RUN REGULARITY IN DIESEL DRIVE CHAIN ELEMENTS

Antoni Iskra

Poznan University of Technology
ul. Piotrowo 3, 61-965 Poznan, Poland
tel.: +4861 665 2511, fax: +4861 665 2514
e-mail: antoni.iskra@put.poznan.pl

Abstract

Following paper presents efforts on deliberate modification of drive transmission elements vibrations aimed at limitation of their nuisance. Some effects of disadvantageous drive vibrations encountered during construction of a test rig will be presented as well. The proposed computational model is fully versatile and takes into account any number of inertia and drive transmitting stiffness. Stiffnesses can be described with any function corresponding to the real behaviour of joints and couplings, which generally are not linear. Damping which illustrate actual, most commonly non-linear characteristics of energy dissipation was also taken into consideration in the drive chain.

Keywords: *resonance vibrations, flying wheels, diesel run regularity*

1. Introduction

One of the IC engine shortcomings is cyclic character of torque transmitted to the power receiver. Due to that torsional vibrations appear which could not be eliminated. This makes that every engine has its characteristic vibrational and acoustic properties. Contemporary produced automobiles are equipped with engines of far limited operational inconveniences but it is impossible to design an engine completely free of vibrations. Term “culture of engine operation” exists in colloquial language as a result of this phenomenon. This idea describes an user’s subjective feeling which relates to the range of rotational speeds when the engine emits discomfortable vibrations and noise. Following paper presents efforts on deliberate modification of drive transmission elements vibrations aimed at limitation of their nuisance

2. Characteristics of tested object

When analyzing engine crank mechanisms made of different producers one can conclude that there is no constant principle of reduction of vibration generated in any engine. Definitely this is a result of cyclic processes performed in reciprocating machine. An analysis of one of the most modern engines, namely the VW TDI R5 AXD proves about the range of undertakings aimed at the reduction of noise and vibrations generated by the engine. Fig. 1 presents engine crankshaft, Fig. 2 – composite flying wheel combined of two inertia wheels fixed with coupling of non-linear characteristics.

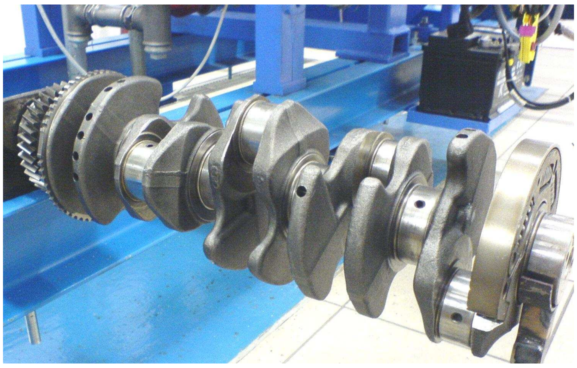


Fig. 1. General view of engine crankshaft, inertial vibration damper on the right

Fig. 2. General view of composite flying wheel

The composite flying wheel performs coupling of non-linear characteristics, presented in Fig. 3.

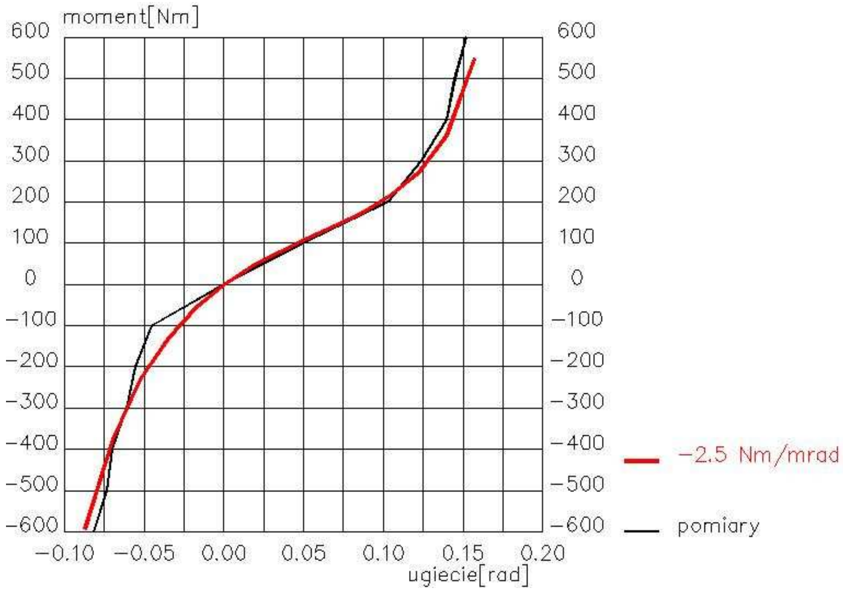


Fig. 3. Flying wheel coupling characteristics; measurements – black line, approximation of 2,5 Nm/mrad stiffness at the origin of the coordinate system – red line

3. Results of drive parameters computer simulation

The drive chain of presented unit performs minor vibrations within the whole operational range. Alas, any changes of inertia moment or stiffness in the drive chain could cause very disadvantageous changes in the drive characteristics. Definition of these parameters can be done using programs presented in literature [1]. The substitute model of vibrating unit has been presented in Fig. 4.

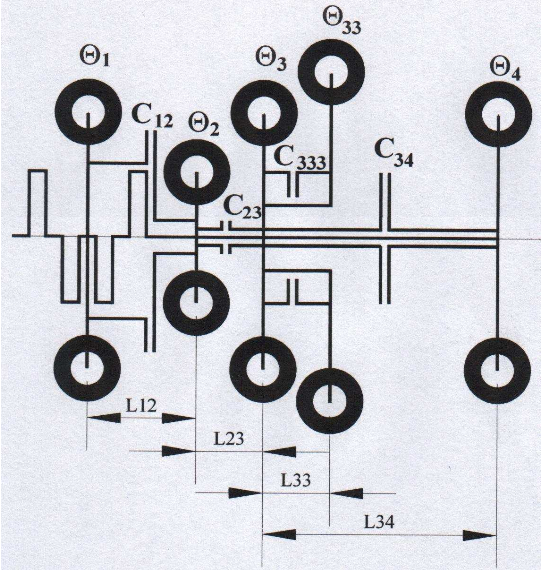


Fig. 4. The model of drive chain from crankshaft of Θ_1 equivalent polar inertia to the dynamometer rotor of Θ_4 polar inertia

According to Fig. 4 following notification of drive chain basic element parameters have been taken on:

- crankshaft of Θ_1 equivalent moment, L_{12} equivalent length and C_{12} damping,
- flying wheel of Θ_2 equivalent moment rigidly coupled to the crankshaft of L_{12} equivalent length and C_{12} damping transferring the torque to the additional flying wheel of Θ_3 polar inertia,
- dynamometer rotor of Θ_4 polar inertia coupled to the flying wheel with an articulated shaft of L_{34} equivalent length.

The articulated shaft has been presented in Fig. 5 and its characteristics – in Fig. 6.

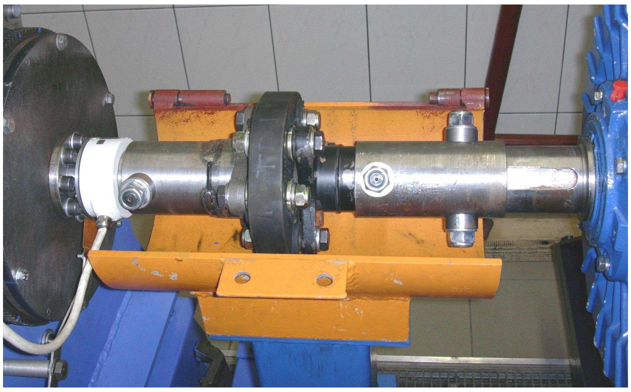


Fig. 5. Engine–to–dynamometer articulated coupling

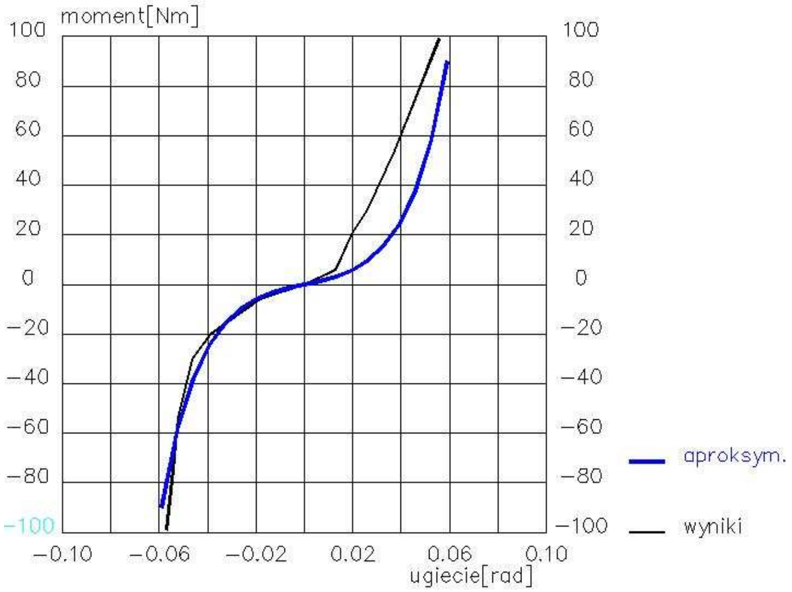
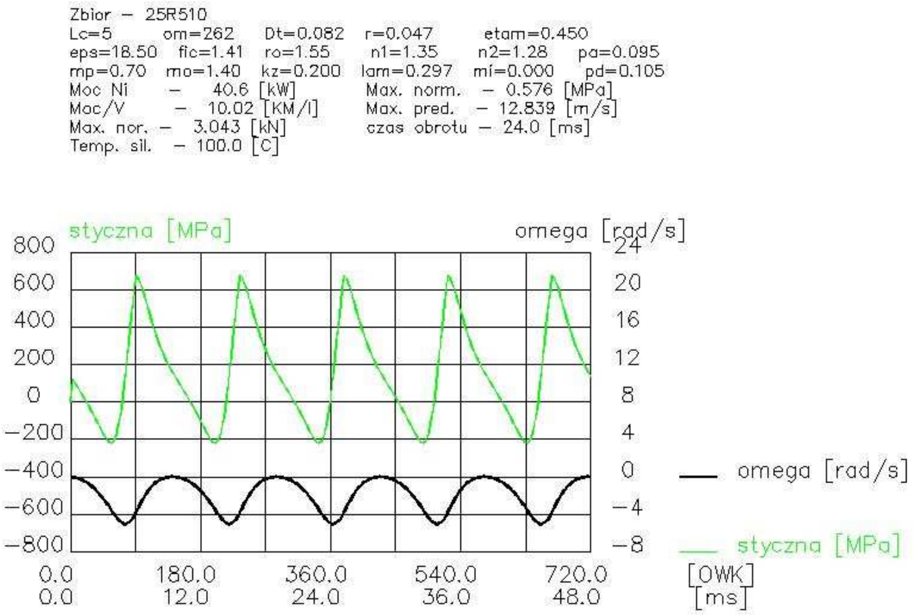


Fig. 6. Characteristics of the articulated coupling presented in Fig. 5; measurements–black line, approximation–blue line

There are very complicated resonance phenomena in the drive chain, which above all affect the engine speed irregularity but also are the source of noise and in extreme case could initiate the instantaneous torque far higher than the static one. Fig. 7 presents the course of engine speed momentary value for average conditions of operation.



```
Zbior – 25R510
Lc=5       om=262    Dt=0.082   r=0.047     etam=0.450
eps=18.50  fic=1.41  ro=1.55     n1=1.35     n2=1.28    pa=0.095
mp=0.70   mo=1.40   kz=0.200   lam=0.297   mi=0.000    pd=0.105
Moc Ni      –    40.6 [kW]          Max. norm.  – 0.576 [MPa]
Moc/V        –  10.02 [KM/l]        Max. pred.  – 12.839 [m/s]
Max. nor. –   3.043 [kN]           czas obrotu – 24.0 [ms]
Temp. sil.   – 100.0 [C]
```

Fig. 7. Course of the TDI R5 AXD engine instantaneous speed variations for conditions presented above; green line–the course of tangential force giving angular speed variations of δ = 1/52 level of irregularity

A disadvantageous phenomenon of increase in engine speed irregularity resulting from the superposition of gaseous and inertia force phases has been encountered in the case of 5–cylinder engine tested. A 4–cylinder engine of similar size and thermodynamics performs almost two times better δ level of irregularity because δ=1/93.

The course of change in momentary value of angular speed of drive chain individual elements schematically presented in Fig. 4 can be seen in Fig.8.

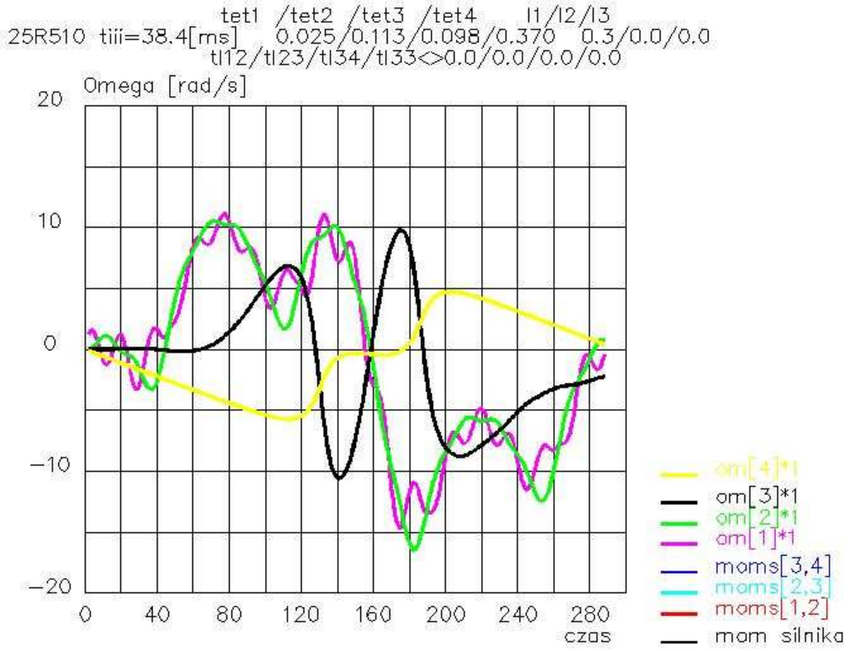


Fig. 8. Course of engine shaft angular speed variation – pink line; of Θ_2 flying wheel firmly fixed to the engine shaft – green line; of Θ_3 flying wheel flexibly coupled to the engine shaft – black line, and of Θ_4 dynamometer rotor –yellow line

Presented in Fig. 8 changes in rotational speed generate the coupling torques in Fig. 9.

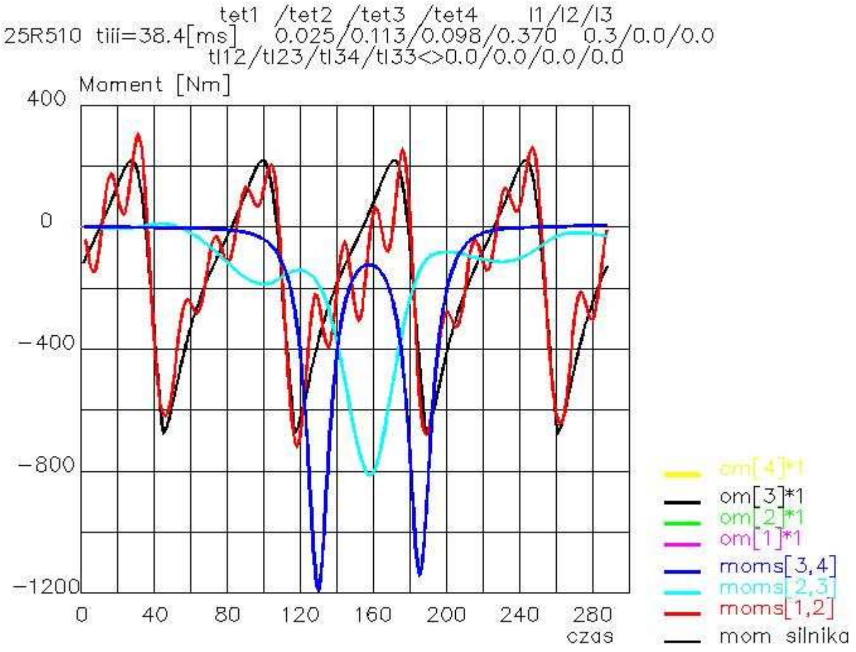


Fig. 9. Course of variations of the TDI R5 AXD engine generated torque – black line and of coupling torques within sections of equivalent shaft (see Fig. 4) – L12 – red, L23 – light blue and L34 – blue

In the analyzed drive chain the course of torque in the joint presented in Fig. 5 develops particularly unfavorably that lead to the failure of pin joint [2].

4. Possibilities of run irregularity level correction

In the case of tested engine – power receiver system the speed irregularity level might be significantly improved and particularly the torque transmitted to the power receiver could be reduced if the coupling characteristics of composite flying wheel was changed. Fig. 10 presents the coupling parameters graph from Fig. 9 but for the flying wheel coupling characteristics taken from Fig. 11.

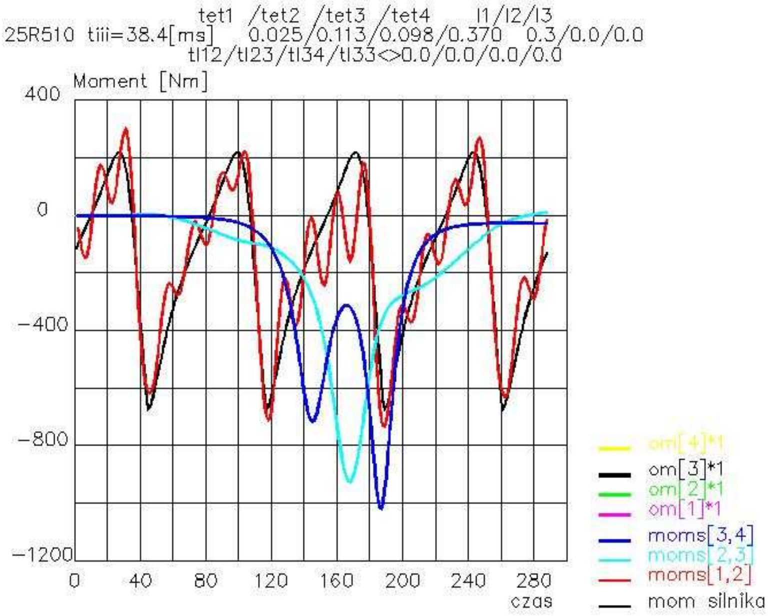


Fig. 10. Course of the TDI R5 AXD engine generated torque variations after the modification of flying wheel set coupling characteristics

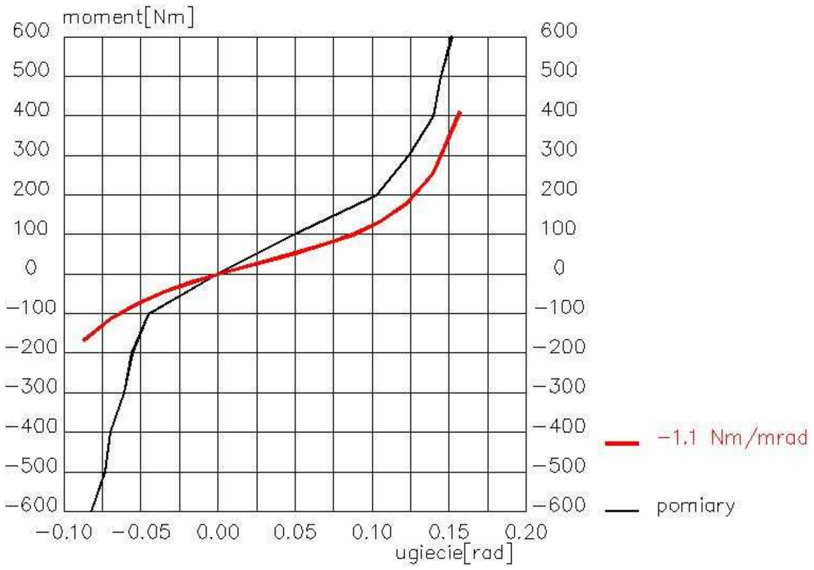


Fig. 11. Flying wheel set coupling characteristics; measurements – black line, approximation with the 1.1 Nm/mrad rigidity at the origin of coordinate system — red line

Comparing graphs in Figs. 9 and 10 one can notice an apparent reduction in maximum value of torque transmitted to the power receiver. However, the flying wheel coupling torque rises by about 10% which does not make a problem, nevertheless the coupling springs of flying wheel set should be appropriately replaced.

5. Conclusions

- One of the fundamental disadvantages of reciprocating engines is the irregularity of torque transmitted to the power receiver, which is the cause of resonance vibrations and noise. Torque transmission by a set of flexibly coupled flying wheels could cause a unfavorable torque increase at the drive chain elements like joints correcting the coaxiality of engine and dynamometer.
- Individual selection of joint characteristics enables the possibility of ease the resonance phenomena but on the other hand reducing the negative effects of resonance for certain parameters of engine operation could lead to the increase of coupling torque in other regions of engine run.

References

[1] Iskra, A. i zespół., *Redukcja obciążenia środowiska spowodowanego biegiem jałowym silnika samochodu w warunkach utrudnionego ruchu miejskiego, Reduction in Environmental Burden Caused by the Automotive Engine Idle Run*, Nr projektu Komitetu Badań Naukowych - 5 T12D 040 25, Poznań 2006.

[2] Iskra, A., *Problemy drgań elementów przeniesienia napędu w fazie rozruchu silnika, Problems of Drive Train Elements Vibrations at Engine Start*, Ogólnopolskie Sympozjum Naukowe – Rozruch silników spalinowych – SYMROZ'2007, 23-25.04.2007 – Szczecin, Malmö, Kopenhaga.