INFLUENCE OF THE ANGLE ENCODER CLUTCH ON COURSE OF ROHR

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Abstract

Rate-of-Heat-Release (further ROHR only) pattern is one of the most significant results, which is obtainable from evaluation of in-cylinder pressure record. It is necessary to ensure correct synchronization of recorded pressure shape with crankshaft position. For this purpose incremental angle encoder (IRC) is usually used as a source of sampling pulses.
During R&D work carried-out on author's workplace effect of torsional compliancy of clutch between crankshaft and encoder shaft was observed. The torsional vibration of IRC excited by the engine running roughness can produce angle deviations to the indicating record. This effect induces illusive deformation of pressure curves causing significant declination of ROHR pattern.
In the article methods and results of investigation of this deteriorating phenomenon are described together with final solution.

Keywords: In-cylinder pressure indicating, ROHR pattern, angle encoder clutch

1. Introduction

The record of in-cylinder pressure pattern and its evaluation is one of the most powerful means for experimental optimisation of internal combustion engines. The behavior of the engine cycle can be investigated using this technique. The use of the in-cylinder pressure record is an extremely powerful tool by which experimental data are confronted with the results of a mathematical model of the engine working cycle.
For this purpose testing engines in the author's laboratory are equipped permanently with cooled or uncooled pressure transducer and an incremental angle encoder. IRCs are permanently connected through clutches located at the free ends of the crankshafts.
During R&D work carried-out on author's workplace effect of torsional compliancy of clutch between crankshaft and encoder shaft was observed. The torsional vibration of IRC excited by the engine running roughness can produce angle deviations to the indicating record. Instantaneous crankshaft speed varies during reciprocating engine operation. There are various reasons, which could induce these fluctuations. For example the impact of mass forces acting on a crank gear, cylinder-to-cylinder variation and cycle-to-cycle variation etc. should be included.

2. Description of the test bed

A test bed with examined engine (4x Ø75,5x72mm) is equipped with conventional DAQ; see scheme in Figure 1. Voltage outputs from pressure transducers, amplified thermocouple voltages and analogue outputs from laboratory set of analyzers are multiplexed to A/D converter input. DAQ main station measures engine speed using counter board. Absolute angle encoder is coupled with pointer shaft on dynamometer scale. Digital inputs of

A/D board process digital information from angle encoder describing engine torque. Gas flow meter is used for fuel consumption measurement. It is multiplexed to A/D converter input as well. Special SW equipment [1] installed on DAQ station ensures timed data acquisition their visualisation on-line (either as a graph or as a table), calculation of derived values (such as power or BMEP) and storage of the data to a disk file.
Test bed with examined engine is equipped with conventional in-cylinder pressure recording as described above. Examining engine is equipped permanently with cooled pressure transducer and an IRC. IRC is permanently connected through a clutch located at the front end of the crankshaft (see Figure 2). Special software was developed for recording in-cylinders pressure patterns during engine run [2] and for off-line evaluation of such record [3].

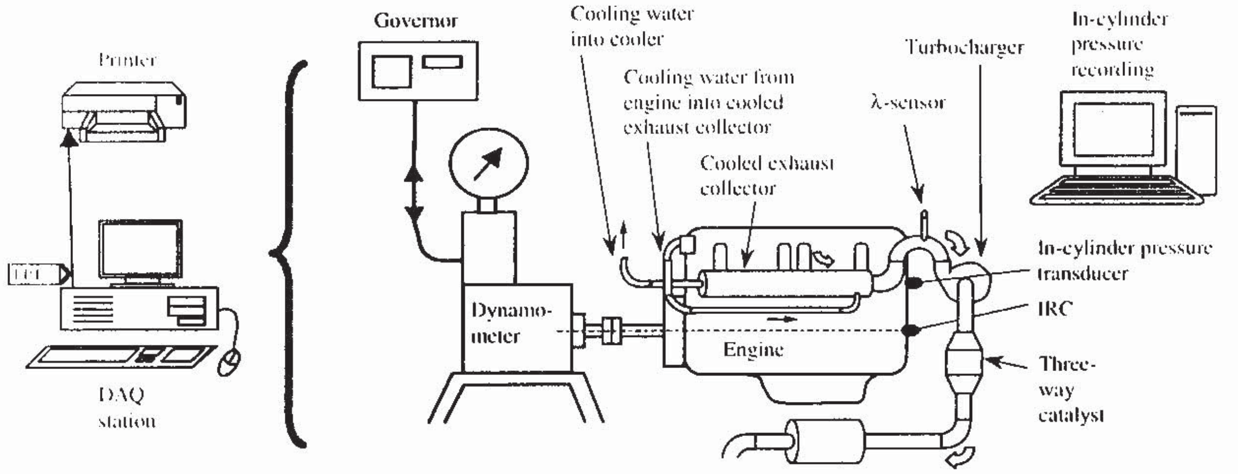
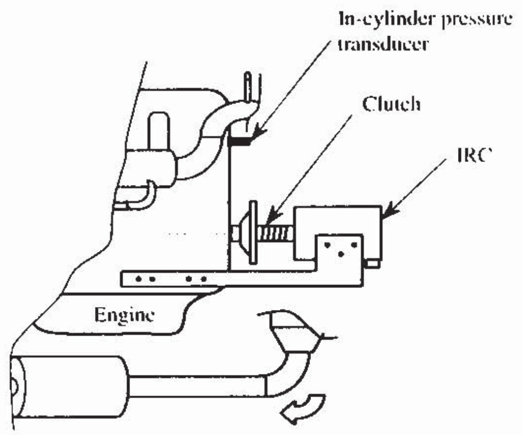


Figure 1. Scheme of the test bed layout with examined engine.



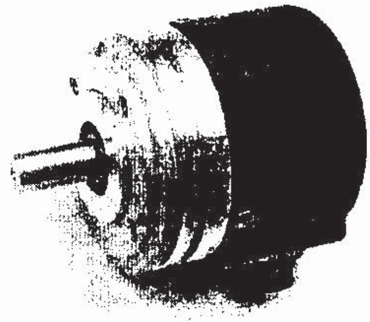


Figure 2. Detail view of the clutch layout and IRC.

3. Deteriorating of ROHR course

Deteriorated and non-deteriorated courses of ROHR shown in Figure 3 expressed in relation of Normalized Heat Release Q_{nm}. [4]:

$$Q_{nm} = \frac{Q}{m_p \cdot H_u} \quad [-] \tag{3.1}$$

where: Q – Heat evaluated from in-cylinder pressure record,
m_p – mass of fuel in cylinder,
H_u – lower fuel value

Both of the ROHR courses were evaluated from measured in-cylinder pressure data in the same engine-operating mode. There were used two types of clutches. ROHR courses in Figure 3a were evaluated from measured data at a constant engine speed RPM = 2800 min^{-1} and at widely opened throttle (W.O.T.). ROHR courses in Figure 3b were evaluated from measured data at a constant engine speed RPM = 2500 min^{-1} at W.O.T. It was investigated that deteriorating phenomenon is caused by torsional compliancy of used clutch.
In the author's laboratory was developed a special software and a method for elimination of fluctuations above. However, by reason of correct in-pressure recording ensure, it is necessary to remove the primary problem – the torsional compliancy (oscillation) of clutch.

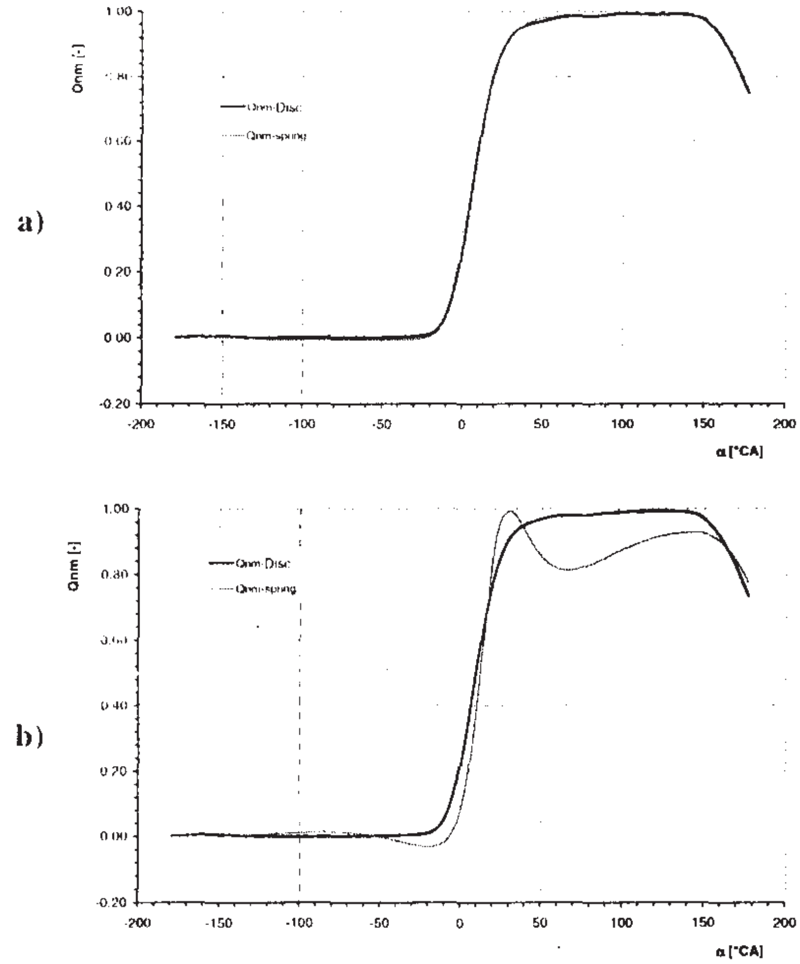


Figure 3. Courses of ROHRs, a) O.K., b) deteriorated by clutch torsional compliancy.

4. Performed experiments

Together three large set of measurements were performed on the test bed, described in Figure 1. The goal of measurements was to find the solution for elimination of described phenomenon. Each set of measurements was performed with other type of clutch. The three tested types of clutches are shown in Figure 4. Spring-type clutch has the smallest torsional stiffness, spiral-type clutch has larger torsional stiffness then Spring-type clutch and spring disc-type clutch has the largest torsional stiffness of the all tested clutches.
Measurements were performed at engine speed in a range from 1200 to 3000 min^{-1} (at W.O.T.) with step RPM= 100 min^{-1}. About 100 cycles of in-cylinder pressure were recorded in each point of measurements together with acquired data from DAQ. So each set of measurements consisted from 19 measured points.

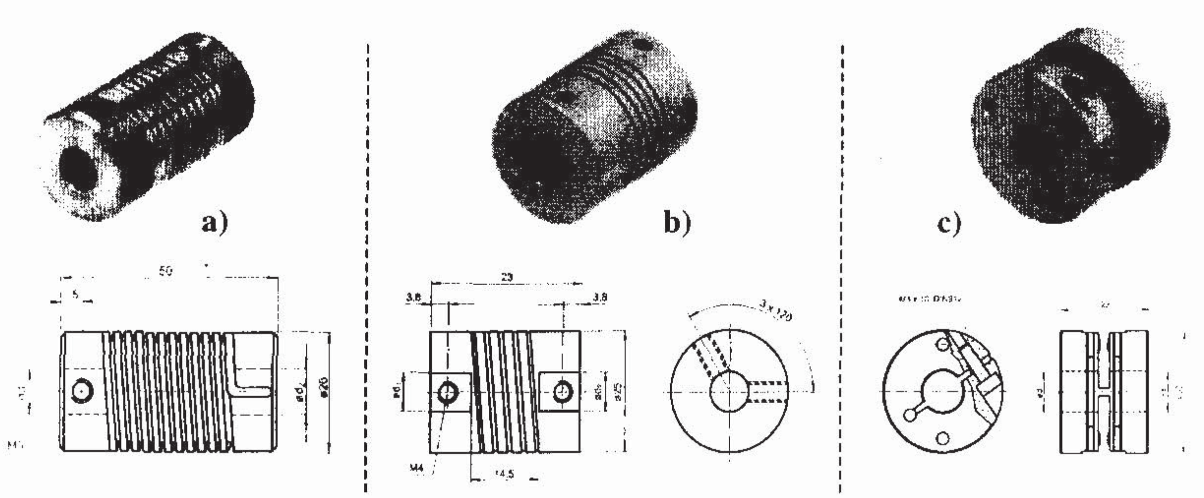


Figure 4. Tested clutches, a) Spring-type, b) Spiral-type, c) Spring disc-type

5. Comparative parameter determination of ROHR deviation

Recorded patterns of in-cylinder pressure were evaluated by special software [3], as described above. One average shape of in-cylinder pressure was created from recorded patterns of about 100 cycles in each measured point. Courses of thermodynamic quantities e.g. ROHR were evaluated from average cycle.

Spring disc-type clutch was used as a comparative clutch, because it has the largest torsional stiffness. Courses of Q_{nm} were evaluated from measured data comport with a constant engine speed RPM = 1200 min^{-1} at W.O.T (shown in Figure 5). These courses refer to measurements with used spring type-clutch (marked as Spring in graphs given below) and spring disc-type (marked as Disc in graphs given below). A comparative parameter is necessary to determine for next investigation of torsional compliancy phenomenon. The comparative parameter should be allow to compare the ROHR courses deviation with using various type of clutches and to find out the maximal and minimal values of deviation in the all measured points.

There was determined ΔQ_{nm} (see Figure 5) as a comparative parameter. This parameter was calculated in range of crankshaft angle α [°CA] from −180° to 180°CA (compression and expansion stroke of piston) in each point of measurements, for all three tested clutches.

Next, there was found-out the courses of ΔQ_{nm} must be choicely investigated. It is necessary to detect when effect of clutch torsional oscillation (overshooting) turn up really and when it is a heat release deviation in combustion chamber only.

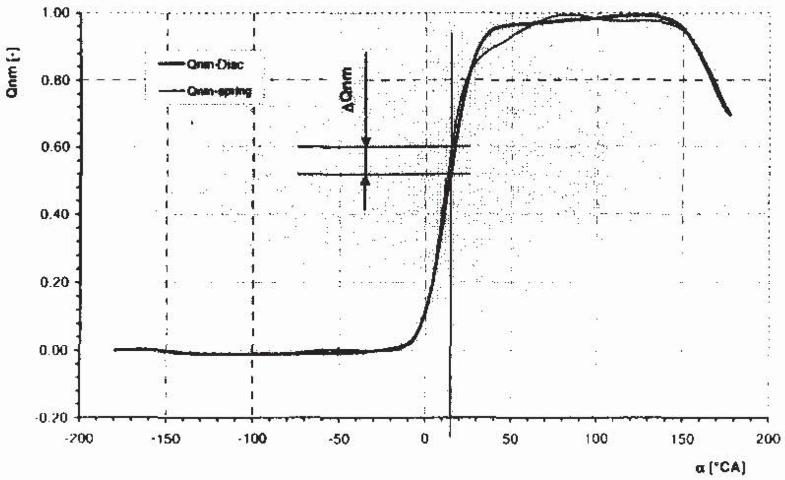
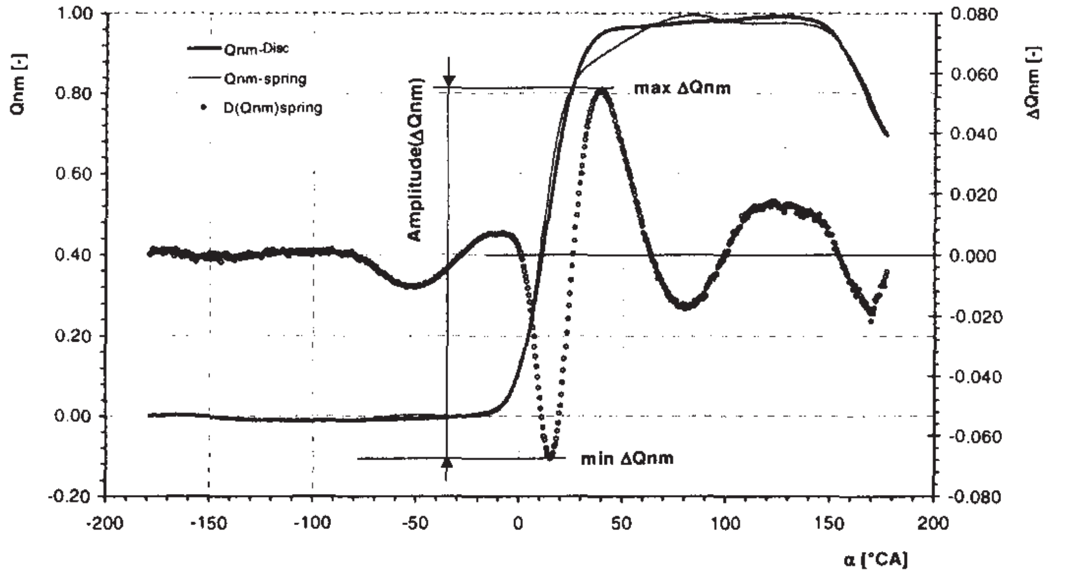


Figure 5. Comparative parameter determination of ROHR deviation

a)



b)

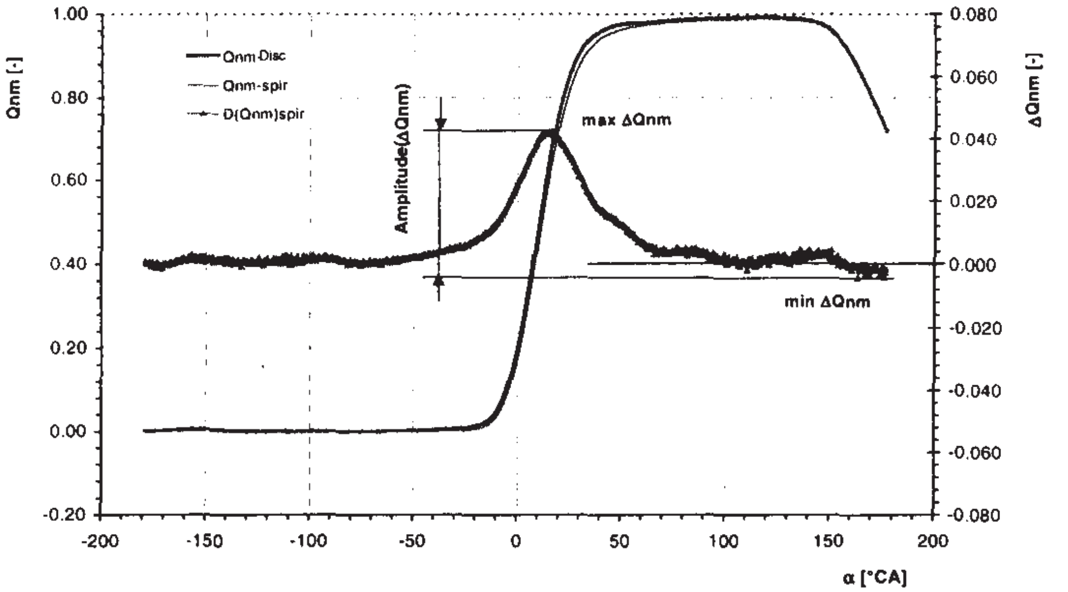


Figure 6. Courses of Q_{nm} and ΔQ_{nm}, a) in case with clutch torsional oscillation, b) without clutch torsional oscillation

Heat release in combustion chamber doesn't have the same course exactly in the same test engine mode at other measurement. Reasons can be e.g. the change of atmospheric pressure, humidity, another course of spark on the spark plug etc. The course of ΔQ_{nm} and its maximal and minimal values in regard of zero value ΔQ_{nm} were determined as an instrument for correct determination of clutch torsional overshooting phenomenon. Determination of clutch torsional overshooting by course of ΔQ_{nm} is shown in Figure 6.

6. Final evaluation of ROHR deteriorated courses

The course of ROHR was investigated in the all courses Q_{nm} (3x19) from three large set of performed measurements by established parameter ΔQ_{nm}. Measurements with spring disc-type clutch and courses of Q_{nm} as well were selected as comparative, because the clutch has the largest torsional stiffness. In Figure 7 amplitudes of deviation ΔQ_{nm} courses comport with using of spring-type clutch and spiral-type clutch are shown. Next the courses of maximal and minimal values of ΔQ_{nm} comport with using of spring-type clutch and spiral-type clutch are shown in Figure 7 as well. It is possible to obtain from this courses the area of engine speed in which the clutches achieved minimal and maximal value of torsional oscillation.

Spiral-type clutch oscillated torsional less then the spring-type clutch. It can be shown from courses in Figure 7. This fact was expected. Spring-type clutch achieved maximal value of torsional oscillation in area of engine speed RPM = 2500 min^{-1}. There was expected engine speed RPM = 1200 min^{-1}. Spring-type clutch achieved minimal value of torsional oscillation in area of engine speed RPM = 2800 min^{-1}.
Spiral-type clutch achieved maximal value of torsional oscillation in area of engine speed RPM = 2600 min^{-1} and minimal value in area of engine speed RPM = 2500 min^{-1}. Amplitudes of deviation ΔQ_{nm} courses comport with using of spiral-type clutch are higher in areas of lower engine speed then RPM = 2600 min^{-1}, however, in these areas it isn't torsional oscillation of clutch but heat release deviation in combustion chamber, as described above.

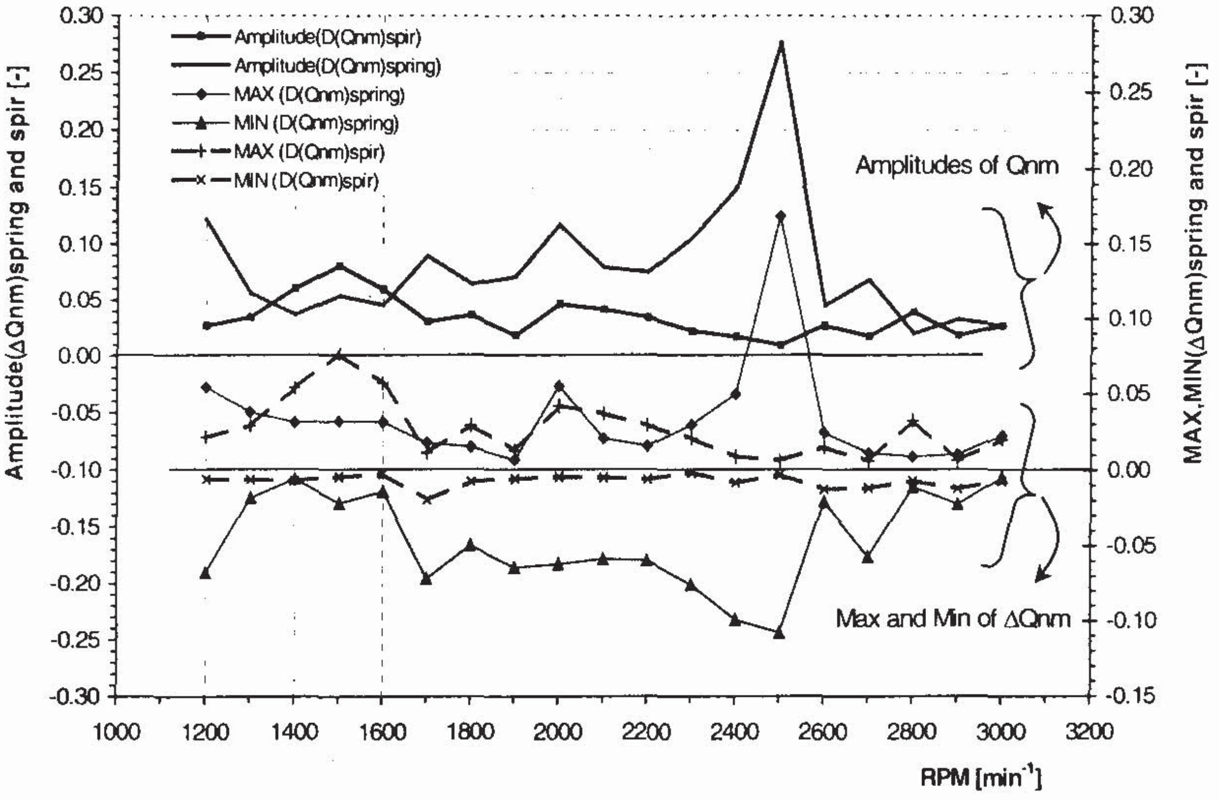


Figure 7. Finally courses ΔQ_{nm} describing torsional oscillation of the both of clutches (Spring-type and Spiral-type)

a)

b)

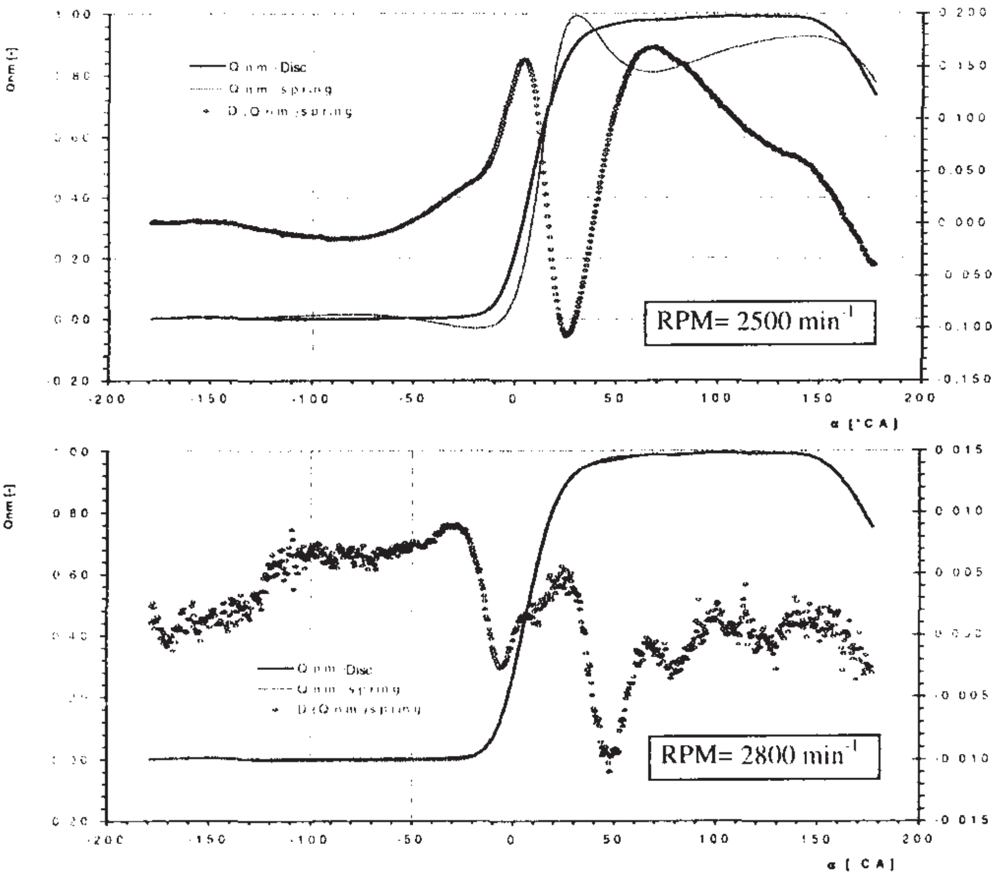


Figure 8. Torsional oscillation of Spring-type clutch, a) maximal, b) minimal

a)

b)

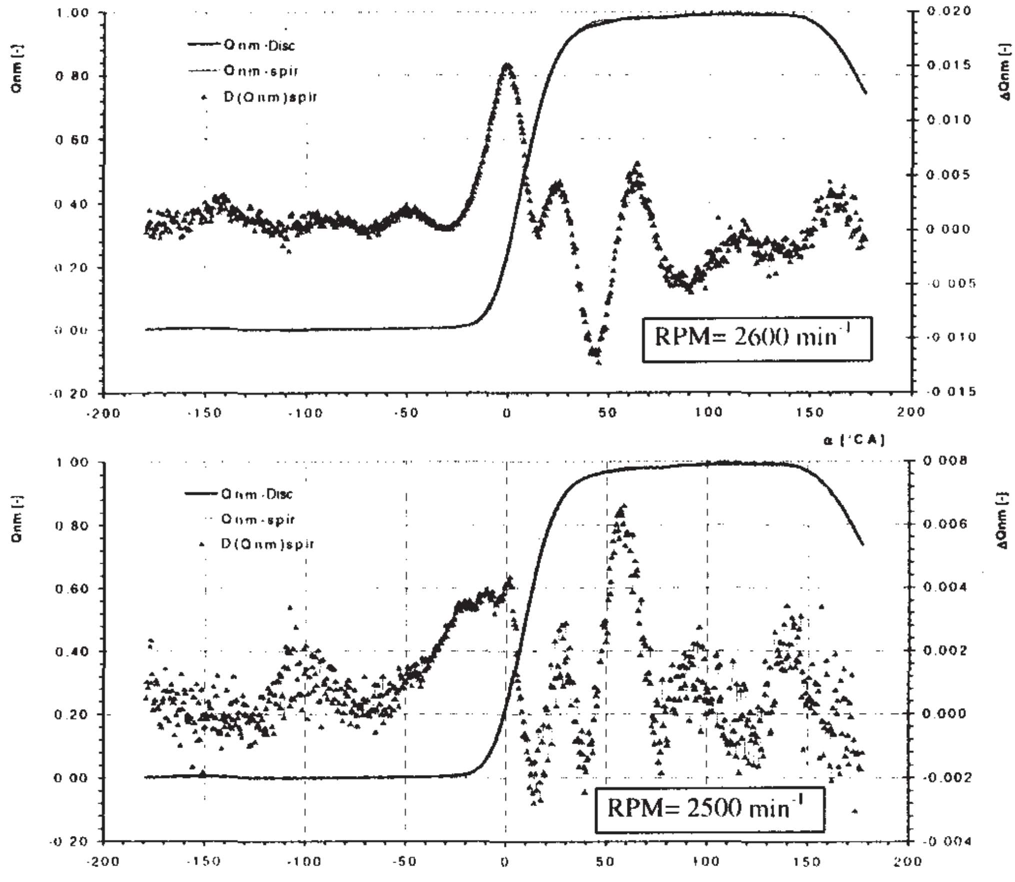


Figure 9. Torsional oscillation of Spiral-type clutch, a) maximal, b) minimal

To make inside more complete, in Figure 8 the courses of Q_{nm} and ΔQ_{nm} in area of maximal and minimal value of torsional oscillation of spring-type clutch are shown. In Figure 9 the courses of Q_{nm} and ΔQ_{nm} in area of maximal and minimal value of torsional oscillation of spiral-type clutch are shown.

7. Conclusion

In article an influence of torsional compliancy of the tested clutches on the evaluated courses of ROHR was described. Three various types of clutches were tested. The spring disc-type clutch was chosen as a comparative clutch, because the clutch has the largest torsional stiffness. In appropriate graphs deviations of ROHR courses evaluated by using of spring-type clutch and spiral-type clutch from ROHR courses by using of spring disc-type clutch are shown.

A result on the base of ROHR courses is spring-type clutch isn't acceptable for correct in-cylinder pressure recording. Using the spring-type clutch induces large deviations of ROHR courses. Spiral-type clutch using is more acceptable for correct in-cylinder pressure recording, but it was found-out a small torsional oscillation in range of engine speed over RPM= 2500 min^{-1}.

Using of the spring-disc type clutches is preferred in author's laboratory. Clutches with even more torsional stiffness are desirable.

Note: There were necessary about 5500 recorded in-cylinder pressure diagrams evaluate for depiction of ROHR amplitude deviations in regard with engine speed (Figure 7). Introduced values of ROHR deviation amplitudes and their courses in regard of engine speed hold for examined engine only, not generally.

Acknowledgements

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