IMPROVEMENT OF MAGNETIC FILTERS' PERFORMANCE BY CONTROLLING REGIONAL FIELD WITH PWM USING A DIGITAL SIGNAL CONTROLLER

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Abstract: *In this paper, a new method for the improvement of the performance of magnetic filters for the removal of disperses mixtures with magnetic characteristics from industrial liquids and gases is investigated. In order to accelerate the reduction of the concentration of dispersed mixture, it is suggested that the intensity of the external magnetic field throughout the magnetic filter should be adjusted regionally. To achieve this goal, an intermediate control circuit with PWM (Pulse Width Modulation) driver capable of driving the external magnetic fields of magnetic filter regionally based on three regions is designed. The dsPIC30F2010 Digital Signal Controller (DSC; Microchip®) is used in the controller circuit. The experimental results show that the concentration of dispersed magnetic mixture contained in the aqueous suspension passed from magnetic filter is reduced more efficiently. It is claimed that due to the adjustment of the external magnetic field intensity applied to the magnetic filters throughout the magnetic filter, the filter performance is increased, the electrical energy consumption is reduced, and the optimum design of magnetic filters is achieved.*

Keywords: *Magnetic filters, disperse particle concentration, control circuits, Digital Signal Controller (DSC), dsPIC30F2010, Pulse Width Modulation (PWM)*

1. Introduction

The removal process of magnetic-featured dispersed mixtures from liquids and gases in the external magnetic fields have been known since ancient times [1]. The theory and the implementation of cleaning these environments from low-concentration and micron-sized dispersed mixtures in high gradient magnetic fields has rapidly evolved in the past four decades [1-4]. The methods called High Gradient Magnetic Separation (HGMS) and High Gradient Magnetic Filtration (HGMF) have been used successfully for the enrichment process of minerals in the mining engineering [1] and applied to various problems in environmental engineering as an effective method [5-7].

Nowadays, HGMF methods have been used in various technological processes such as energy production, nuclear, chemical and petroleum industry. They provide increased efficiency in these industrial areas [8-11].

In recent years, systems and devices primarily developed for high gradient magnetic fields have been adopted in the magnetophoresis operations of nano and micro technological processes widely [10,12].

The principals of HGMS and HGMF have been used effectively in the processes of magnetic drug targeting, immunomagnetic cell separation, purification of fermentation products and purification of recombinants in medical and biological systems [13-17].

High gradient magnetic systems have also been suggested as advantageous methods in many other technological processes [18-22].

Various high-gradient magnetic field structures have been used in the systems of HGMS, HGMF and other applications [23, 24]. The reason for using all these systems in industrial and other applications is due to their very high performance. Therefore high-gradient magnetic field systems and devices require an optimum construction and high performance.

In many studies, the superconductive magnetic systems have been used as external magnetic field sources in order to increase the effectiveness of high gradient magnetic fields systems [11, 25, 26].

Received on: 07.02.2017
Accepted on: 13.03.2017

Numerous studies have been carried out to determine optimal system parameters by improving the theory of these systems and by increasing performances of HGMS and HGMF systems [2, 4, 7, 27-32].

In all these theoretical and practical studies, the parameters of both geometric and operation parameters such as concentration of dispersed mixtures, flow rate, external magnetic field intensity, temperature, and filter length etc. of high gradient magnetic field systems have been assumed to be constant. However the reference values of these parameters vary due to operation conditions. These conditions substantially affect the system performance.

During the operation of these systems, whether the system performance should be kept constant or should be improved is one of the current problems from the practical point of view. For this purpose, during the operation of high-gradient magnetic field systems, it is necessary to control the basic parameters and to make the required adjustments. It is not possible to carry out this operation neither by means of the theoretical and experimental models mentioned above nor by others proposed in the related literature.

In this study, increased capture performance of particles by magnetic filter from liquid and gases including low concentration and fine sizes particles with magnetic properties are proposed. For that purpose as a new method, regional regulation method used to determine the values of magnetic field of filter's magnetic system.

By investigating the parameters affecting the performance of HGMF, the current value in the winding of external magnetic field system (solenoid) is adjusted regionally throughout the filter. In accordance with this purpose, a PWM driver control system [33,34], which can adjust the current value of model filter solenoid system within three regions with time, is designed and the effects of this system on the filter performance is investigated. Stable operation conditions of the designed control system have been examined and their characteristics have been determined. Some suggestions have been proposed to operate this control system with HMGF used in industry.

2. Formulation of the problem

As shown in Figure 1, the magnetic filter or separator consists of non-magnetic body, magnetic system generating an external magnetic field (magnet, solenoid, core-type electromagnet), and input and output pipes and filter matrixes.

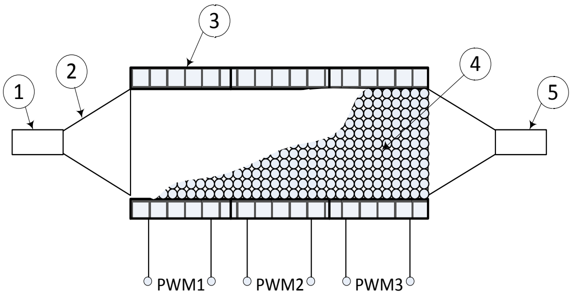

Figure 1. The principal scheme of the magnetic filter, 1- The inlet pipe, 2- The body, 3- The external electromagnetic field system (solenoid) 4- The filter matrix, 5- The outlet pipe.

The matrix elements of magnetic filter consist of magnetisable ferromagnetic materials (spheres, rods, wires, metallic turnings). These matrix elements can easily be magnetized with the effect of external magnetic field and thus they constitute local high gradient magnetic fields around themselves and at tangent points. While the suspensions including micron and submicron-sized particles are passing from matrix, the particles held by high gradient magnetic fields are collected in this region [9]. The efficiency or performance of magnetic filter is determined by the cleaning coefficient [8,9]:

$$\frac{\psi}{\lambda} = 1 - \frac{C_{out}}{C_{in}} \tag{1}$$

Where ψ is the cleaning coefficient of the filter, λ is the rate of the magnetisable particles of the mixture within suspension, C_{in} and C_{out} are the filter inlet and outlet concentrations of the mixture within suspension, respectively.

In general, the filter performance depends on geometric, magnetic, hydrodynamic and rheological parameters of the system. The most effective parameters from these parameters are the length of the magnetic filter (L), the filtration velocity (V_f) and the external magnetic field intensity (H or B) [27-29]. The magnetic filter performance in non-stationary state can be expressed as follows [9]:

$$\psi = \lambda[1 - e^{(\alpha t/t_0 - \beta x)}] \tag{2}$$

Where t is the time, t_0 is the stable operation time of the filter, x is the length through the filter, β is the adsorption coefficient of particles, α is the detachment coefficient of the adsorbed particles.

It is determined that the operation parameters of the real magnetic filters used both in industry and in laboratory is around at $V_f \leq 0.1$ m/s, $H \leq 150$ kA/m, β=(1…2) m^{-1}, α=0.1-0.6 h^{-1}, L=1-1.2 m [7, 8]. The particle adsorption coefficient of filter matrix (β), constituted from ferromagnetic spheres can be presented as follows [9, 30, 31]:

$$\beta = 2.6\ 10^{-3} \left(\frac{V_m}{V_f}\right) \frac{1}{d} \tag{3}$$

$$V_m = \frac{3k\mu_0\mu^{1.38}H^2\delta^2}{\eta d} \tag{4}$$

Where, k is the magnetic susceptibility of adsorbed particle, μ is the magnetic permeability of matrix elements, δ is the particle size (diameter), d- is the sphere diameter of matrix element, η is the dynamic viscosity of the suspension.

As can be seen, one of the most important parameters affecting the performance of the magnetic filter is the external magnetic field intensity (H). While the magnetic filter is in operation, an adjustment on the magnetic field intensity (H) causes a change in the filter performance. In practice, the change of magnetic field intensity varies in a wide range H = (10-150) kA/m [8, 9]. At low and average values of the magnetic field intensity (H = (10-100) kA/m), to obtain the filter cleaning coefficients ψ = % (70…85), the filter length must be around L = (1-1.2) m [8]. Experimental studies have shown that it is possible to obtain high performance from the magnetic filter even at low magnetic field values [8,9]. In this case, particles accumulated in the filter are aggregated in a certain area on the input side of the filter. Therefore, the remaining region of the active length of the filter operates at very low efficiency. Not using the filter length optimally results in both the rise in the amount of consumed electricity and the waste of the magnetic materials over time; thus, leading to the reduction in the filter performance. Accordingly, when the magnetic filter is in operation, various regions of the filter matrix could be run in different operation states by means of creating non-homogeneous distribution of the magnetic field intensity throughout the filter. It is possible to adjust all regions of the filter matrix automatically with the same performance by taking care of operation conditions of the filter system. In this case, the supply currents of winding or coils providing the external magnetic field of the magnetic filter must be adjusted locally. While coils in the input region of the magnetic filter are supplied with less current, the currents of windings towards the filter output must be automatically and regionally increased. In this study, an automatically controlled PWM drive circuit is proposed to achieve the goal of driving the magnetic filter windings accordingly

3. Material and method

3.1. The characteristics of the magnetic filter

Solenoid type magnetic filter windings with the total length of L_1 = 300 mm, L_2=300 mm and L_2=250 mm and with the inner diameter of 25 mm, consist of three regions with $l_1 = l_2 = l_3$ = 100 mm. The ferromagnetic spheres whose diameters are d = 5 mm are used as the filter matrix element. Magnetic filter and filter matrix element used in experimental are shown in Figure 2 and Figure 3, respectively.

The aqueous solution, whose size is δ = 1 - 2 µm, is used as the cleaning environment. The previously prepared magnetic section containing corrosion particles is around at % 80-85, (λ = 0.8-0.85).

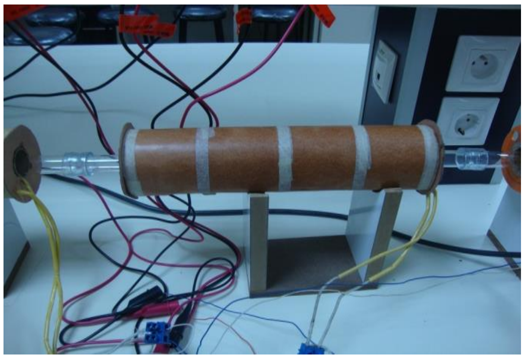

Figure 2. Solenoid type magnetic filter

Figure 3. Filter matrix

Flow of aqueous suspension from filter matrix has been carried out as non-recycled (single-layer) and the filter speed has been around V_f = 0.01m/s.

The voltage applied to the windings of the solenoid could be adjusted in the range of U = 0V-50V by changing the duty ratio of the PWM signal. In this case, the current in solenoid windings was limited at $I \leq 2.5$ A and the magnetic field intensity in the solenoid centre was measured as $H \leq 30$ kA/m. Both the control circuit and the software have been realized for driving solenoid windings by means of PWM signals, which provide regional (three regions) max 50V DC voltage. Due to its low cost and good technical properties, the dsPIC30F2010 Digital Signal Controller was used in the control circuit.

3.2. PWM control scheme

PWM control scheme, producing the required PWM signals and adjusting duty ratios by using the dsPIC30F2010 Digital Signal Controller (DSC), is shown in Figure 4. The dsPIC30F2010 DSC contains 16x16-bit working register array, 10-bit Analog-to-Digital Converter (A/D) with six input channels and three PWM modules [35]. Also, the DSC can multiply and divide signed or unsigned fractional/integer numbers in machine language. Because of these advantages, the control program was written in machine language. In terms of performance, the dsPIC30F2010 has superior properties than 16F and 18F series processors previously manufactured by Microchip [36].

In Figure 4, three potentiometers are connected to AN0, AN1 and AN2 analog inputs of the dsPIC30F2010. These potentiometers adjust the duty rates of FILTER1, FILTER2 and FILTER3, respectively. The adjusted duty rates are

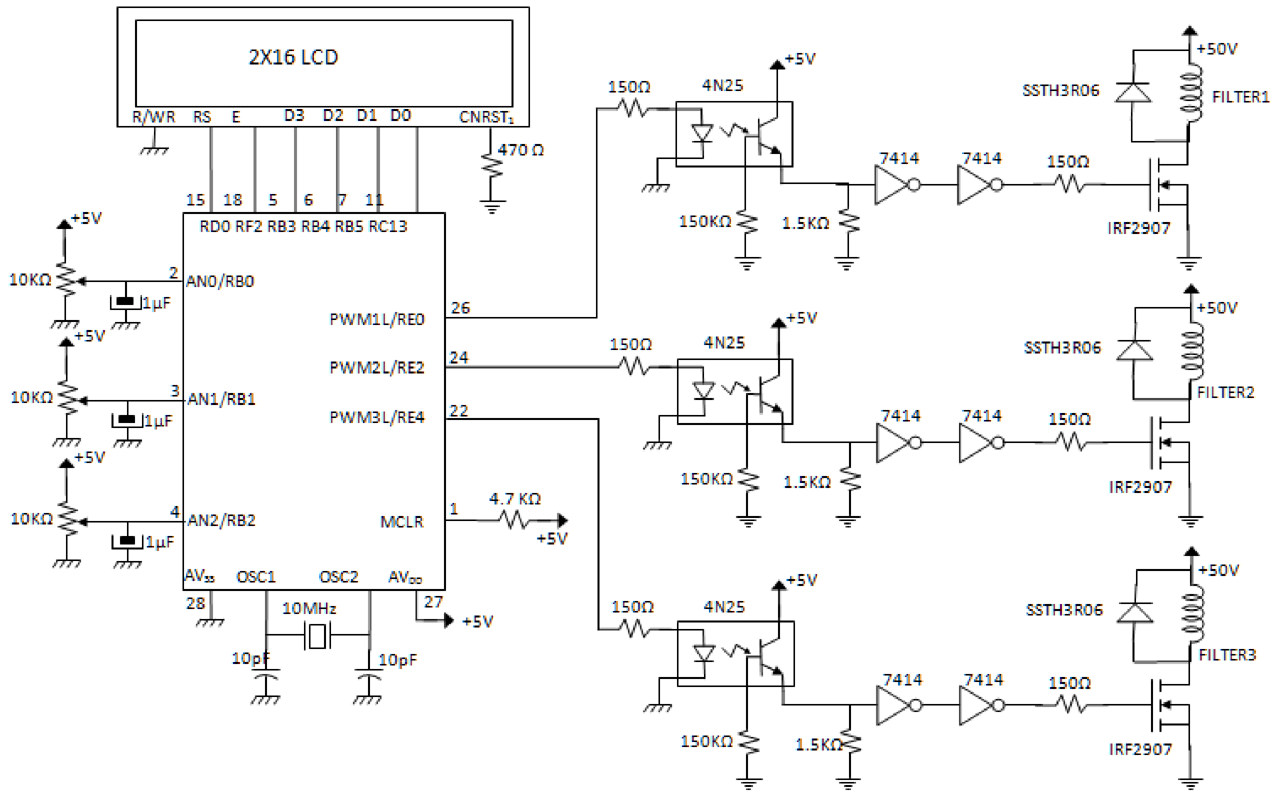

Figure 4. PWM Control Scheme using dsPIC30F2010

shown on an LCD as percentages under labels of DUTY1, DUTY2 and DUTY3. The PWM output signals are taken from PWM1L, PWM2L and PWM3L pins of the DSC and are applied to the driver inputs. IRF2907 MOSFET components and opto-couplers are used to convey the PWM signals to solenoids in the drive circuit. The drain-source voltage and drain current of IRF2907 are 75V (V_{DSS}=75V) and 75A (I_D=75A), respectively.

3.3. The flowchart of the control program

Figure 5 shows the flowchart of the control program where the initialization of peripheral devices of dsPIC30F2010 DSC is achieved and three separate PWM signals are generated.

In Figure 5. (a), Stack Pointer, ADC and PWM module, PORTE and LCD are initialized. After writing DUTY1, DUTY2 and DUTY3 messages on LCD, the interrupt request initialization is done for ADC. Then, the Interrupt request is enabled and the main program waits for the ADC interrupt request.

The flowchart of the ADC interrupt request program is shown in Figure 5. (b). Firstly, the digital value corresponding to the analog input for each channel is read. These digital values determine the duty ratio of PWM signal to be applied to solenoids. The values read from ADC are firstly scaled with the equation (5). Then they are loaded to PDC [35] determining the duty ratio in the processor:

$$PDC = \frac{PDC_{max}}{1023} X_{ADC} \quad (5)$$

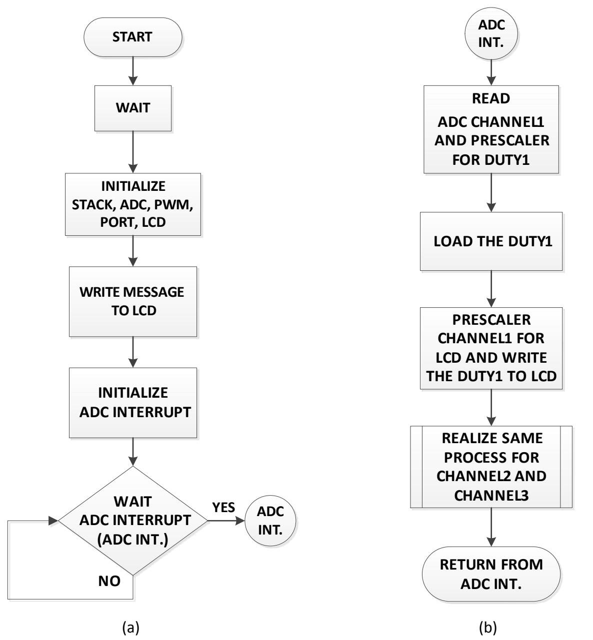

Figure 5. The flowchart of a) The initialization program, b) The interrupt request program.

Where X_{ADC} refers to the digital value of the analog input read from the related channel of ADC. This digital value has the maximum value of 1023.

As f_{PWM} is 1 KHz and $T_{DUTYmax}$ is 1ms, the maximum value to be loaded to PDC is 5000 (PDC_{max} = 5000).

The scaling shown in equation (6) is applied to show the duty ratio of each PWM signal on LCD as a percentage from % 0 to % 100.

$$\%DUTY = \frac{100}{1023} X_{ADC} \qquad (6)$$

The scaling operations shown in equations (5) and (6) can easily be implemented in assembly language, thanks to the 16 bit multiplication and division instructions of the dsPIC30F2010 processor. The control program is shown in appendix.

The experimental setup and output signal on filter2 are shown in Figure 6, Figure 7, respectively.

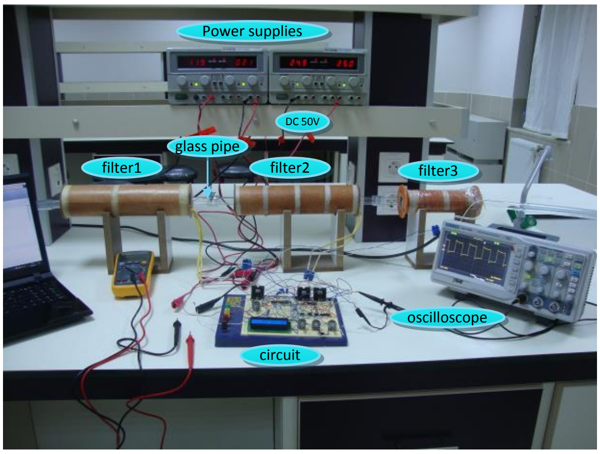

Figure 6. The experimental setup

Figure 7. The PWM output signal on filter2 (f=1 KHz, Duty=%50, volt/div x10)

4. Results and discussions

The results of [9] are taken into account to assess the effect of splitting the electromagnetic solenoid into two or more regions and then by applying different voltage values to each region. Then equations (2), (4) are used in order to define the experimental concentration output variation of these results. Each solenoid used in this study consists of three independent solenoids of which length is 100 mm and the total length of the solenoid is 300 mm. Each solenoid is driven by a PWM driver output in the control circuit, separately. By adjusting duty rates of PWM signals by means of three separate potentiometers, individual solenoid currents were adjusted in the range of 0.1A -0.8A. Ferromagnetic spheres in 5 mm diameter were used as magnetic filter matrix elements. The suspension prepared as C_{in}=50 ppm has been passed from the magnetic filter as non-recycled. The filter performance or concentration rates calculated by determining the magnetic filter output concentration of the magnetic dispersion mixture in suspension.

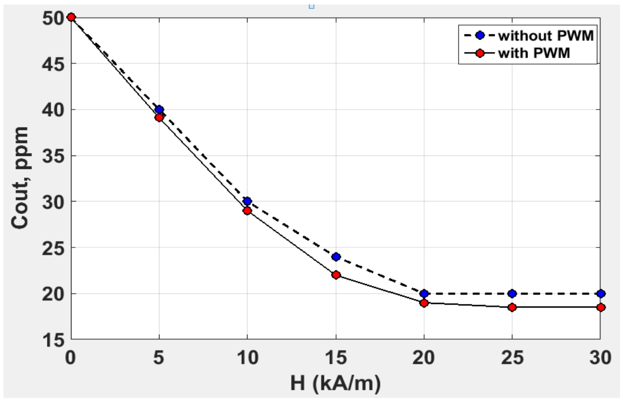

Figure 8. The change of output concentration of captured particles relationship with external magnetic field intensity.

The changes of concentration and effectiveness coefficients of magnetic filter respectively are demonstrated with PWM and without PWM situations at Figure 8 and Figure 9.

The various of external magnetic field intensity are adjusted for first solenoid accordingly Figure 8 and Figure 9. The magnetic field of second and third intensity solenoid is respectively adjusted based on equations (1) and (2) by using PWM control system. When the PWM is used, the filter performance will be increased as shown in both Figure 8-9. In this case, results will be more effective in magnetic filters and separator which have a high flow rate used PWM.

Accordingly filter length considering equation 1-3, the change of magnetic filter performance and concentration ratio can be evaluated. This comparison is shown at Figure 10. By adjusting duty rates of PWM signals by means of three separate potentiometers, individual solenoid currents were respectively selected as 0.510A, 0.625A and 0.765A in the flow direction of the suspension in the magnetic filter.

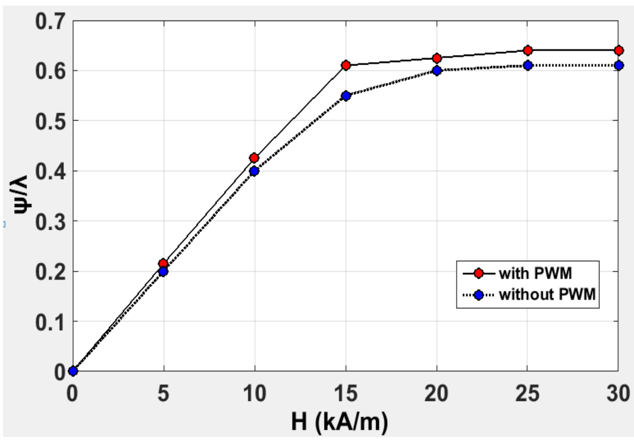

Figure 9. The change of effectiveness coefficient (performance) of the filter relationship with external magnetic field intensity.

For these current values, the magnetic flux density (the magnetic field intensity) in the center of the solenoid with no core are as follows B(H)=0.019T (1520 A/m), 0.022 T (17507 A/m) and 0.028 T (22282 A/m),respectively.

As can be seen from Figure 10, the concentration in the filter output of the magnetic disperses mixture due to the use of the PWM control circuit, is less than the one without PWM. This is due to the fact that relatively small size and weak magnetic-featured particles are hold in the regions with higher magnetic field instead of the entrance of the filter. Therefore, because of the regional non-homogeneous magnetization of the filter matrix, the possibility of the filter performance increases. This result is of great importance in the magnetic filter and separators with ferromagnetic matrix. Because in many industries such as nuclear power plants, chemical technology, paper industry, the sizes and concentrations of disperse mixtures within fluids used, are very low. In the technological processes using these fluids, high quality cleansing is necessary for the fluid environments from disperse mixtures. In this case, as proposed in this paper the use of PWM control units in electrical circuits of the magnetic filters and separators may be the most effective method. Furthermore, when driving the magnetic filters with the conventional techniques, solenoids are driven directly without PWM. This means that the solenoids are supplied with high electrical current consistently. In addition, driving solenoids of magnetic filters with previously known conventional methods increases the complexity and the cost of the electronic circuit design and thus the realization of such circuits becomes very difficult. As a result, power elements used in classical filters draw more current and therefore consume more electric power.

Driving the magnetic filter with the PWM technique, namely switching the current of the solenoid on and off to obtain the desired amount in a fixed period, reduces the power consumption and enables the solenoid to be driven easily.

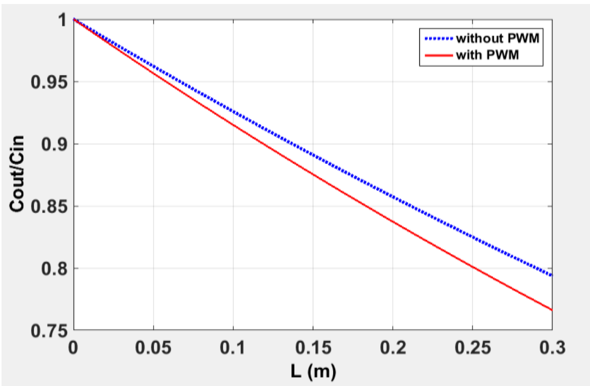

Figure 10. The change of filter performance for filter lengths.

This method also allows supplying solenoid with the optimum regional current value in a desired period. Because of long operation time of magnetic filters and separators, it is clearly seen that driving solenoids with PWM technique provides a significant contribution to electrical energy saving. Thus, using of PWM techniques and control circuits in the magnetic filters and separators will possibility provide an improvement in the performance of these systems, facilitate the design of control circuit, reduce the circuit cost and power consumption, and increase the effectiveness of the technological processes.

5. Conclusions

In order to increase the performance of magnetic filters and separators it is possible to regionally adjust magnetic fields of these devices. For this purpose, multi-channel PWM drive circuits can be used. Magnetic filters can be driven with multi-regional adjustable voltage by increasing the number of magnetic filter windings and with the help of specially designed PWM drivers. In this case, the performance of magnetic filter can be increased by using solenoids with different magnetic field intensities in different regions.

The PWM control circuit design proposed in this paper allows driving magnetic filters with 300 W (by using IRF2907) or higher power. This situation allows the use of PWM control in industrial type electrical circuits of magnetic filters and separators effectively. The PWM control circuits not only permit the adjustment of the current and voltage of magnetic circuits of magnetic filters and separators, but also it provides the optimal energy savings for these systems. The use of PWM driver circuits in the magnetic filters reduces cost of circuit and facilitates the circuit design. Connecting PWM control circuits in serial and parallel can be effectively used in the operation of magnetic filters and separators.

6. References

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7. Appendix

PWM Control program for dsPIC30F2010 in assembly langauge

```
;       .equ __30F2010,1
        .include "P30F2010.inc"
        .global __ADCInterrupt
        .weak __reset
        __reset:
        .equ    SAYI1,0x0800
        .equ    LW1,0x0802
        repeat  #0x3FF
        nop
        repeat  #0x3FF
        nop
        mov     #0x0900,w15
        call    PWMSRT
        call    DSPSRT
        call    LCDSRT
        call    PWMYAZ
DNG:    goto    DNG
__ADCInterrupt:
        push.s
        bclr    IEC0,#ADIE
        mov     ADCBUF0,w2
        mov     #5000,w7
        mul.uu  w2,w7,w10
        mov     #1023,w8
        repeat  #17
        div.ud  w10,w8
        mov     w0,PDC1
        mov     ADCBUF0,w2
        mov     #99,w7
        mul.uu  w2,w7,w10
        mov     #1023,w8
        repeat  #17
        div.ud  w10,w8
        mov     w0,SAYI1
        mov.b   #0x07,w9
        call    BINBCD
        mov     LW1,w11
        call    EMIR
        mov     #0xC2,w1
        call    LCDYAZ
        call    LHZR
        mov     ADCBUF1,w2
        mov     #5000,w7
        mul.uu  w2,w7,w10
        mov     #1023,w8
        repeat  #17
        div.ud  w10,w8
        mov     w0,PDC2
        mov     ADCBUF1,W2
        mov     #99,w7
        mul.uu  w2,w7,w10
        mov     #1023,w8
        repeat  #17
        div.ud  w10,w8
        mov     w0,SAYI1
        mov     #0x07,w9
        call    BINBCD
        mov     LW1,w11
        call    EMIR
        mov     #0xC7,w1
        call    LCDYAZ
        call    LHZR
        mov     ADCBUF2,w2
        mov     #5000,w7
        mul.uu  w2,w7,w10
        mov     #1023,w8
        repeat  #17
        div.ud  w10,w8
        mov     w0,PDC3
        mov     ADCBUF2,W2
        mov     #99,w7
        mul.uu  w2,w7,w10
        mov     #1023,w8
        repeat  #17
        div.ud  w10,w8
        mov     w0,SAYI1
        mov     #0x07,w9
        call    BINBCD
        mov     LW1,w11
        call    EMIR
        mov     #0xCC,w1
        call    LCDYAZ
        call    LHZR
GEC:    bset    IEC0,#ADIE
        bclr    IFS0,#ADIF
        pop.s
        retfie
PWMSRT:
        mov     #0x0000,W3
        mov     W3,PTCON
        mov     #0x0FFF,W3
        mov     W3,PWMCON1
        clr     PTMR
        mov     #2500,W3
        mov     W3,PTPER
        mov     #0x0000,W3
        mov     W3,PDC1
        mov     W3,PDC2
        mov     W3,PDC3
        bset    PTCON,#PTEN
        return
PWMYAZ:
        mov     #0x81,w1
        call    LCDYAZ
        call    GOST
        mov     #'P',w1
        call    LCDYAZ
        mov     #'W',w1
        call    LCDYAZ
        mov     #'M',w1
        call    LCDYAZ
        mov     #'1',w1
        call    LCDYAZ
        call    EMIR
        mov     #0x86,w1
        call    LCDYAZ
        call    GOST
        mov     #'P',w1
        call    LCDYAZ
        mov     #'W',w1
        call    LCDYAZ
        mov     #'M',w1
        call    LCDYAZ
        mov     #'2',w1
        call    LCDYAZ
        call    EMIR
        mov     #0x8B,w1
        call    LCDYAZ
        call    GOST
        mov     #'P',w1
        call    LCDYAZ
        mov     #'W',w1
        call    LCDYAZ
        mov     #'M',w1
        call    LCDYAZ
        mov     #'3',w1
        call    LCDYAZ
        call    EMIR
        mov     #0xC1,w1
        call    LCDYAZ
        call    GOST
        mov     #'%',w1
        call    LCDYAZ
        call    EMIR
        mov     #0xC6,w1
        call    LCDYAZ
        call    GOST
        mov     #'%',w1
        call    LCDYAZ
        call    EMIR
        mov     #0xCB,w1
        call    LCDYAZ
        call    GOST
        mov     #'%',w1
        call    LCDYAZ
        bset    IEC0,#ADIE
        bset    ADCON1,#ADON
        return
EMIR:   bclr    PORTD,#0
        repeat  #0x3FF
        nop
        nop
        return
GOST:   bset    PORTD,#0
        repeat  #0x3FF
        nop
        nop
        return
LCDYAZ:
        swap.b  w1
        mov.b   w1,w0
        call    YAZ
        call    ONAY
        swap.b  w1
        mov.b   w1,w0
        call    YAZ
        call    ONAY
        return
YAZ:    sl      W0,#0x03,W0
        mov     W0,PORTB
        bset    PORTC,#13
        btss    W0,#6
        bclr    PORTC,#13
        return
ONAY:   do      #10,KMRS
        nop
KMRS:   nop
        bset    PORTF,#2
        do      #500,KMRS1
        nop
KMRS1:nop
        bclr    PORTF,#2
        repeat  #0x3E8
        nop
        return
DSPSRT:
        mov     #0xFFF8,w3
        mov     w3,ADPCFG
        mov     #0x00E4,w1
        mov     w1,ADCON1
        mov     #0x0408,w1
        mov     w1,ADCON2
        mov     #0x1008,w1
        mov     w1,ADCON3
        clr     ADCHS
;reading AN0,AN1,AN2
        mov     #0x0007,w1
        mov     w1,ADCSSL
        mov     #0x1FFF,w13
        bset    IPC2,#ADIP0
        bclr    IPC2,#ADIP1
        bclr    IPC2,#ADIP2
        bclr    IFS0,#ADIF
        clr     PORTE
        clr     PORTB
        mov     #0x07,w3
        mov     w3,TRISB
        clr     TRISE
        bclr    TRISD,#0
        clr     TRISF
        clr     PORTF
        clr     PORTD
        clr     PORTC
        bclr    TRISC,#13
        return
LCDSRT:
        call    BEK100
        mov.b   #0x03,w0
        call    YAZ
        call    ONAY
        call    BEK100
        mov.b   #0x03,w0
        call    YAZ
        call    ONAY
        call    BEK100
        mov.b   #0x03,W0
        call    YAZ
        call    ONAY
        mov.b   #0x02,W0
        call    YAZ
        call    ONAY
        mov.b   #0x02,W0
        call    YAZ
        call    ONAY
        mov.b   #0x08,W0
        call    YAZ
        call    ONAY
        mov.b   #0x00,W0
        call    YAZ
        call    ONAY
        mov.b   #0x06,W0
        call    YAZ
        call    ONAY
        mov.b   #0x00,W0
        call    YAZ
        call    ONAY
        mov.b   #0x0C,W0
        call    YAZ
        call    ONAY
        mov.b   #0x00,w0
        call    YAZ
        call    ONAY
        mov.b   #0x01,w0
        call    YAZ
        call    ONAY
        call    BEK100
        return
BEK100:
        do      #1000,BK100
        repeat  #0x3FF
        nop
BK100:  nop
        return
LHZR:   call    GOST
        swap.b  w11
        and.b   w11,#0x0F,w1
        add.b   #0x30,w1
        call    LCDYAZ
        swap.b  w11
        and.b   w11,#0x0F,w1
        add.b   #0x30,w1
        call    LCDYAZ
        return
BINBCD:
        clr     LW1
BCD1:   sl.b    SAYI1
        rlc.b   LW1
        mov     LW1,w0
        add.b   #0x03,w0
        btsc    w0,#3
        mov     w0,LW1
        mov     LW1,w0
        add.b   #0x30,w0
        btsc    w0,#7
        mov     w0,LW1
        dec.b   w9,w9
        bra     nz,BCD1
        sl.b    SAYI1
        rlc.b   LW1
        return
        .end
```

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