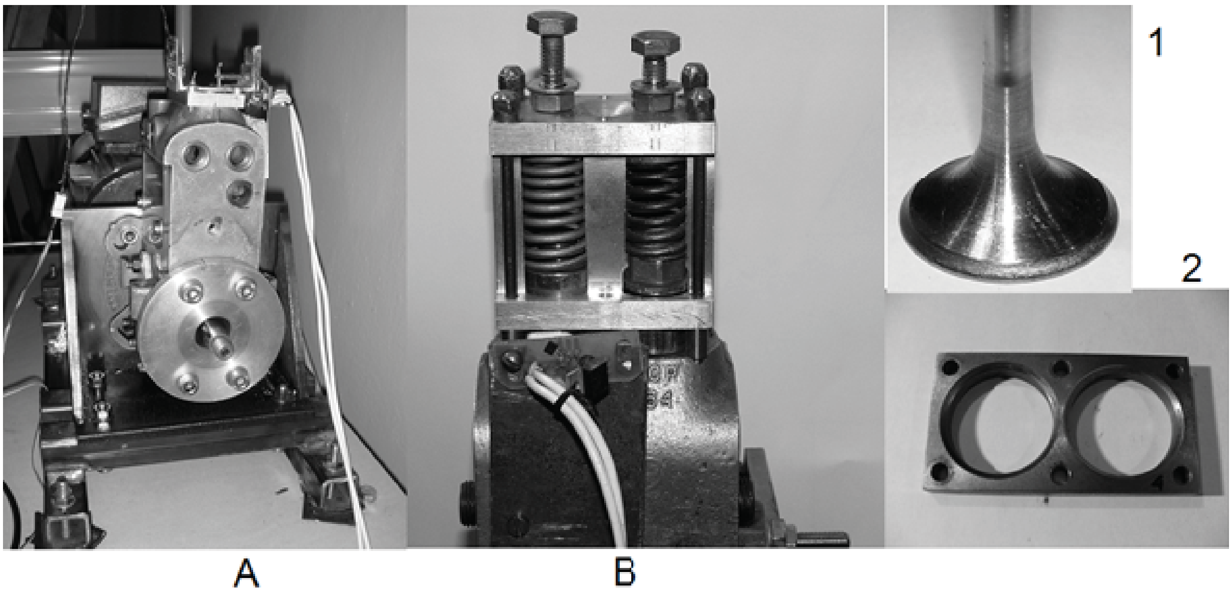

Fig.1. The research stand for a measurement of the valve lift and acceleration, of the seat insert temperature, of the sound level; valves driven by the camshaft
1 – valve, 2 –plates with manufactured seat inserts, A- research stand for valves of KTM, B – research stand for valves of Rover

3. Simulation model.

The simulation model of the analyzed seat insert – valve – valve guide assembly has been presented in the figure 2. Such model has been needed to calculate the values of the settle velocity for the analyzed valve. The model has been connected of the camshaft 1, valve lifter 2, valve spring 3, valve guide 4, seat insert 5 and valve 6. The boundary conditions have been following:
The valve guide and the seat insert have been fixed. The axis of the camshaft has been fixes either, but the camshaft could make rotates with constant velocity. The material properties of elements of the modeled assembly have been constant. The valve and the valve lifter could move along their common axis, which has been fixed. Between the valve top and valve lifter the clearance of the desired value has been introduced. In the initial position the valve has been closed and the camshaft has been in rest.

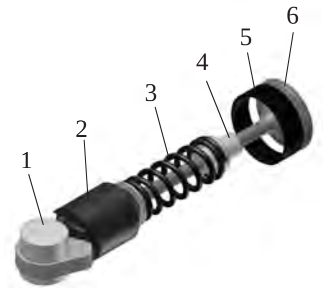

Fig. 2. The scheme of the researched seat insert - valve - valve guide assembly, driven by camshaft; 1 - camshaft, 2 - valve lifter, 3 - valve spring, 4 - valve guide, 5 - seat insert, 6 - valve

Masses of analyzed valves have been presented in the Tab. 1:

Tab. 1. The masses of the analysed valves

The valve of engine	Material	Mass [g]
Rover	Ti6Al4V alloy	18.7
KTM small	TiAl6Zr4Sn2Mo2 alloy	25.7
Rover	Steel	32
KTM big (higher)	Steel	40.7
KTM small	Steel	45

4. The results of researches

The results of simulation have been presented in the Fig. 3-6, for valve lift equal 4 mm and camshaft rpm equal 1000 and in Fig. 7 - for camshaft rpm equal 900.

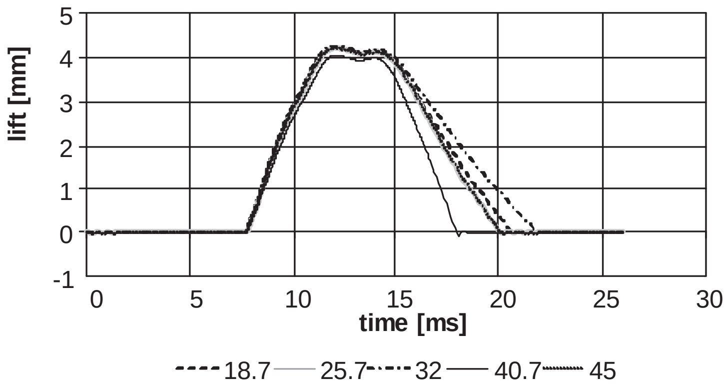

Fig. 3. Valve lift vs. time, for different valves

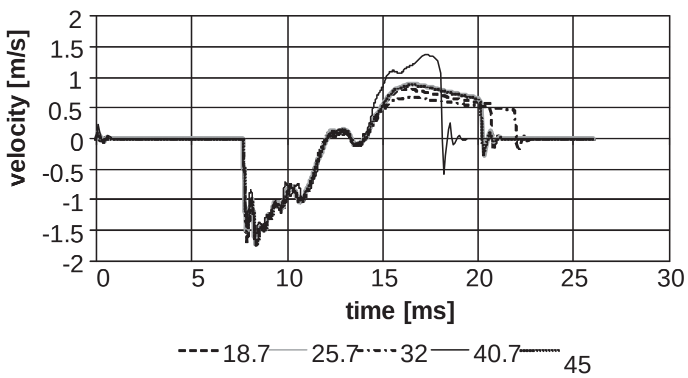

Fig. 4. Velocity of valve vs. time for different valves

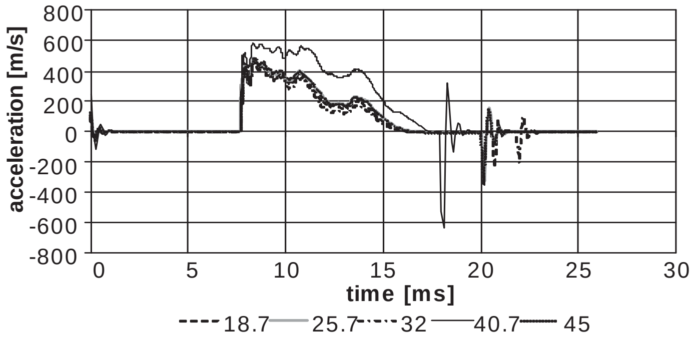

Fig. 5. Valve acceleration vs. time for different valves

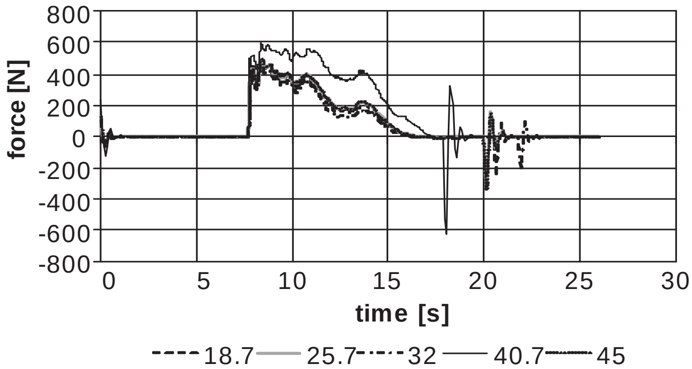

Fig. 6. Total force vs. time for different valves

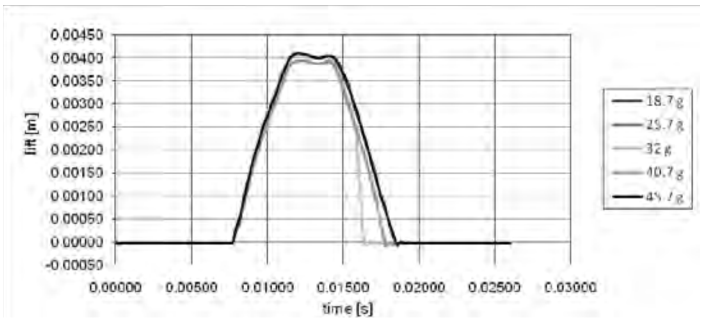

Fig. 7. Calculated valve lift vs. time, for different valves

The results of simulation and of measurement for the big steel valve of KTM engine, when valve lift has been equal 5 mm have been presented in Fig. 8-13.

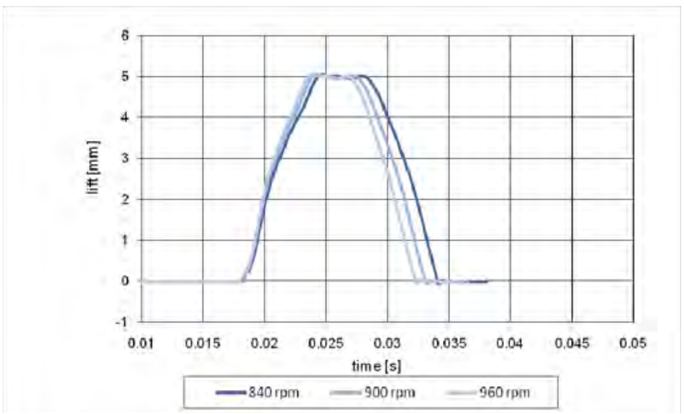

Fig. 8. Calculated valve lift vs. time and camshaft rpm

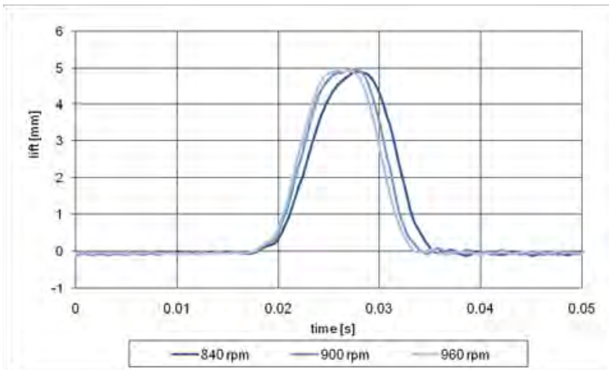

Fig. 9. Measured valve lift vs. time and camshaft rpm

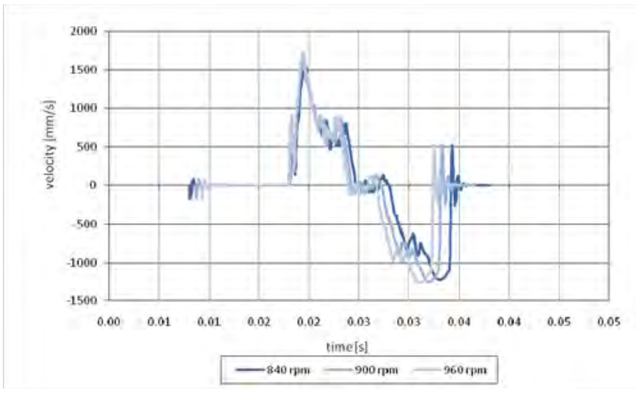

Fig. 10. Calculated valve velocity vs. time and camshaft rpm

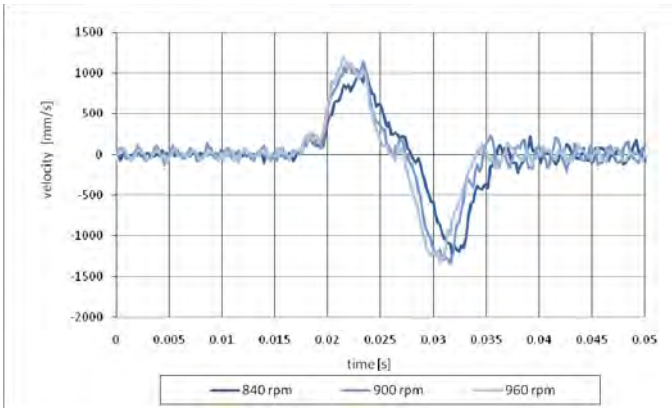

Fig. 11. Valve velocity calculated on the base of measured valve lift vs. time and camshaft rpm

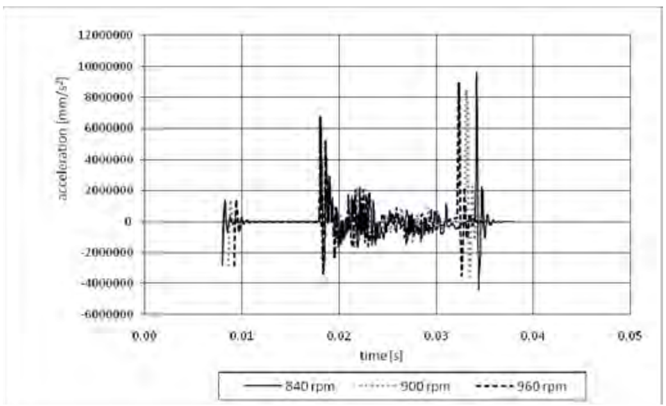

Fig. 12. Calculated valve acceleration vs. time and camshaft rpm

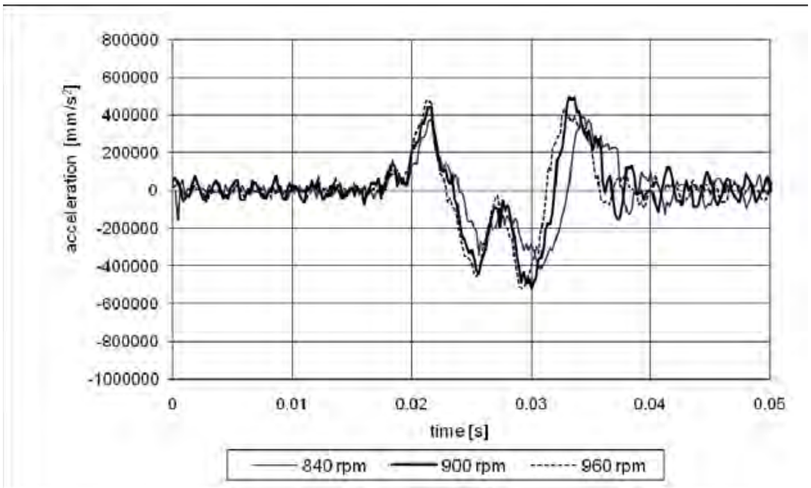

Fig. 13. Measured valve acceleration vs. time and camshaft rpm

The values of valve lift, velocity and acceleration vs. time, for the valve lift equal 5 mm and for the different camshaft rps have been shown in the figures 14 – 16.

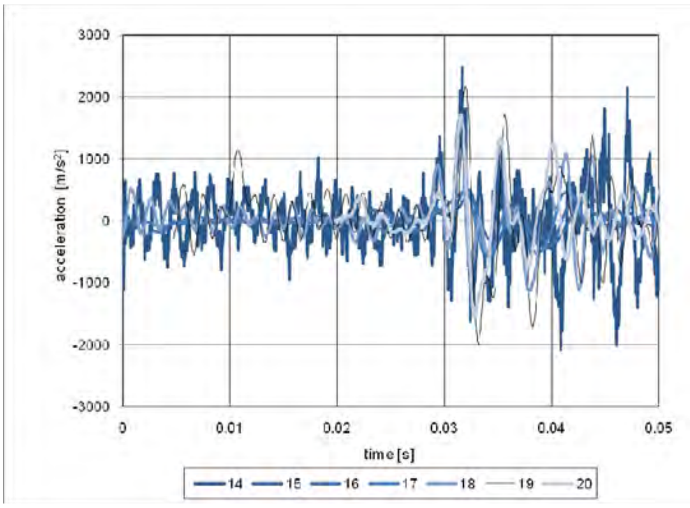

Fig. 14. Measured valve lift vs. time and camshaft rps

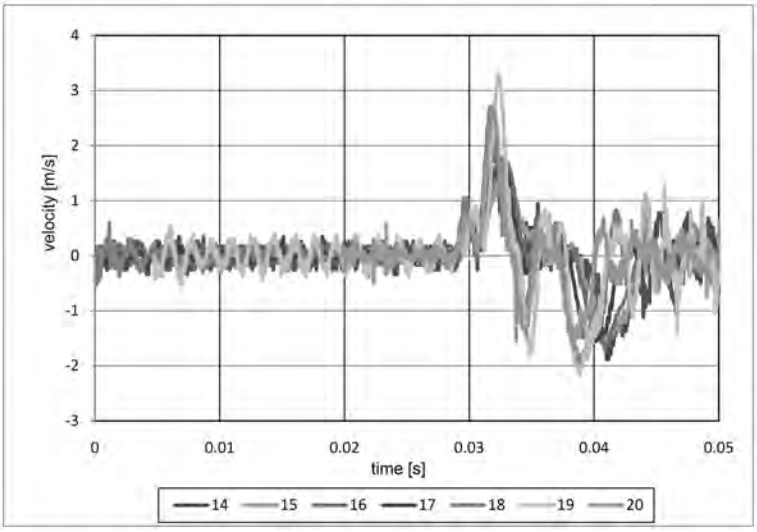

Fig. 15. Valve velocity calculated on the base of measured valve lift vs. time and camshaft rps

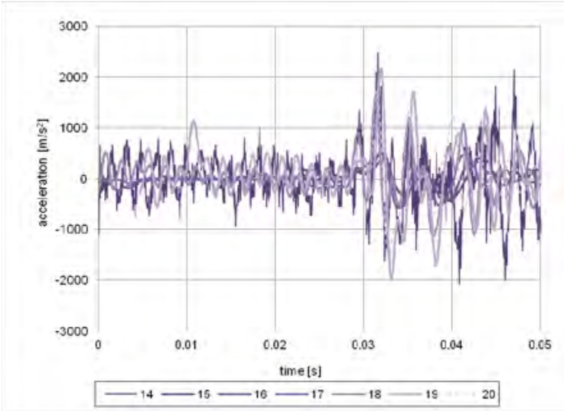

Fig. 16. Measured valve acceleration vs. time and camshaft rps

Results of sound level vs. time, for different valve lift have been shown in the Fig. 17-19.

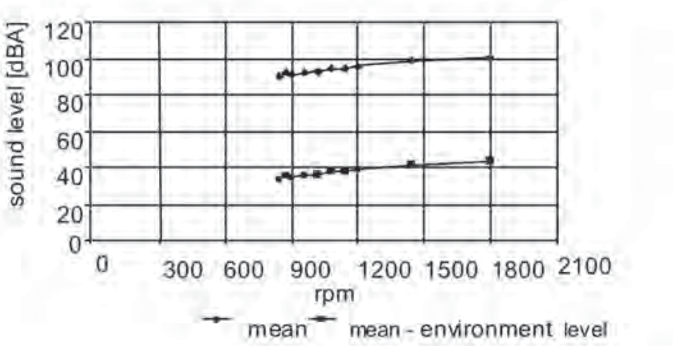

Fig. 17. Measured sound level vs. camshaft rpm, for valve lift equal 1 mm

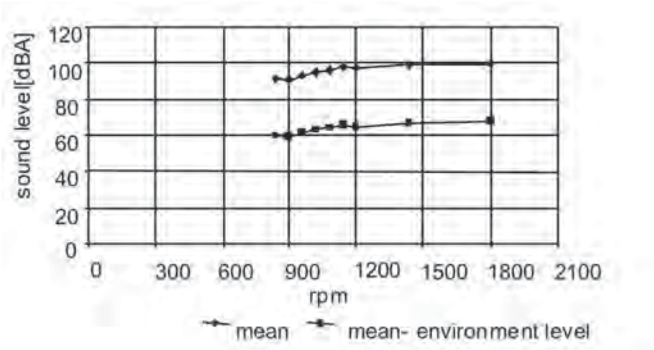

Fig. 18. Measured sound level vs. camshaft rpm, for valve lift equal 7.5 mm

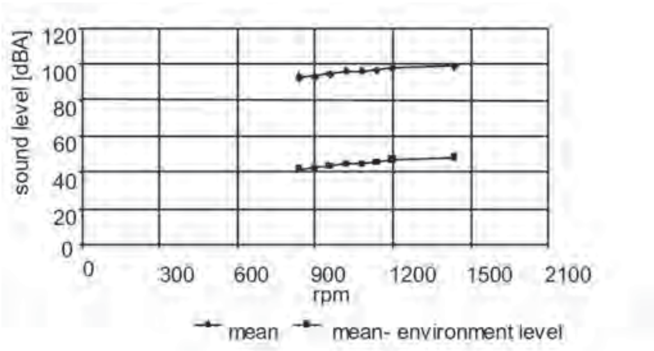

Fig. 19. Measured sound level vs. camshaft rpm, for valve lift equal 6 mm

The results for the measured wear of valves, seat inserts and guides have been presented in Tab. 2 and 3.

Tab. 2. Wear of analyzed valves and seat inserts

Valve material	Seat insert material	Valve wear [mm3]	Seat insert wear [mm3]
Big steel KTM	Cast iron	6.553	3.213
Small steel KTM	Bronze	0.051	1.888
Small steel KTM	Cast iron	2.175	56.754
TiAl6Zr4Sn2Mo2 KTM	Cast iron	2.921	6.655
Ti6Al4V Rover	Cast iron	9.918	3.829
Steel Rover	Cast iron	1.213	0.412

Tab. 3. Wear of analyzed valve guides

Valve guide material	Wear [g]	Wear [mm^3]
Bronze KTM	0.02	2.25
Cast iron KTM	0.08	10.26
Bronze Rover	0.03	3.37
Cast iron Rover	0.12	15.38

5. Conclusion

1. The maximal values for valve velocity and for valve acceleration obtained from simulation have been greater than those from the measurement about 50%. The settle velocity has been slightly greater for steel valve than for the valve made of TiAl alloy. The settle velocity and impact force have been much greater for the big (higher) steel valve than for small steel valve, although the big one has been of smaller mass.
2. Valves have been opened quicker for greater camshaft rpm. Valves made of TiAl alloy have been closed earlier than steel valves, but the mentioned big steel valve has been closed earlier than small steel valve.
3. The settle velocity of valve and acceleration during impact has been slightly increased with the increase of camshaft rpm.
4. The sound level has been increased nonlinearly with the frequency increase and has been nearly independent on the valve lift.
5. The values of valve wear have been the highest for the big steel valve of KTM engine and for Ti6Al4V valve of Rover engine, when they have mated with cast iron seat insert. The wear of seat insert has been the highest for cast iron seat insert of KTM engine. The wear of valve guide has got the highest value for cast iron guide of Rover engine.
6. The wear of titanium valve has been only little greater than of the steel valve, but the wear of cast iron seat insert has been much greater for steel valve case.
7. The wear of valve guides, made of bronze has been several times less than those of cast iron.
8. It can be stated that the best couple is the valve made of TiAl alloy mated with the seat insert and with valve guide made of bronze. The valves made of TiAl alloy can mate better with seat inserts made of cast iron than the steel valves.

References

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[2] Zbierski, K., *Bezkrzywkowy magnetoelektryczny rozrząd czterosuwowego silnika spalinowego,* Monografia, Wydawnictwo Politechniki Łódzkiej, Łódź 2007.

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