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ENERGY- SAVING FAN

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Abstract: The paper presents a fan with DC brushless motor used to circulate air in the combustion chamber of a solid-fuel furnace. A way of constructing the permanent magnet motor using much less steel and copper than present motors has been shown. Thanks to the use of sensorless control, the control system of the motor is simple and allows continuous speed control. The fan with a new motor consumes much less energy than the one with three-phase asynchronous motor. The motor and control system can be applied in other fans.

Keywords: fan, brushless motor, sensorless control.

1. INTRODUCTION

There is a widespread belief that high performance motors should not be used in the drives with rated power of approx. 200 W as higher price of motors and control systems is not compensated by lower energy consumption.However, when the number of fans is sufficiently big (e.g. in the extruder for the production of PET bottles there are 8 to 40 fans) energy savings can be significant. Therefore, a new system was designed.The paper describes the modernization of the DNG 2-2.5 fan It is a small centrifugal fan produced in Austria supplying 210^3 m of air per hour. The fans of this type use three-phase asynchronous motors with a power of 150 W and a rated speed of 2650 rpm. The paper presents a new fan drive of muchhigher efficiency. New drive is built on the basis of a brushless DC motor with a power of 100 W. Using this type of motor eliminates problems connected with motor start in asynchronous motors and guaranteesstepless speed control in a wide range [3, 4, 5, 9, 14]. In addition, when using the supply voltage of 24V, the fan can be fed from a battery (for example a car battery) in case of no power grid. Low, supply voltage improves safety of the extruder operation.

2. DESIGN ASSUMPTIONS

When designing the construction of the fan it was assumed that as much as possible should be used of the existing solution. We used the existing rotor and case of the fan, while changing only the motor driving the fan. We designed a new, brushless DC motor with permanent magnets, since this is the only type of motor guaranteeing a high efficiency at low power. Due to the quickness and easiness of assembly and the price of the magnets, we adopted a solution with cubic, neodymium interior magnets. A further advantage of this design choice is the impossibility of the magnets becoming unglued and of the associated motor failures. It was assumed that the supply voltage is 24 V and the speed of the fan should be controllable in a range of between 500 and 2700 rpm.

3. DESIGN AND FUNCTION OF THE SYSTEM

The drive system of the fan consists of a brushless DC motor and a control system based around a specialized processor. In typical applications three signals describing the position of the rotor with respect to the stator are needed for correct operation. Sensorless control [1, 2, 6, 7, 8, 10, 11, 12, 13] was used in the presented drive, which additionally reduced the cost of the drive and improved its reliability. The controller uses a measurement of the rotation voltage in an unpowered phase of the coil [6] to sense the position of the rotor. In Figure 1, we show the magnetic circuit of our motor. Computations of the properties of this circuit were conducted in the FEMM 2015 software. Figures 2, 3 and 4 show the internal construction and the view of a complete fan. In Figure 5 we show a block diagram of the control system with a marked spot where a battery can be connected in case of failure, while Figure 8 shows the complete control system of the designed motor.

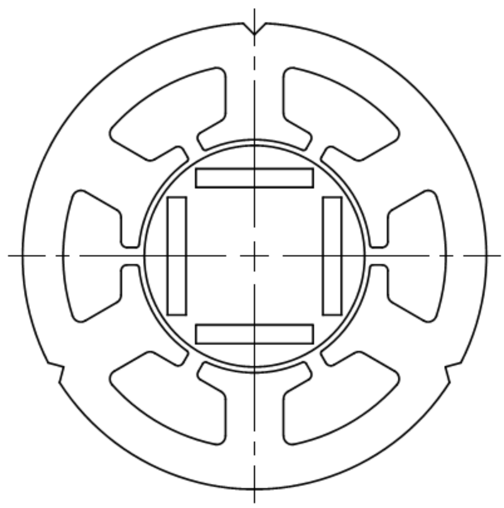

Fig. 1. Magnetic circuit of the designed motor

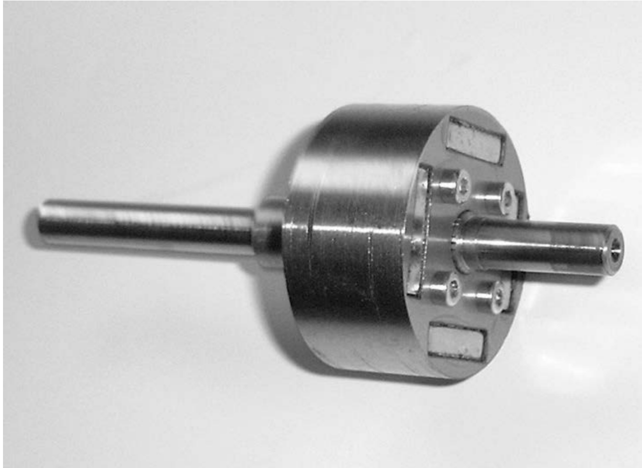

Fig. 2. View of the rotor

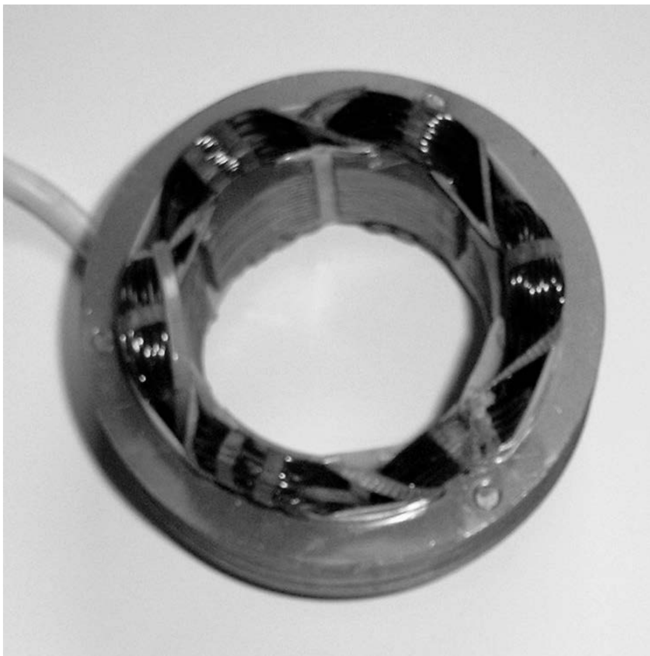

Fig. 3. View of the stator with coils

Fig. 4. View of the fan with the designed motor

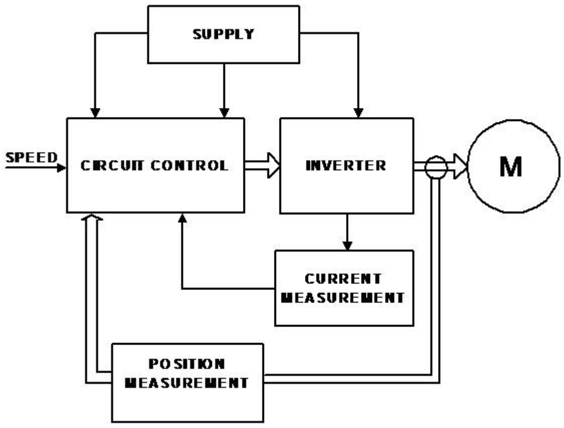

Fig. 5. Block diagram of the motor power system

A sensorless control system using a voltage measurement in unpowered coil was used to power the motor. By determining the zero crossing of the back emf one can easily control the motor. The easiest way of controlling the motor with back emf is the observation of the neutral point voltage. The ideal voltage waveforms at this point are shown in Figure 6, and the actual ones in Figure 7.

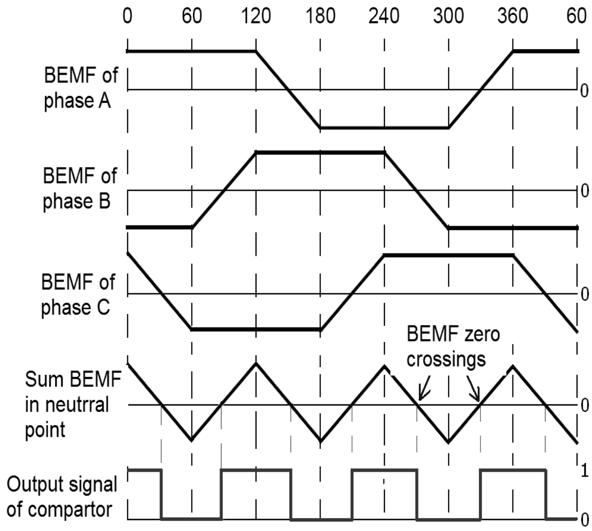

Fig. 6. Ideal waveforms of back emf and their sum in the neutral point

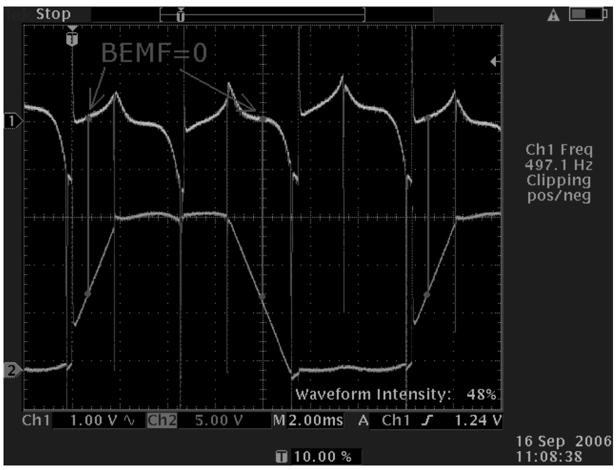

Fig. 7. Actual voltage waveform in neutral point (yellow) and back emf of one phase (blue) with marked zero crossings

The instant back emf crosses zero in unpowered phase is not synonymous with the switching-on of further transistors of the circuit shown in Figure 5. To determine the instant of inverter valve commutation one has to use a delay depending on the speed of the rotor in which the rotor covers the distance equal to 30 electrical degrees. Methods based on the observation of the back emf can be used for rotational speeds ranging from 10 to 100%. Below these values, the back emf is too small to properly determine the position of the rotor [5], [10]. Figure 8 shows a control system constructed according to the described principle of operation.

The waveforms in Figures 6 and 7 illustrate the case when the engine has a maximum speed resulting from power supply and motor parameters. For the rotational speed to be smaller than the maximum one, with group of inverter valves switched on, PWM is used for adjustment and the rotational speed of the motor depends on pulse width modulation. To reduce the switching losses in the inverter PWM control is conducted only by lower or upper transistors. In our case are upper inverter transistors. The system presented in Figure 5 was designed on the basis of a dedicated processor TB6575 and VMOS power transistors with n and p channels. Figure 8 shows the designed control system operating according to the principle of sensorless control.

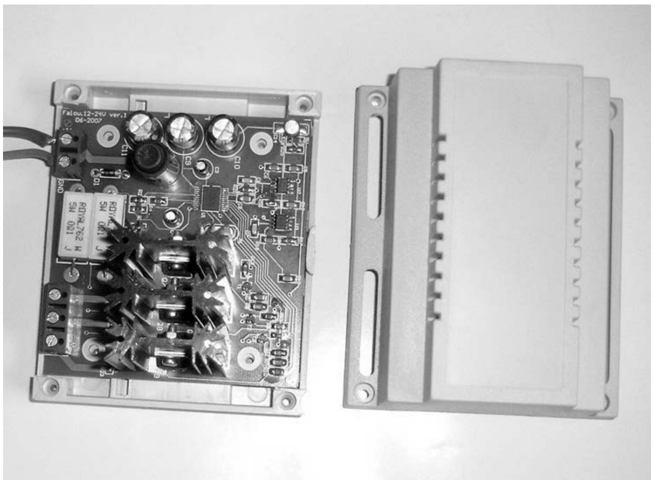

Fig. 8 View of power system supplying fan motor

As can be seen in Figure 8 inverter power transistors are placed on three radiators and the entire system is installed in a small, typical housing mounted on a rail.

4. FAN TESTS

System tests included motor start-up and operation checks for rotational speeds ranging from 500 to 2700 rpm under normal supply voltage as well as supply voltage reduced by 15%. In all cases, for different rotational speeds and reduced voltage, the operation of the drive was stable, and there were no problems during start-up. The fan with the new motor was compared with the existing one in terms of power consumption under rated supply voltage. The fan with asynchronous motor with supply voltage 3x380 V and the speed of 2650 rpm consumes 105 VA. The same fan with the new brushless DC motor, supply voltage of 24 V and the same rotational speed consumes 32.2 W.

5. CONCLUSIONS

The presented fan is only slightly more expensive than the one used so far and ensures a stable and adjustable rotational speed in a wide range of 500 to 2700 rpm. The low price results from both the simplicity of the motor itself and a small number of elements of the control system. As demonstrated by the measurements the fan uses three times less energy at the same rotational speed, that is, for the same amount of forced air. When using the nominal voltage of 24 V, the fan can be powered from a battery. This is important in case of power grid outage. Material savings are also significant here. Their scale – the reduction of the magnetic circuit and coil weight is evidenced in Figure 9 presenting the asynchronous three-phase motor used so far and a new brushless DC motor.

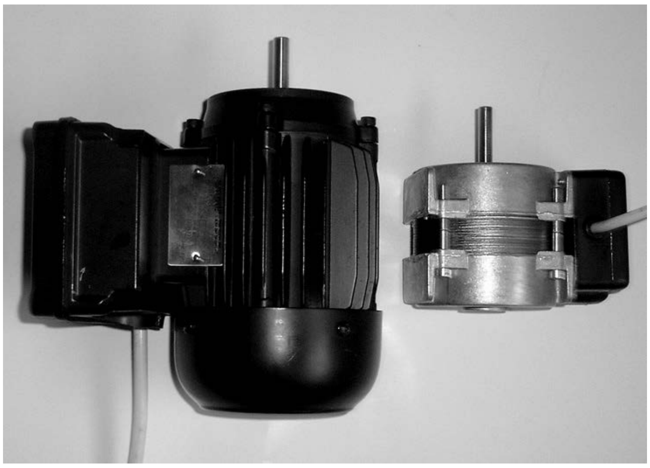

Fig. 9. Used and new fan motor

The use of permanent magnet modern motors in small electrical drives contributes to significant reduction of energy consumption and material savings. With long-term operation slightly increased manufacturing costs of the drives are compensated by low energy and operating costs. The presented fan is currently being tested in real production conditions, in the extruder.

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ENERGOOSZCZĘDNY WENTYLATOR

W pracy pokazano nowy napęd z bezszczotkowym silnikiem prądu stałego przeznaczony do wentylatora używanego w nadmuchu powietrza w ekstruderze do produkcji butelek PET. W dotychczas stosowanych w tych urządzeniach wentylatorach używano trójfazowych silników asynchronicznych małej mocy. Ze względu na dużą liczbę używanych wentylatorów – do 40 sztuk w jednym ekstruderze, pobór energii przez wentylatory jest znaczny. Z tego względu zdecydowano się na opracowanie nowej konstrukcji napędu wentylatora o zmniejszonym poborze energii. Opracowany napęd składa się z bezszczotkowego silnika prądu stałego oraz z energoelektronicznego układu sterowania pracą silnika. W artykule pokazano konstrukcję silnika z magnesami trwałymi, na który zużyto znacznie mniej żelaza i miedzi w porównaniu z silnikiem dotychczas stosowanym. W silniku nie ma czujników położenia wirnika i dlatego w układzie sterowania wykorzystano procedurę określania położenia wirnika na podstawie pomiaru napięcia w punkcie neutralnym uzwojenia. Dzięki zastosowaniu sterowania bezczujnikowego zmniejszono liczbę połączeń układu sterowania z silnikiem. Zastosowanie w układzie sterowania specjalizowanego procesora uprościło ten układ i umożliwiło płynną regulację prędkości obrotowej. Wentylator z nowym układem napędowym zużywa znacznie mniej energii niż wentylator z asynchronicznym silnikiem trójfazowym stosowanym dotychczas. Opracowany silnik i układ sterowania może być również stosowany w wentylatorach o innym przeznaczeniu.

Słowa kluczowe: wentylator, silnik bezszczotkowy, sterowanie bezczujnikowe.