REDUCTION OF VIBRATIONS GENERATED BY A VARIABLE TORQUE IN 5-CYLINDER IN-LINE ENGINES

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Abstract

Despite undoubted advantages of a 5-cylinder in-line engine, its basic drawback is the lack of partial balancing the torque variability generated by gas forces by means of the torque caused by inertia forces. Such a desired phenomenon occurs in 4-cylinder engines. Accordingly, these engines - within a wide range of rotational speed – demonstrate greater engine smoothness than potentially better 5-cylinder engines. In the article, a concept of generating the moment of inertia forces by means of the proper rollers reducing the amplitude of the moment caused by gas forces is presented. Such a solution will allow for a significant mitigation of vibrations of 5-cylinder engines, and they are in many respects better than 4-cylinder ones, which has been justified more extensively in this article.

The paper concerns the opportunity of constructing a 5-cylinder engine of the external torque stability equivalent to the torque stability of a 4-cylinder engine. It will allow obtaining a much better unit from the commonly used present 4-cylinder engines for the drive of passenger cars. An engine of the same swept capacity in the 5-cylinder rather than 4-cylinder version will be characterized by numerous advantages, and first and foremost: the space between the front wheels of the vehicle will be optimally used. 4-cylinder engine generates vary large summary forces of the 2nd order, which is manifested by intensive vibrations in the plane axis of the cylinders.

Keywords: *reduction of vibrations, 5-cylinder in-line engines*

1. Introduction

5-cylinder in-line engines are becoming more and more popular in the front drive passenger cars and vans. The overall dimensions of such engines allow for their transverse assembly to the vehicle axle, which is standard for the front drive.

With the same swept capacity one obtains an increase of 25% in power than in a 4-cylinder engine. Also, the torque generated by a 5-cylinder in-line engine caused by gas forces is more uniform than in a 4-cylinder unit.

Figure 1 presents a general view of the engine room with a 5-cylinder engine assembled transversely.

Fig. 1. A 5-cylinder engine of a VW Transporter van

As it can be noticed, a 5-cylinder engine entirely occupies the space between the front wheels, therefore, mounting a longer engine of acceptable overall dimensions (such as a 6-cylinder one) is impossible.

2. The torque transferred to the power receiver via the shaft

A variable torque transferred to the power receiver generates torsional vibrations of the engine, therefore, since the engine was invented there have been attempts to reduce the torque variability caused by the gaseous and inertia forces. The simplest way to such restriction is rotating the shaft by a larger number of pistons and at the same time the angle intervals between the ignitions should be kept constant. With this assumption a 5-cylinder engine generates the course of torque presented in Fig. 2 as a specific tangential force.

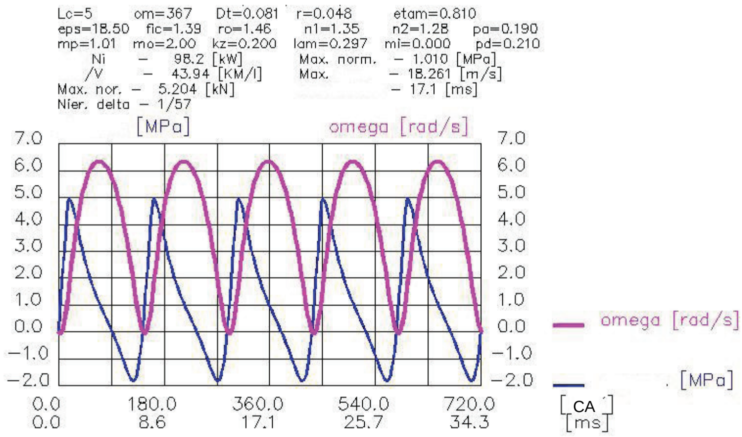

Fig. 2. The course of the specific tangential force – the thinner blue line – and the momentary rotational speed – the thicker line; a 5-cylinder 4-stroke engine, 90% load at a nominal rotational speed of 3500 [rpm] – 367 [rad/s]

A very large amplitude of torque variations results from an unfavourable torque summation produced by the inertia of reciprocating masses. These torqueses, which originate from particular cylinders, neutralize each other giving a zero torque at the shaft as a result. In the case of a 4-cylinder engine, the torques caused by the inertia of reciprocating masses does not neutralize each other and when added to the torques generated by gas forces they decrease the amplitude of the summary torque. Fig. 3 presents the torques caused solely by the 1st and 2nd order inertia force in a 4-cylinder in-line engine.

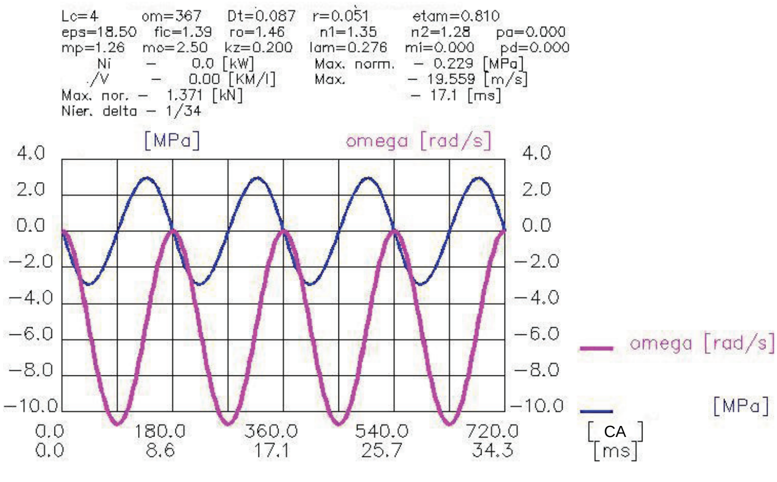

Fig. 3. The course of a specific tangential force – the thinner blue line- and the shaft momentary rotational speed – the thicker magenta line; a 4-cylinder 4-stroke in-line engine with no load of gaseous forces at the nominal rotational speed of 3500 [rpm] – 367 [rad/s]

The torque caused by gas forces for the considered engine is characterized by as large an amplitude – Fig. 4 - as for a 5-cylinder engine – Fig. 2 – but the summary torque in the 4-cylinder engine changes to a much lesser extent – Fig. 5 – than it is in the case of the 5-cylinder engine.

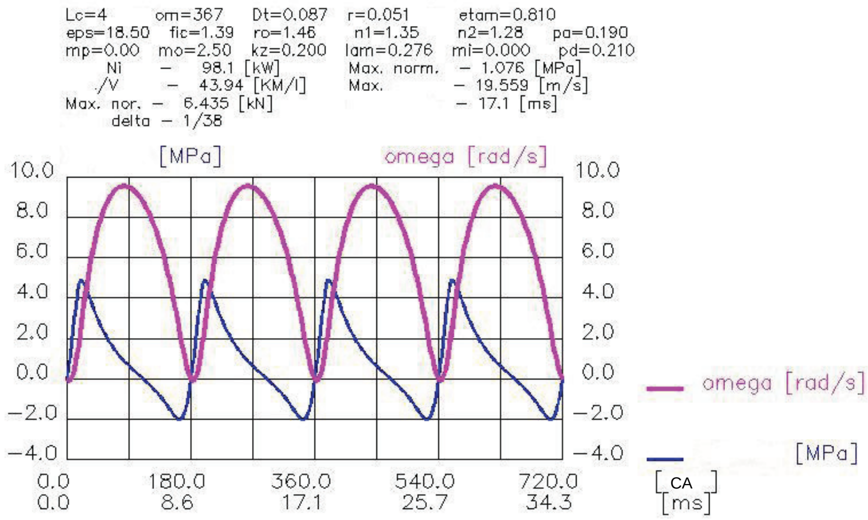

Fig. 4. The course of a specific tangential force – the thinner blue line- and the shaft momentary rotational speed – the thicker magenta line; a 4-cylinder 4-stroke in-line engine with no load of inertia forces with a 90% load of gaseous forces at the nominal rotational speed of 3500 [rpm] – 367 [rad/s]

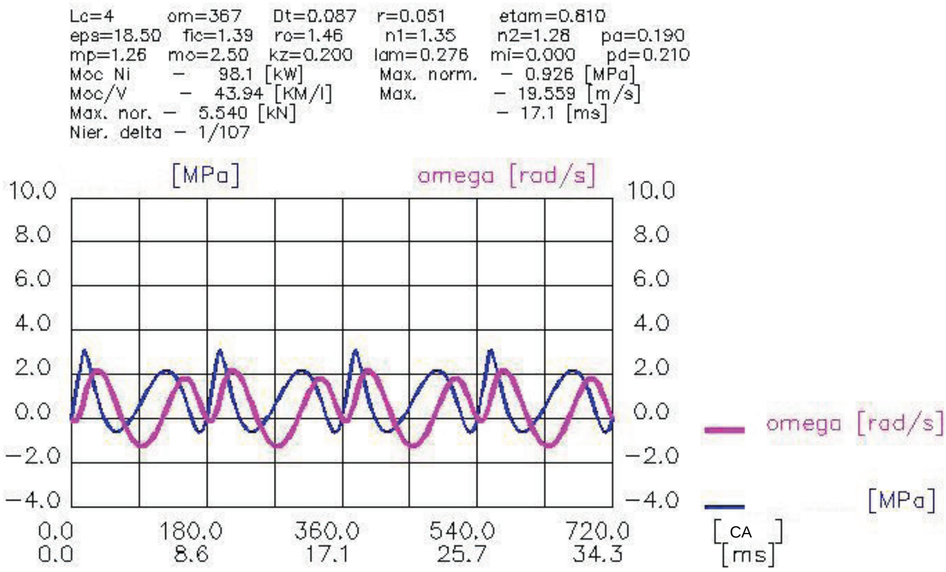

Fig. 5. The course of a specific tangential force – the thinner blue line- and the shaft momentary rotational speed – the thicker magenta line; a 4-cylinder 4-stroke in-line engine with the load of inertia forces and a 90% load of gas forces at the nominal rotational speed of 3500 [rpm] – 367 [rad/s]

3. Reduction of the external torque imposing a load on the 5-cylinder in-line engine mounting

In a 5-cylinder 4-stroke engine, the torque generated on the crankshaft by inertia forces cannot be used to reduce the maximum values of the torque caused by a gas force, since the frequency of this torque is 1.25 times greater than the frequency caused by the 2nd order forces. One can, however, apply a simple system of rollers reducing the external torque which imposes a load on the engine mounting. A diagram of such a system is presented in Fig. 6.

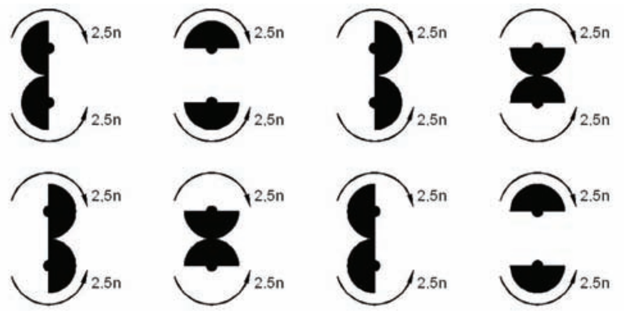

Fig. 6. A diagram of partial balancing external torques imposing a load on the 5-cylinder in-line engine mounting by means of 4 rollers vibrating pair-wise and in the opposite directions with the rotational speed 2.5 times greater than the rotational speed of the engine shaft

As a result of applying the suggested balancing, one can obtain a significantly milder course of the external torque of the engine being considered, as it is evidenced by the graph presented in Fig. 7.

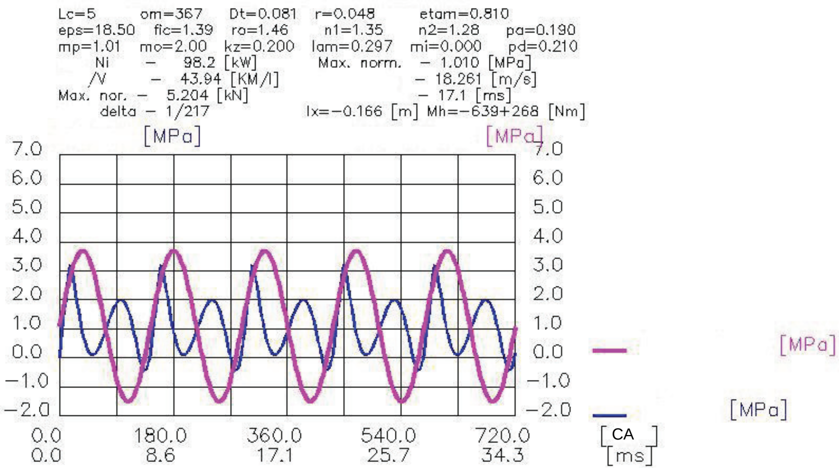

Fig. 7. The course of a specific tangential force – the thinner blue line- and the shaft momentary rotational speed – the thicker line; a 5-cylinder 4-stroke in-line engine with the load of 90% at the nominal rotational speed of 3500 [rpm] – 367 [rad/s] equipped with the balancing rollers

4. Summary

1) The possibility of constructing a 5-cylinder engine of the external torque stability equivalent to the torque stability of a 4-cylinder engine will allow for obtaining a much better unit from the commonly used present 4-cylinder engines for the drive of passenger cars. An engine of the same swept capacity in the 5-cylinder rather than 4-cylinder version will be characterized by numerous advantages, and first and foremost, the space between the front wheels of the vehicle will be optimally used. One should also mention that a 4-cylinder engine generates vary large summary forces of the 2^{nd} order, which is manifested by intensive vibrations in the plane axis of the cylinders.
2) The external torques generated in a 5-cylinder in-line engine caused by both 1^{st} and 2^{nd} order forces were omitted in this work.
3) Both the engine shaft and block are susceptible structures, which may lead to vibrations under favourable conditions, in effect of which the graphs in Fig. 2-5 and 7 should be regarded only as approximate.

References

[1] Iskra, A., *Dynamika mechanizmów tłokowych silników spalinowych*, Wydawnictwo PP, pp. 1-271, Poznań 1995.