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INFLUENCE OF THE DRIVE WITH FREQUENCY INVERTER ON PRESSURE PULSATION OF A GEAR PUMP

Abstract: The article presents the results of preliminary experimental tests focused on pressure pulsations of gear pump type PGP511 with the inverter-fed drive. The obtained results were compared with the pressure pulsation of the examined gear pump powered in a conventional way. A cycle of measurements was carried out for variable hydraulic resistance and fixed temperature of hydraulic fluid. The obtained results were analyzed in time and frequency domains.

1. Introduction

Development of modern hydrostatic systems is not connected only with increasing density of the transmitted power and enhancing efficiency of the selected elements of the hydraulic system, but it also comprises reducing vibration and noise levels (with mechanical or hydraulic sources) [6, 10]. Vibration resulting from pressure pulsation, caused by the irregular flow rate (pressure pulsation) of the system's hydraulic fluid, causes the accelerated wear of working parts, reduces accuracy of positioning the receivers and increases emission of noise. Therefore, it is necessary to conduct research aiming at the analysis of phenomena influencing pressure pulsation on the discharge line. [2, 3, 4].

We may observe a tendency to replace traditional solutions, in stationary hydraulic systems with variable displacement pumps, with a mechatronic equivalent with the similar functionality [1, 8, 9]. A hydraulic power unit that is based on this concept most commonly features a fixed displacement pump powered by electric motor with infinitely adjustable rotational speed. Drive system of a displacement pump with infinitely adjustable rotational speed enables setting pump's flow rate in a way allowing for obtaining the desired speed of the hydraulic receiver. Thereby, we obtain a hydraulic system with volumetric control that is characterized by the improved performance as compared to hydraulic units with throttle control. [5, 7].

This article, however, focuses on a certain danger connected with using frequency inverters. Authors of the publication pose the following question: is transferring harmonic distortion on pumping pressure pulsation possible for the drive with frequency inverter?

The obtained pumping pressure pulsation curves were analyzed in time and frequency domains. Time domain analysis was carried out in order to determine peak-to-peak value of pumping pressure that influences fatigue wear of the hydraulic system components and is responsible for generating increased levels of vibration and noise. Frequency domain analysis was carried out in order to identify the differences between frequency responses in case of the examined gear pump powered either by the motor with frequency inverter or with the same motor with direct electric power supply.

2. Measuring station and experiment plan

A measuring system (Fig. 1) has been composed of a gear pump with external gear design (series PGP511 produced by Parker Hannifin) with the capacity of $8cm^3$, powered by asynchronous AC motor was fed by the Parker Hannifin AC10 frequency inverter and conventionally (direct electric power supply) and a throttle valve 9N600S (regulation of hydraulic resistance). A pressure sensor HDA 4748-H-0250 was mounted at the discharge flange of the pump. Working fluid temperature (mineral oil HLP46 class) during the experiment was 40°C. Results of the experiment were acquired using HYDAC HMG3010 measuring and data-acquisition device.

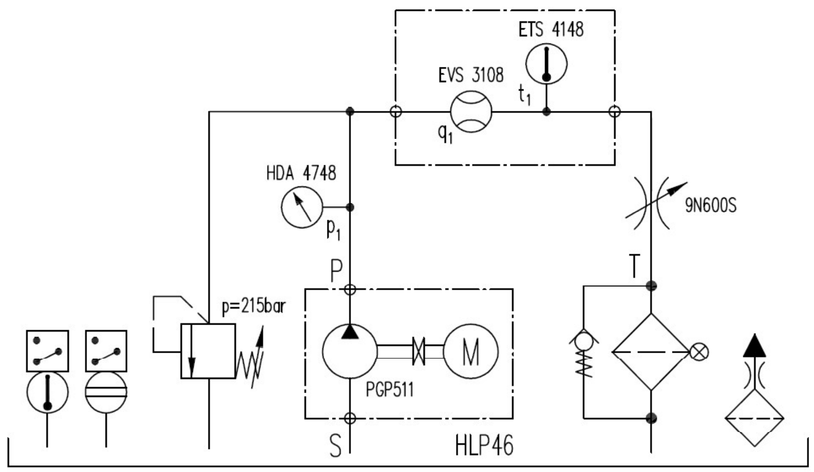

Fig. 1. Simplified hydraulic diagram of a measuring station

Measurements were carried out according to table 1. The tests were conducted for the system with conventional drive with asynchronous motor powered by inverter. Variable parameters included pressure in the pressure line at the constant temperature of the working fluid (t=40°C, HLP46 oil) and fixed electric grid frequency. The pressure was set by assuming hydraulic resistance of the pressure line by opening of the throttle valve.

Table 1. Experiment plan

No.	Test symbol	Pressure in the pressure line [bar]	Frequency of motor current [Hz]	Inverter drive system
1	PC_50	50	50	No
2	PC_100	100		
3	PC_150	150		
4	PF_50	50		Yes
5	PF_100	100		
6	PF_150	150		

Frequency of sampling signals registered during the experiment was 10kHz. Peak-to-peak pressure value was determined over the 100ms time interval. 16384 samples analyzed in the rectangular window were taken for the FFT-based data processing.

3. A comparative analysis of pump pulsation with inverter drive and with direct electric power supply

Selected comparative results of pumping pressure pulsation for the conventional drive system of a gear pump and a inverter drive are presented in table 2.

Table 1. Selected results of experimental tests

No.	Test symbol	Pressure in the pressure line [bar]	Time domain			Frequency domain	
			p_{max} [bar]	p_{min} [bar]	Δp [bar]	p_n for 25Hz [bar]	p_p for 300Hz [bar]
1	PC_50	50	49,5	50,4	0,9	0,057	0,32
2	PC_100	100	99,3	100,5	1,2	0,096	0,374
3	PC_150	150	149,7	150,9	1,2	0,128	0,276
4	PF_50	50	20,2	51,1	0,96	0,07	0,256
5	PF_100	100	99,5	101,1	1,6	0,122	0,331
6	PF_150	150	149,9	151,4	1,5	0,144	0,345

Basic experiments aiming at comparing gear pump drives are PC_100 and PF_100 according to table 1, whose pressure spectrums are presented in fig. 4 and 5.

Pressure pulsation spectrums presented in fig. 2 and 3 are similar. In both, we may observe a dominant band spectrum correspondent to the frequency of teeth engagement f_p. Amplitude of pressure pulsation for this frequency is 0,374bar with power supply direct from the network and 0,331bar with inverter drive. We may assume that using the inverter slightly (by about

11,5%) improved pressure pulsation for the dominant frequency. Another positive aspect of the inverter drive is eliminating pressure pulsation for the first harmonic frequency of pump shaft rotation $2*f_n = 50Hz$. On the other hand, within the range of low frequencies we may observe their higher amplitudes for the pump powered by the inverter.

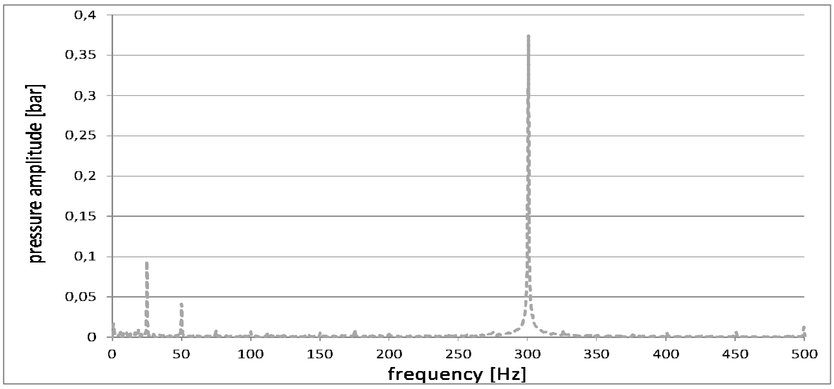

Fig. 2. Pressure pulsation spectrum for experiment PC_100 (without inverter)

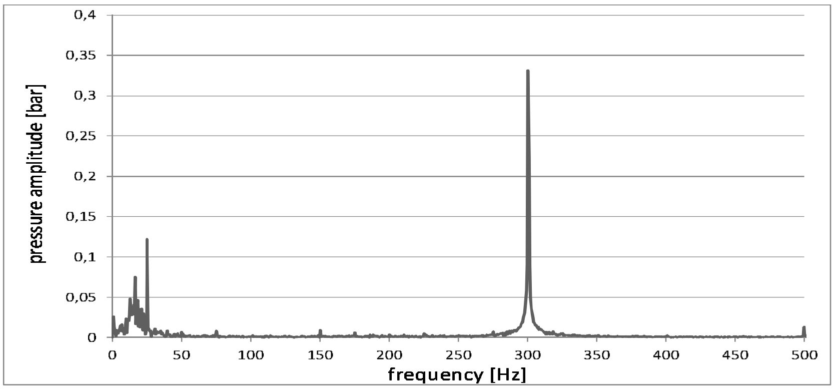

Fig. 3. Pressure pulsation spectrum for experiment PF_100 (with inverter)

For the purposes of more accurate comparison, fig. 4 presents both spectrums within the range up to 100Hz. It may be noticed that pressure pulsation for the frequency of pump shaft rotation f_n is 29% greater in case of the inverter drive.

Additionally, a blurred pressure pulsation band spectrum with maximum for the frequency 16,5Hz was observed in the pressure pulsation spectrum of a pump powered by the motor with inverter. It is quite unfavorable due to the possibility of evoking the response of a pressure line in a wider range of low frequencies that may overlap the line's natural frequencies in lengths of meters.

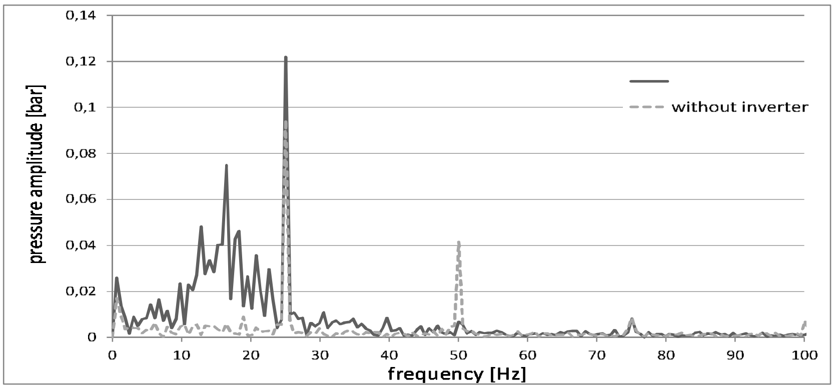

Fig. 4. Pressure pulsation spectrum for experiments PC_100 i PF_100

In order to confirm or deny the differences in the operation of a gear pump depending on its drive system, we have repeated the tests for pumping pressures 50bar and 150bar. Fig. 5 demonstrates spectrums for both drives with average pumping pressure 50 bar; analogical spectrums obtained for the average pumping pressure 150bar are presented in fig. 6.

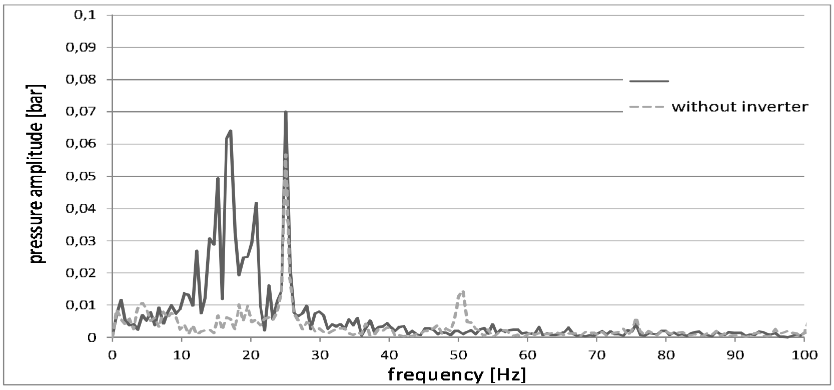

Fig. 5. Pressure pulsation spectrum for pumping pressure 50 bar

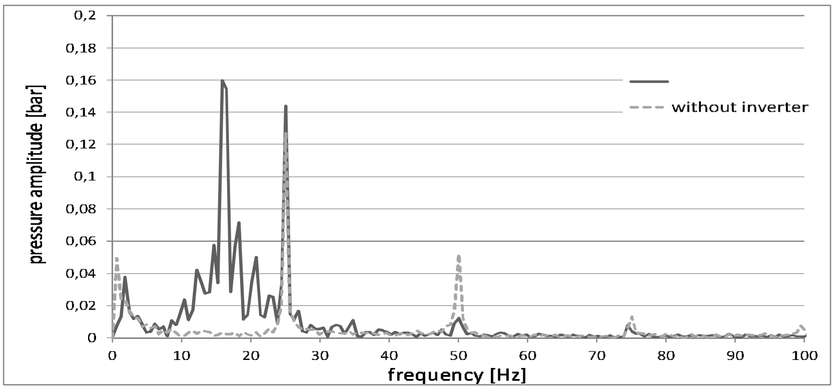

Fig. 6. Pressure pulsation spectrum for pumping pressure 150 bar

Results shown in fig. 5 and 6 are very similar to the spectrums obtained in experiments PC_100 and PF_100. Therefore, it may be assumed that it is a characteristic feature for the examined pump with inverter drive to demonstrate pressure pulsation within the frequency range between 12Hz to 20Hz. It may also be observed that the maximum value of this pulsation, occurring at about 16,5Hz, depends on the average pumping pressure (from 0,064bar at minimum value of average pressure to 0,16bar at its maximum value). These figures are proper for nominal rotational speed of pump's motor.

4. Conclusion

Results of the research indicate that there is a dependency between drive type of a gear pump and pumping pressure pulsation. It is, however, hard to conclude that this is an unambiguously negative influence. The obtained results proved that within the range of lower pumping pressure, pressure pulsation for the dominant frequency f_p was lower in case of the inverter drive. Furthermore, with this drive type, we did not observe the band spectrums of the first harmonic frequency of pump shaft rotation. The undoubted disadvantage of the inverter drive for gear pump PGP511 is the occurrence of blurred band spectrums of pressure pulsation in the range of low frequencies. A thorough examination of the causes of this phenomenon would require constructing a new research unit enabling measuring torque on the motor shaft and electrical values at its power supply provided by the inverter.

Additionally, another undesirable feature of the inverter drive is a noticeable increase of pressure pulsation amplitude at the frequency of pump shaft rotation.

In conclusion, it must be noted that hydraulic power units equipped with inverter should be examined by the interdisciplinary team of researchers in terms of their electrical, mechanical and hydraulic properties.

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