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THE ADVANTAGE OF USING THE MICROCONTROLLER PIC18F4455 AS A CONTROL TOOL FOR A BAND SAW

The paper describes a system that utilizes a microprocessor in controlling the clamping force of the band saw teeth against the cutting metals. This control system allows the blades to operate more efficiently, and prolongs the blade life. It also has an influence on the removal of chips from the blade and maintains a constant strength over the blade. The system can operate in the vertical and horizontal position. A highly advanced and powerful microcontroller PIC18F4455 is programmed to operate with feedback from 4 sensors. Additionally system requires the parametrical data on the shape, the profile and the kind of material to be cut, for adjustment the process of cutting. Feedback control is implemented via a collocated force actuator/rate sensors. The control theory is used to develop controllers, which achieve robust stability.

1. Introduction of the cutting bandsaw

At present various cutting band saws are utilized at a large scale. The manufacturers equip the cutting band saws with several sophisticated control systems. Despite these measures, parasitic phenomena can occur during the cutting process. A band saw is typically used for woodworking, metal working, and cutting a variety of other materials. The machine is named in reference to its blade, consisting of a narrow band of toothed metal. This band rides on two wheels, at some distance from one another, in the same vertical plane,.. Band saws are particularly useful for cutting irregular shapes. The radius of the curve that can be cut on a particular saw is determined by the width of the band.

A general view of a band saw is shown in Fig. 1.

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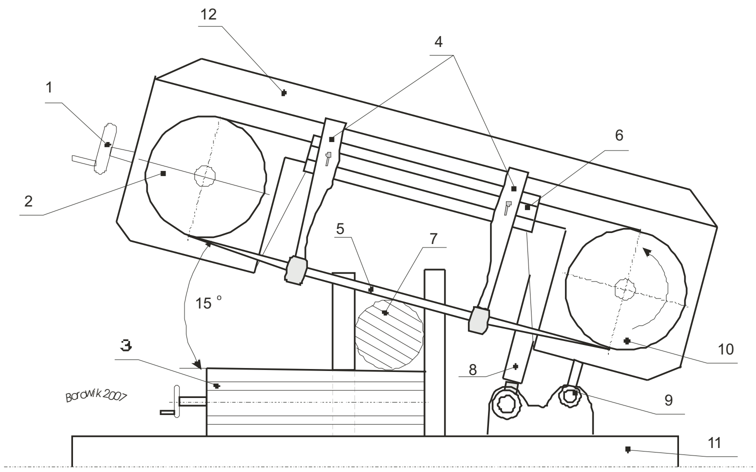

Fig. 1. Identification of parts during operation of a basic cutting band saw

1. Blade tightening screw
2. Passive wheel
3. Assembling clamping block
4. Stationery blade guard
5. Blade
6. Support of blade guard
7. Material to be cut
8. Hydraulic linear motor
9. Head frame pulley
10. Passive wheel
11. Frame of cutting bandsaw
12. Head of cutting bandsaw

During cutting of metals, the blades of the teeth take over an impulse load. It also applies to an endless band saw. The magnitude of this load depends on several factors, such as the clamp between the saw and the stock, the thickness of the material to be cut, and the number of teeth being in contact with the work piece. The clamp of the work piece to the saw is especially important. It is difficult to protect the teeth of the saw from overloading when cutting a profiled material, tubes, pipes or contours.

The number of teeth engaged in the cutting process is calculated based on the profile section of the material to be cut. The input data are stored in the register of a microcontroller for processing.

2. Mechanical system model of band saw

In the band saw, the clamp of the saw to the work piece is controlled by an electro- hydraulic device. The main role plays a linear hydraulic motor driven by a pump, which is controlled by a microprocessor.

The block diagram of the mechanical system of the band saw is shown on Fig. 2.

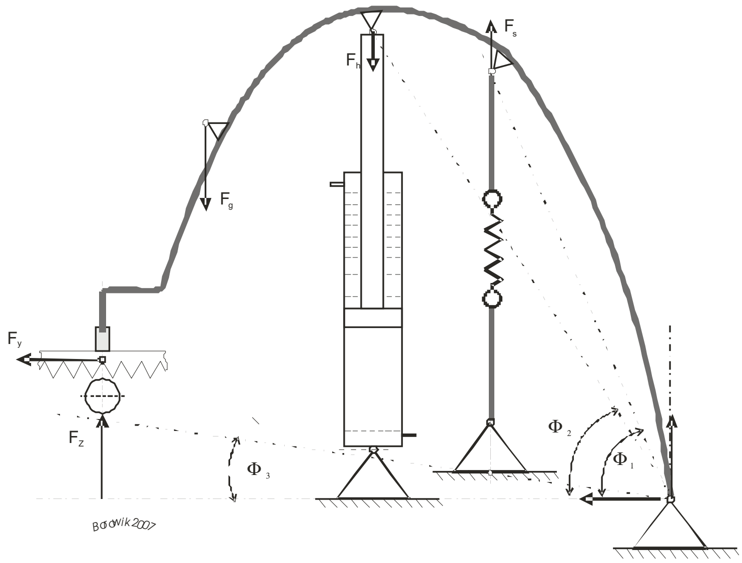

Fig. 2. Block diagram of mechanical system of band saw .
F_h – Force of hydraulic motor
F_g – Force of gravity
F_s – Force of spring
F_y – Force of blade bandsaw
F_z – Clamping force

In the presented investigations, we decided to use the PIC 18F4455 microcontroller to control the clamp between the saw blade and the work piece. For this purpose, the software code was prepared in the assembler language.

One provides input parameter values describing the material to be cut and its shape (whether it is solid, or profiled, single or in bundle). Another input signal comes from an optical sensor carrying information about the number of teeth of the saw simultaneously engaged in the cutting process. The microcontroller generates the output signal PWM and controls the pump; the system works in a closed feedback loop. The pump is coupled with the hydraulic linear motor.

We choose the PIC 18F4455 microcontroller, because it enhanced the PWM capabilities.

3. Model of hydraulic control system of band saw

In the hydraulic system, the motor of the PWM-controlled pump plays the main role. A block diagram of the hydraulic feed system is shown in

Fig. 3. The linear hydraulic motor is controlled by Three Way Valves VT_1 and VT_2. The valves operate in the regime opposite to each other. When one of them is opened, the other one is closed. Solenoid's controlling valves are driven by the signal from the microcontroller.

As shown in the block diagram [Fig. 3], the motor M it is driven by the PWM module. The duty cycle is generated as the result of input signals.

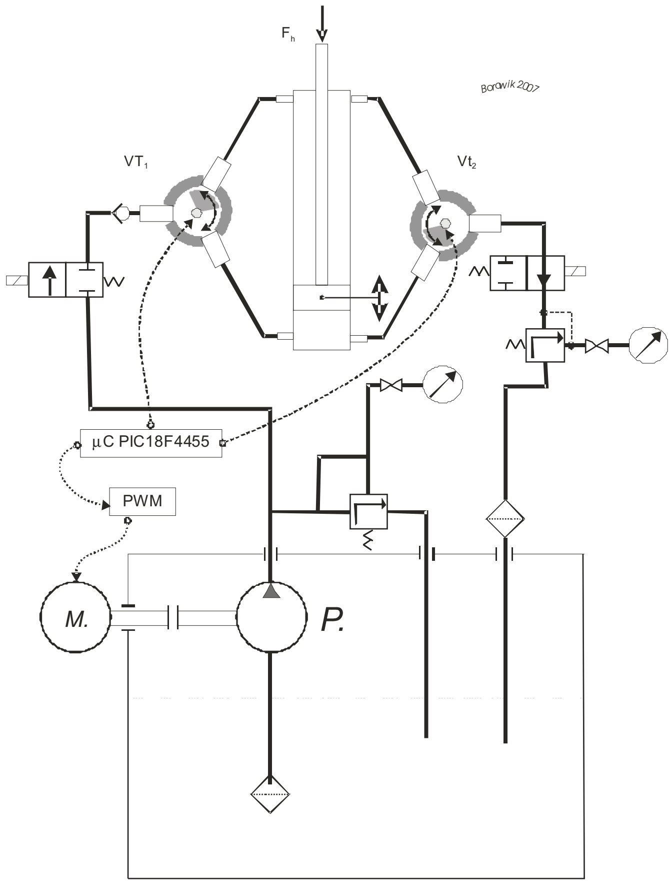

Fig. 3. Hydraulic control system of the cutting band saw
VT_1, VT_1 – Three Way Valves
M – Motor
P – Pump

Designed system allows for controlling the pump pressure with a high accuracy and there is no need to control the pump valve. Therefore, adjusting the throttle is no longer necessary.

Among the forces acting on the teeth, there are the downward force of the saw head pushing the teeth into the cut, and the pulling force arising as the blade moves through the cut.

4. Pulse width modulation circuit capability of PIC18F4455

The microcontrollerPIC 18F4455 has two CCP (Capture/Compare/PWM) modules: CCP1 and CCP2. Each module contains a 16-bit register, which can operate as a 16-bit Capture register, a 16-bit Compare register or a PWM Master/slave Duty Cycle Register. CCP1 is implemented as an Enhanced CCP module with standard Capture and Compare modes and Enhanced PWM mode.

Register CCPxCON (x = 1or2) standard mode

bit 7-6	Unimplemented
bit 5-4	In PWM mode these bits are the two LSbs (bit 1 and bit 0) of the 10 bit PWM duty cycle. The eight MSbs of the duty cycle are found in CCPR1L
bit 3-0	11xx = PWM mode

Register CCP1CON enhanced mode

bit 7-6	Enhanced PWM Output Configuration bits.
bit 5-4	In PWM mode these bits are the two LSbs (bit 1 and bit 0) of the 10 bit PWM duty cycle. The eight MSbs of the duty cycle are found in CCPR1L
bit 3-0	11xx = PWM mode

4.1 PWM mode

An efficient solution is provided by the switch mode PWM. Microcontrollers offer simple commands to vary the duty cycle and frequencies of the PWM control signal. The discrete on/off states of the modulation are used to control the voltage across or current through the load. In the DC motor, the speed control systems may be able to operate a lower speed, if they are controlled by PWM. The application of the analog current to control the motor would not produce a significant torque at low speed. The magnetic field created by the small current would be too weak to turn the rotor. On the other hand, a PWM current can create short pulses of the magnetic flux at full strength, which can turn the rotor at an extremely slow speed. A high frequency can cause an inductive load to be saturated. If we choose the right frequency, the controlled load will act as a stabilizer, the momentum will allow the motor to rotate smoothly. In the diagram below the PWM output is shown.

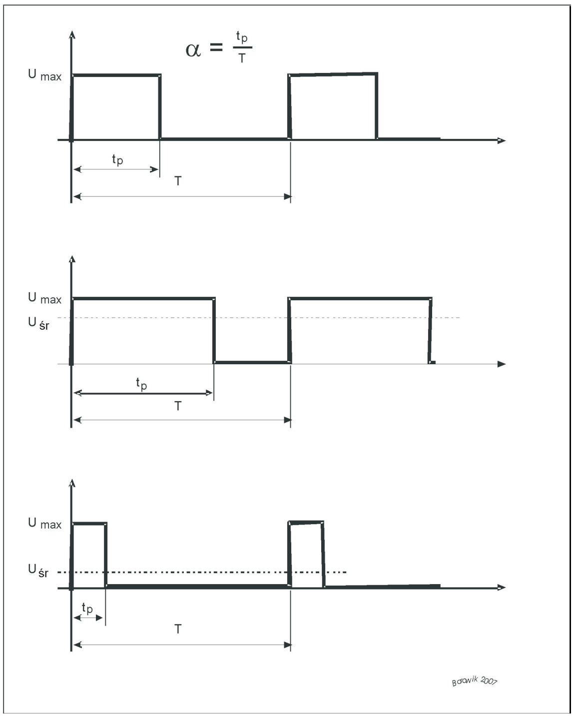

Fig. 4. Pulse train with the same frequency and different duty cycle.
T = const
For various t_p , duty cycle $\alpha = t_p$ / T,
where:
α is the so-called duty cycle;
t_p is the duration that the function is non-zero;
T is the period of the function.

For example, in an ideal pulse train (having rectangular pulses), the duty cycle is the pulse duration divided by the pulse period. For a pulse train in which the pulse duration is 1 μs and the pulse period is 4 μs, the duty cycle is 0.25. The duty cycle of a square wave is 0.5, or 50%. For the oscillator frequency of 4 MHz, the output PWM frequency would be:

$$f_{PWM} = \frac{f_{osc}}{4_{Osc\ cykles} \cdot parameter_{(PR2+1)} \cdot \beta}\ , \tag{1}$$

where β – prescaler value.

Thus, the TRISB bit 3 must first be cleared. Then two bits in the CCP1CON: bit 2 and 3 have to be set to raise the PWM mode. In the PWM mode, the PWM period TPWM is specified in the PR2 register. The PWM period can be calculated using the following formula:

$$\text{PWM Period} = [(\text{PR2}) + 1] * 4 * \text{TOSC} * \text{TMR2 prescaler value}$$
$$\text{PWM frequency is defined as 1/[PWM period]} \tag{2}$$

The prescaler is an integral part of the Timer 2 and may take the values of: 1:1, 1:4 and 1:16. It can be set by the configuration bits of the T2CON register: T2CKPS1 and T2CKPS0. The Timer2 postscaler can not be used for the determination of the PWM frequency. The PWM frequency depends on the number that is written to the PR2 register. It can be a decimal value of 0 to 255. The highest, possible value can be:

$$T_{PWM_{max}} = T_{cm} \cdot 256 \cdot 16 = 4096\mu s\ . \tag{3}$$

The maximum time period that can be obtained is equal to 4096 machine cycles

$$T_{PWM_{max}} = T_{cm} \cdot 4096 = 4096\mu s\ . \tag{4}$$

We can obtain the minimum PWM period equal to the machine cycle $T_{PWM_{min}} = T_{cm} \cdot 1$,
while the maximum value can vary for different microcontrollers and their prescaller capabilities.

The next operation should be the setting of the duty cycle. It is the time, when the PWM output is in the state HIGH, as shown in the diagram below.

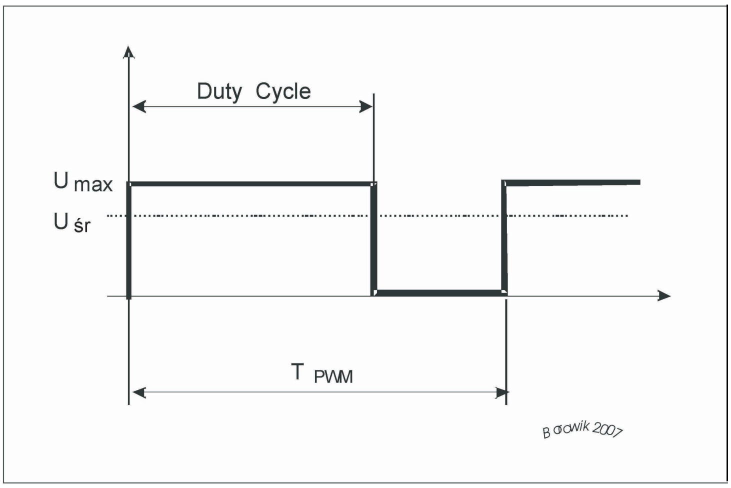

Fig. 5. The impulse duty cycle, modulated for the time period T PWM

4.2 PWM duty cycle

The duty cycle is the time, in which the output remains high. It can be calculated by using the following formula:

$$\text{PWM duty cycle} = (\text{CCPR1L} + \text{CCP1X} + \text{CCP1Y(10bits)}) \text{ x Tosc x} \\ \text{x TMR2 prescale value .} \tag{5}$$

Example: Maximum duty cycle on 4MHz.
Condition:

$$f_{osc} = 4\text{MHz} ,$$

$$T_{cm} = \frac{1}{4 \cdot 10^6} \cdot 4 == 1\mu\text{s} ,$$

$$\beta_{Pres} = 1 : 16 prescaler .$$

The maximum *Duty Cycle* δ_{max} can be calculated as:

$$\delta_{max} = (\text{CCPR1L} + \text{CCP1X} + \text{CCP1Y (10bits)}) * \text{T}_{osc} * \beta_{max} = \\ = 1023 * 0.25\mu\text{s} * 16 = 4092\mu\text{s} ,$$

where :

CCPR1L + CCP1X + CCP1Y makes the 10 bits register that can take the values of $0 \div 1023$. (6)

One can find, that the PWM duty cycle can be controlled with a precision of 1024 pieces of division to the PWM period.

5. Conclusion

The aim of the presented investigations was to considerer the possibilities of improving the reliability and efficiency of a band saw. This aim was achieved by employing the microcontroller PWM module for controlling the hydraulic feed system. Another aim was to equip the band saw machine with a self-aligning head.

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Zastosowanie mikrokontrolera PIC18F4455 w systemie sterowania siłami docisku w pile taśmowej

S t r e s z c z e n i e

Celem przeprowadzonych badań było zastosowanie układu sterownia naciskiem piły na przecinany materiał. W układzie sterowania wykorzystano programowalny mikrokontroler serii PIC. Program wypalony na pamięci flash umożliwia regulację ciśnienia w układzie hydraulicznym przez co możliwe staje się odpowiednie sterowanie naciskiem piły. Dla sterowania silnikiem pompy wykorzystano moduł PWM. Poprzez sterownie programowalnym procesorem uzyskano powtarzalność nacisków dla ciętych w procesie seryjnym elementów.