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The Research of Pulse Width Modulation in Agriculture Automatic Micromotors Systems

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Introduction

In modern agricultural technological processes automatic control use hundreds of electric motors and micromotors. The motors in automatic control systems usually continually commutated to power supplier [1] or parameters of power supply are changed [2]. When mechanical pulse speed control is used, the numbers of disadvantage exist such as commutation speed limits, many mechanical switches consuming additional power and others.

Pulse speed control with semiconductors widely used in automatic control. Electro transmission with semiconductors pulse speed control has high commutation rate (300–10000) Hz also has high efficiency wide range of speed regulation and the speed regulation is accurate [3].

From experimental research was determinate optimal commutation period in pulse width converter – micromotor system, which is 0,6 ms for chosen micromotor. At this commutation period, maximal limiting current is 45 mA and speed regulation characteristic in continues current zone is linear and parallel to natural micromotor speed regulation characteristic.

Aim of work

The aim of the article is to research the pulse width influence to direct current micromotors speed control, power losses and speed regulation characteristic.

Materials and methods

When the DC fed with rectangular form of power supply, the micromotor current and rotation speed fluctuate [4]. Many parameters of DC micromotor such as power losses in motor, coefficient of efficiency, cutting off current width, optimal commutation period depend on fluctuation intensity. For the motors whose speed regulation time constant (T_m) bigger than motor armature time constant ($T_m > T_i$), a current fluctuations is determined with no mattering to motor speed fluctuation. Additional power losses ΔP_s, which arise in DC motors with separate excitation and applied pulse power supply, are calculated:

$$\Delta P_s = I_s^{\,2}\ r_a \frac{\varepsilon^2 (1-\varepsilon)^2}{12} \left(\frac{T_k}{T_i} \right)^2 ; \tag{1}$$

here I_s – short–circuit current of DC motor A; r_a – DC motor armature resistance; ε – relative width of pulse; T_k – period of commutations; T_i – DC motor armature time constant.

The optimal period of commutation, T_k we calculate from expression:

$$T_k = \frac{1}{f_k} . \tag{2}$$

The f_k optimal commutation frequency [5] calculated from equation:

$$f_k = k_f \sqrt[3]{\frac{\alpha_k\ r_a^{\,2}}{L_a^{\,2}\ (t_+ + t_-)}} ; \tag{3}$$

here $t_+ = 0{,}5\ 10^{-6}$ s, $t_- = 3{,}3\ 10^{-6}$ s [5]; L_a – motor armature inductance 48 mH.

$$\alpha_k = \frac{U}{r_a\ I_r} ;$$

here I_r – rated armature current.

Equation (2) shows that the optimal theoretical period of commutation is $T_k = 0{,}6$ ms.

There also exist power losses in electronic switches. The biggest power loss in the electronic scheme is when they are commutating. When relation between optimal commutation period T_k and DC motor armature time constant T_i is less than one second, the power losses in transistors define equation:

$$P_{sw} = I_a^2\ r_a\ \frac{t_{sw}}{2\ T_k} , \tag{4}$$

There t_{sw} is total on/off switch time of transistor switcher.

Whole power losses in the DC micromotor and switcher define equation:

$$\sum \Delta P = \Delta P_{\text{s}} + P_{\text{sw}}. \tag{5}$$

Equations (1) and (5) define transistor switcher and additional power losses dependence to width of pulse ε and commutation period T_{k} value. This definition presented in Fig.1 and Fig. 2. Fig. 1 describes how additionally power losses ΔP_{s} relate to width of pulse ε when commutation period T_{k} change.

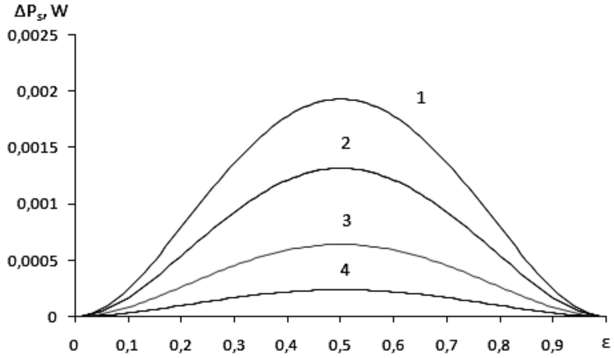

Fig. 1. Relationships between relative pulse width and power lost when 1 – T_{k}=0,0004 s; 2 – T_{k}=0,0003 s; 3 – T_{k}=0,0002 s; 4 – T_{k}=0,0001 s

Figure below shows power losses in electronic switches dependences to commutation period time.

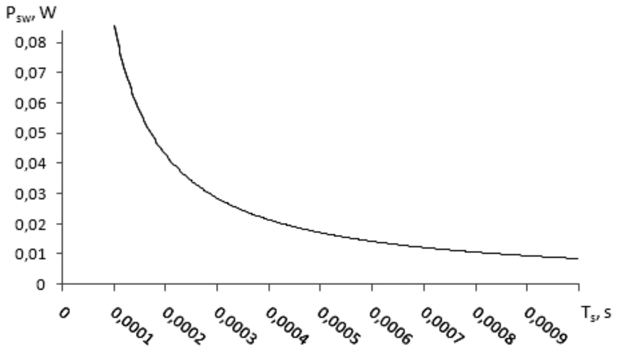

Fig. 2. Power loss dependence on commutation period time when I_{a}=I_{s}=0,47 A

For the experimental research, we chose unipolar current conductivity no reverse wide pulse inverter (WPI) – motor system [6], and no reverse WPI with bipolar current conductivity [7]. We also used DC micromotor (M31E–1) with separately excitation. The main parameters of DC micromotor is rated current 0,05 A, voltage – 5 V, rotating speed – 2700 n/min and armature resistance – 10,6 Ω.

Fig. 3 shows the principal electrical scheme of experimental kit.

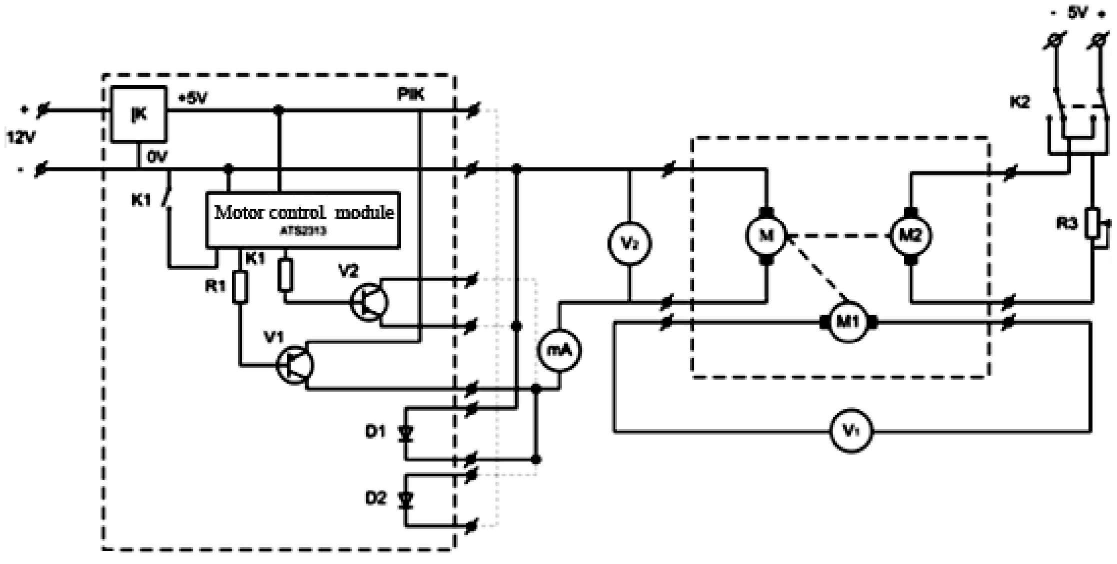

Fig. 3. Principle electrical scheme of experimental kit

The grey lines (Fig. 3) show a wire to switch the WPI inverter – motor system from no reverse unipolar current conductivity to a no reverse bipolar current conductivity mode.

The scheme part (PIK) produce rectangular form voltage pulses to feed motor M. The inverter needs 5 V voltage supply. For it, we used 12 V to 5 V voltage stabilizer (IK). To make a load to motor M we used motor M2 with contrary rotation. The load we changed with potentiometer R3. When it needed to get nominal rotation speed of motor M, we switch K2 to other position. The motor M2 starts turn in the same direction as motor M without the load. Transistor V2 needed when to the motor M we apply bipolar pulse current [8].

During examination of speed regulation characteristic of the system we used four values of ε with different relative width pulses (0,3; 0,5; 0,7; 1), but commutation period we kept T_{k} = const. The measurements we made with five different periods (3 ms, 2 ms, 1,5 ms, 0,6 ms and 0,3 ms). To monitor micromotor armature instant current for analysis of transient process in the system we used oscilloscope.

Result and discussion

The speed regulation characteristic of no reverse WPI – motor system presented in Fig. 4 and in Fig. 5.

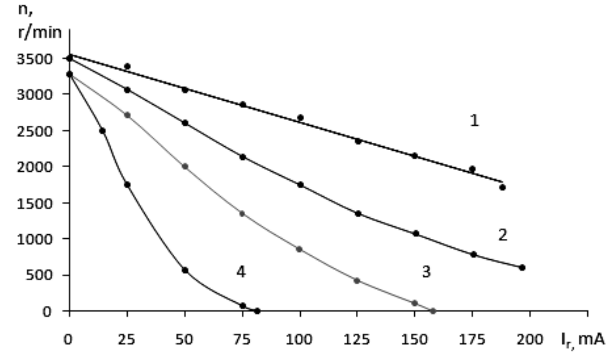

Fig. 4. Speed regulation characteristic of no reverse unipolar conductance system's WPI–micromotor (M31E–1) with T_k=3 ms; there 1 – ε=1; 2 – ε=0,7; 3 – ε=0,5; 4 – ε=0,3

The figures show, that when the pulse time (width) ε is shorter, then goes down rigidity of speed regulation characteristic of no reverse WPI – motor system. That mean when commutation period is set to $T_k = 3$ ms, then no reverse WPI – motor system works in zone of breakable current mode.

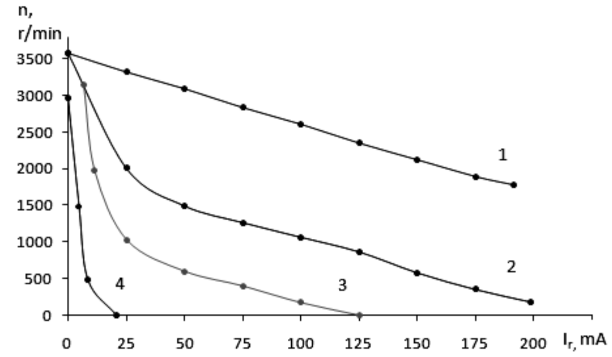

Fig. 5. Speed regulation characteristic of no reverse unipolar conductance system's WPI–micromotor (M31E–1) with T_k =0,3 ms; there 1 – ε=1; 2 – ε=0,7; 3 – ε=0,5; 4 – ε=0,3

From the figures, we can state that when the commutation time T_k goes down, then breakable current mode zone is shortening. There also we can see that when commutation time goes down the short cut current became smaller (Fig. 4) for example when T_k = 3 ms and ε=0,5 then I_s is 165 mA and when T_k = 0,3 ms (Fig. 5) and ε=0,5 then I_s is 128 mA. This means bigger power loss is on current inverter WPI.

Another results we got on a system with WPI of bipolar current conductivity mode. On the Fig. 6 and Fig. 7, we can see that speed regulation characteristic of this system in the breakable current mode zone. They are linear and linearity more likes natural motor characteristics comparing to system with no reverse current conductivity of WPI. This is because when transistor V1 of WPI switched off the transistor V2 turns on, then motor goes to recuperative braking mode. Such situation shortening discontinues current mode time.

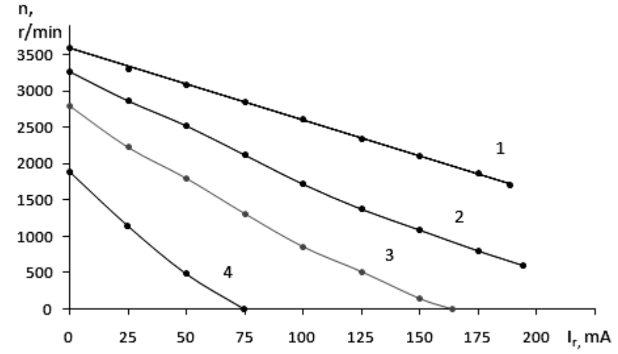

Fig. 6. Speed regulation characteristic of no reverse system's WPI–micromotor (M31E–1) with bipolar conductance and T_k =3 ms; there 1 – ε=1; 2 – ε=0,7; 3 – ε=0,5; 4 – ε=0,3

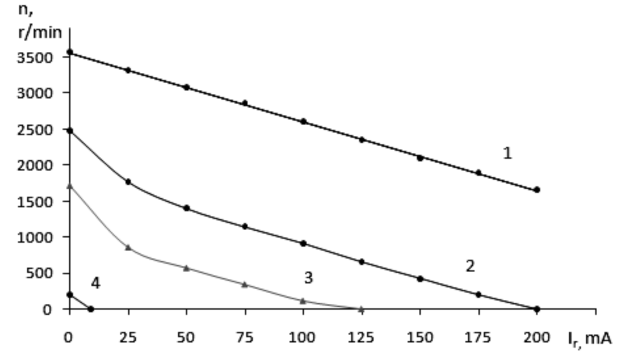

Fig. 7. Speed regulation characteristic of no reverse system's WPI–micromotor (M31E–1) with bipolar conductance and T_k =0.3 ms; there 1 – ε=1; 2 – ε=0,7; 3 – ε=0,5; 4 – ε=0,3

Rotation speed of motor M dependency on relative pulse width when there is different commutation periods presented in Fig. 8 and in Fig. 9.

The figures show that practically lines are the same on unipolar and bipolar WPI – motor systems. The micromotor good control characteristics reaches when the WPI commutation period T_k is equal or less than 0,6 ms.

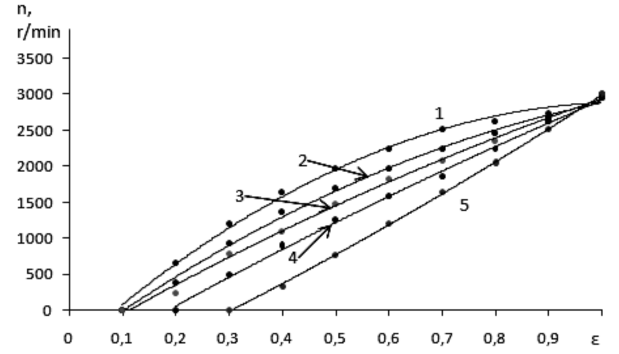

Fig. 8. Control characteristics of no reverse system's WPI–micromotor with unipolar conductance where 1 – T_k=0,3 ms; 2 – T_k=0,6 ms; 3 – T_k=1,15 ms; 4 – T_k=2 ms; 5 – T_k=3 ms

By concluding experimental results, the best speed regulation and control characteristics is when current commutation period of WPI – motor system is around 0,6 ms on chosen type of motors.

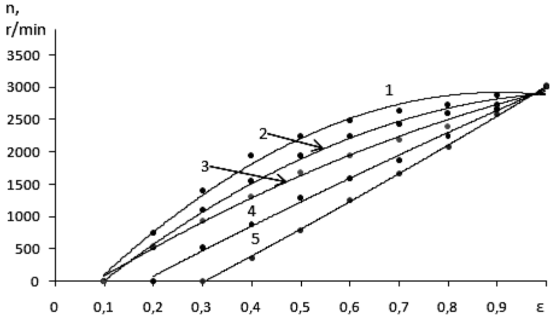

Fig. 9. Control characteristics of no reverse system's WPI–micromotor with bipolar conductance; where 1 – T_{k1}=0,3 ms; 2 – T_k=0,6 ms, 3 – T_k=1,15 ms, 4 – T_k=2 ms, 5 – T_k=3 ms

Conclusions

1. After theoretical calculation of additional power losses in WPI – motor system (motor M31–E–1, 0.018 W) we got the smallest power loss as commutation period is T_k = 0,6 ms.
2. In bipolar current conductivity WPI – motor system short–circuit current values is smaller than in unipolar current conductivity case. It is determine the larger power losses in system.
3. After evaluation speed regulation and control characteristics of WPI – motor system from experimental results we state that optimal commutation period of WPI in our case is 0,6 ms.

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In agricultural technological processes automation control increasingly is used the micromotors and micro drives. This leads to investigate the speed regulation characteristic of micromotors and expanding field of using in agricultural technological processes automation. The aim of the article is research the current modulation influence to direct current micromotor speed regulation characteristic and power losses. From experimental research was determinate optimal commutation period in pulse width converter – micromotor system, which is 0,6 ms. At this commutation period maximal limitary current is 45 mA, and speed regulation characteristic characteristic's in continues current zone is linear and parallel to natural micromotor dynamoelectric characteristic. For these reasons, pulse width modulation system can be used in the agricultural process automation chain, where are required the speed control. Ill. 9, bibl. 8 (in English; summaries in English, Russian and Lithuanian).

Р. Веялис, А. Заянчкаускас. Исследование микромашин автоматики с импульсно-широтной модуляцией в сельском хозяйстве // Электроника и электротехника. – Каунас: Технология, 2009. – № 2(90). – С. 85–88.

Изучается система: широтно–импульсный преобразователь (ШИП) и микроэлектродвигатель постоянного тока с независимым возбуждением. Из экспериментальных результатов установлено, что оптимальный период коммутации ШИП и микроэлектродвигателя постоянного тока с независимым возбуждением есть 0,6 мс. При этим периоде коммутаций максимальный ток составляет 45 mA, а скоростные характеристики прямолинейны и параллельны обычным характеристикам микро машин. Скорость вращения микроэлектродвигателя пропорциональна относительной ширине импульса. По этим причинам система с широтно–импульсный модуляции может быть использована при автоматизации сельскохозяйственных технологических процессов, когда необходимо управление скорости вращения микроэлектродвигателя. Ил. 9, библ. 9 (на английском языке; рефераты на английском, русском и литовском яз.).

R. Vėjelis, A. Zajančkauskas. Žemės ūkyje naudojamų automatikos mikromašinų su impulsine platumine moduliacija tyrimas // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2009. – Nr. 2(90). – P. 85–88.

Žemės ūkio technologinių procesų automatiniam valdymui vis dažniau naudojamos mikromašinos ir mikropavaros. Tai sąlygoja šių mikromašinų greičio charakteristikų tyrimus ir leidžia plačiau naudoti jas žemės ūkio technologiniams procesams automatiškai valdyti. Šiame darbe nagrinėjama sistema: platuminis impulsinis keitiklis (WPI) – nuolatinės srovės nepriklausomo žadinimo mikrovariklis. Remiantis eksperimentinių tyrimų rezultatais nustatytas optimalus platuminio impulsinio keitiklio ir mikrovariklio sistemos komutacijos periodas 0,6 ms. Prie šio komutacijos periodo didžiausioji ribinės srovės vertė tesiekia 45 mA, greičio charakteristikos tolydžiųjų srovių zonoje tiesinės ir lygiagrečios natūraliajai charakteristikai, o valdymo charakteristikoje mikrovariklio greitis kinta proporcingai santykiniam impulso pločiui. Dėl šių priežasčių impulsinė reguliavimo sistema gali būti naudojama žemės ūkio technologinių procesų automatikos grandyse, kur reikia valdyti variklio greitį ar momentą. Il. 9, bibl. 9 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).

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