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Development Two Robust Approaches by Fuzzy-Sliding Mode Control

Fatiha Zaghrat*, Bousserhane Ismail Khalil*, Bouchiba Boussemaha**, Gasbaoui Brahim*

* Electric engineering department, SGRE Laboratory, Tahri Mohamed university, Bechar, Algeria
** Electric engineering department, CAOSIS Laboratory, Tahri Mohamed university, Bechar, Algeria
E-mail : zaghratfatiha@gmail.com, bou_isma@yahoo.fr

Abstract

To reduce the phenomenon of chattering, the major disadvantage of SMC, a lot of approaches have been proposed. In our work, we have introduced hybrids between fuzzy logic and sliding mode control to improve the regulation performance of DC motor. Two fuzzy–sliding (FSMC) approaches were proposed. The hybrids of these two theories allowed giving great robustness with a rapid dynamic response without overshoot, the rise time is good. Simulation and experimental results show that robust controls are highly responsive to conventional commands. In order to meet our needs and validate our results, we have developed a test bench where the engine is controlled using a digital processor called dSpace 1103, in which we have designed a program in real time. Some results are presented and their interpretations.

Keywords: DC motor, sliding mode control (SMC), fuzzy logic, fuzzy-sliding mode control (FSMC).

1. Introduction

In this work, a robust intelligent control strategy based on fuzzy logic and sliding mode control for controlling a DC motor is developed using two approaches. In automatic control, the majority of non-linear control approaches or with inconsistent parameters, conventional control laws may be insufficient. To this end, a number of tools are proposed in the literature [1], including the variable structure system (vss) and fuzzy logic. Sliding Mode Control (SMC) is a robust control methodology for linear and non-linear systems due to its robustness to parameter changes and external disturbances. The main drawback of this approach is the high switching frequency (chattering), the latter is not desirable because it can excite the not modelled high frequency modes in the non-linear control system. To reduce this phenomenon, a command that will provide performance prediction even if the system model is not very well known is required, these types of commands are called "intelligent control", working primarily on the principles of fuzzy logic.

In this paper we apply a hybrid command in fuzzy sliding mode control (FSMC) to reduce the marvel of chattering [2]. We have introduced hybrids between fuzzy logic and sliding mode to improve the tuning performance of DC motor.
In a first approach, a fuzzy Controller(FLC) will be designed to improve the performance of the control by sliding mode. In our proposal, we call the resulting controller, Fuzzy Sliding Mode Controller (FSMC), which has the same command law as the SMC except for the parameters k and component which will be adapted by a system to a fuzzy inference. In the second approach, fuzzy logic and sliding mode are combined to give rise to a new controller concept, the latter thus obtained is part of the family of fuzzy-sliding controllers. This one has the same SMC control structure, apart from the second term , which will be eliminated and replaced by a fuzzy controller [1]. In this context, simulation and experimental results using both approaches will be presented. DC modeling and the SMC algorithm have been addressed in some articles [3], [4], [5].

2. Sliding mode control

The implementation of a sliding mode control law involves two steps:
- The definition of a surface in the state space.
- performing a discontinuous control law, ensuring that the sliding surface is attractive.

The sliding mode command is usually broken down into two terms such as [6], [7]:

$$u = u_{eq} + u_{an} \qquad (1)$$

2.1. Design of sliding mode speed controller

The relative degree is taken as one; hence the surface has the form [8]:

$$\begin{cases} S_1(\omega) = \omega^* - \omega \\ \dot{S}_1(\omega) = \dot{\omega}^* - \dot{\omega} \end{cases} \qquad (2)$$

During sliding mode and steady state, the following are to be done: $s(w) = 0, \dot{s}(w) = 0,\ i_a^n = 0$

$$\dot{S}_1(\omega) = \dot{\omega}* - \frac{1}{J}(L_m i_f i_a - C_r - f_c\omega) \qquad (3)$$

We can draw the equivalent order size:

$$\begin{cases} i_a^{eq} = \frac{1}{L_m i_f}(\omega^* + \frac{1}{J}C_r + \frac{1}{J}f_c\omega) \\ i_a^n = k_\omega sat(\frac{s(\omega)}{\xi_\omega}) \end{cases} \qquad (4)$$

2.2. Design of sliding mode current controller

The relative degree is taken as one; hence the surface has the form:

$$\begin{cases} S_2(\omega) = i_a{}^* - i_a \\ \dot{S}_2(\omega) = i_a{}^* - i_a \end{cases} \qquad (5)$$

We can draw the equivalent order size: $v_a = v_a^{eq} + v_a^n$

$$\begin{cases} v_a^n = k_{ia} sat(\frac{s(i_a)}{\xi_{ia}}) \\ v_a^{eq} = L_a i_a^* + R_a i_a + k_i\omega \end{cases} \qquad (6)$$

Figure.1 shows the SMC control strategy scheme for DC motor. We need two surfaces s_1 and s_2 the first for the speed regulator and the second for the current regulator respectively.

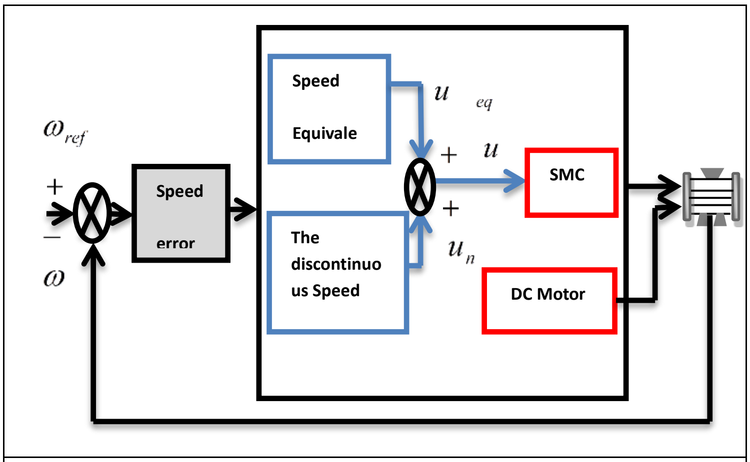


Fig.1. SMC control strategy schema for DC motor

3. Fuzzy-sliding mode control FSMC for DC motor

The main drawback of SMC is high frequency oscillations caused by little time delay which leads to chattering phenomenon [9],[10], that is the last one is produced in discontinuous control part in which, it switches between two values at an infinite frequency $(\pm k)$. The improvement in this frond contains using two fuzzy sliding approaches to reduce switching frequency. In 1^{rst} FSMC approach a FLC is developed in which a fuzzy inference mechanism is apply to generate the equivalent control law parameters k and ksi. In 2^{scd} FSMC approach, the discontinuous part will be eliminated and replaced by FLC, the proposed hybrids FSMC [12] schemes are present in figure (2) and (5). The proposed FLC is consist from the following IF-THEN rules

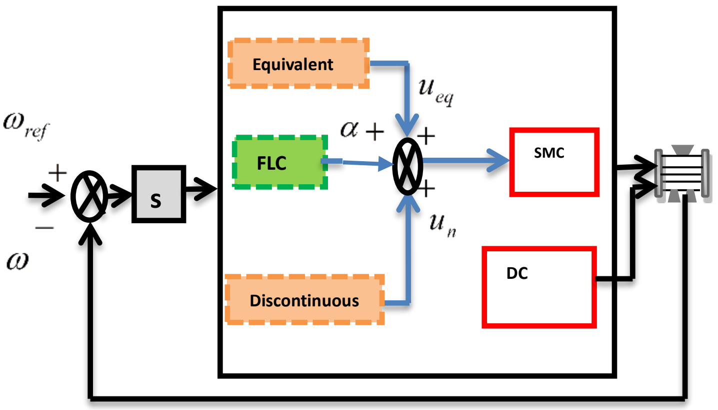
3.1. Principle of the first approach (FSMC1)

Terms K and ξ are adjusted by a fuzzy adapter with two S and $\dot{S}$ inputs of five parent functions and a 5 parents output which are represented in Fig.3 and Fig.4.Here is the whole function of membership and basic rules of the first approach.

Therefore, the law of discontinuous order becomes:

$$i_n^{fl} = k_v^{fl} sat\left(\frac{s(\omega)}{\xi_v^{fl}}\right) \tag{7}$$

$$\begin{cases} k_v^{fl} = \alpha k_v^{fl} \\ \xi_v^{fl} = \alpha \xi_v \end{cases} \tag{8}$$



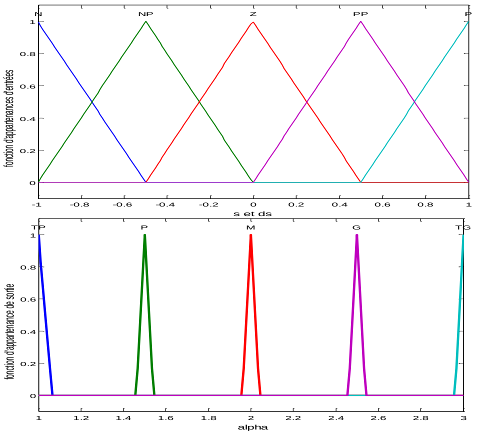


Fig.2. Fuzzy sliding mode 1^{rst} approach scheme

Fig.3. Inputs and output membership function of the discontinuous control.

Table 1. Membership functions

N: Negative	P: Positive
NS:Negative small	PS: positive small
S: small	B: Big
VS: Very small	VB: Very big
Z: Zero	M: Medium

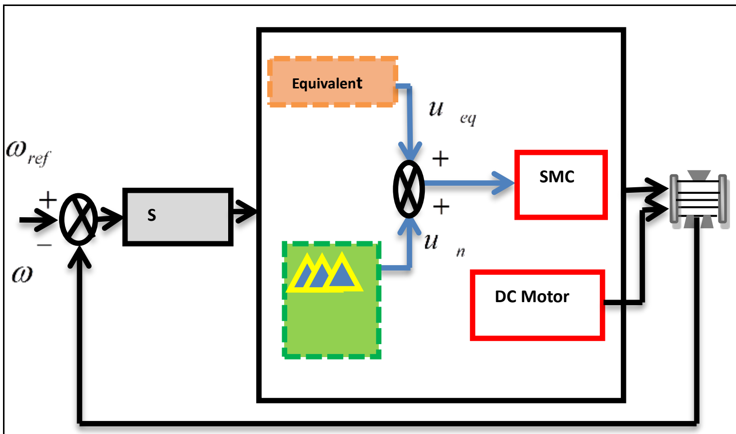
Table 2. Adapter rule base

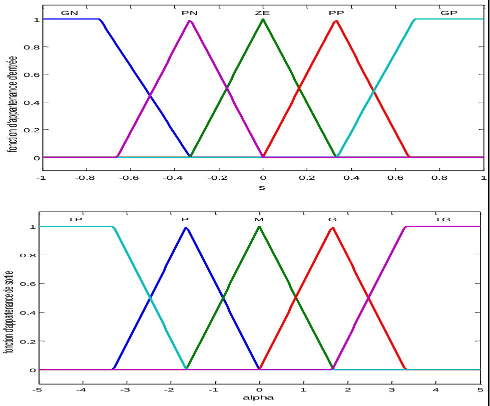
s **ds**	**N**	**VS**	**Z**	**PS**	**P**
N	VB	B	M	S	S
NS	B	M	S	M	S
Z	M	S	VS	S	M
PS	S	M	S	M	V
P	S	S	M	B	VB

3.2. Principle of the 2^{end} FSMC approach

‘‘If the error is negative, then the output of the system is pushed to the positive direction’’.

For this, the term discontinuous can be replaced by a fuzzy controller. This controller has an input and an output, and the rule base is used to establish a connection between s and $\dot{s}$. This is interpreted by rules of form: “If then” [7].





3. Simulation and exprimental result

4.1. Description of the test bench

In general, the entire bench consists of three groups, which are DC motor coupled motor load, the static converter and the control and control assembly based on the card dspace 1104 and Matlab/Simulink. The DC motor coupled on one side to a DC generator of the same power which constitutes the charge, and on the other side to an incremental encoder. The nature of the load is variable this variation is ensured by a Buck chopper. A DS1104 card provides real-time calculations; the axe associated with the engine is controlled by the d card using the digital outputs (Digital O) of the 'panel control' (CP1104). In order to amplify and adapt the control signals generated by space to the inputs of IGBT transistors, a board based on HCPL 3120 has been produced. The card dpace 1104 directs the inputs-digital outputs with voltage levels in TTL logic (0-5 V), but the IGBT drivers work in CMOS logic (0-15 V), hence the need for an interface card (5/15 V) that was designed to perform the adaptation. Two current sensors is used to measure excitation current and induced current. A stabilized power supply DC 5V, 15V for feed the various components.

4.2. Simulation results

4.2.1. First approach fuzzy sliding mode control

Vacuum start with application of a speed range of 100 rad/s. We have run simulations under the following conditions:

* Test 1: Application and removal of load torque Cr=1.43 N.m at moments t = 2sec and t= 4sec, respectively.

* Test 2: Change of instruction (100 rad/s) at time t = 6sec.

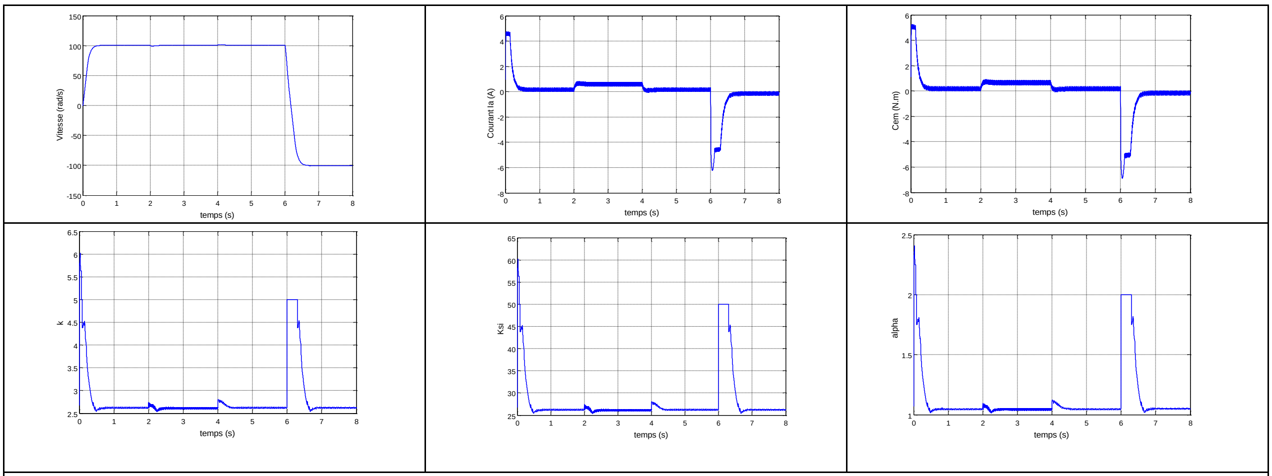


Fig.6. Dynamic behavior of the sliding fuzzy control (1st approach)

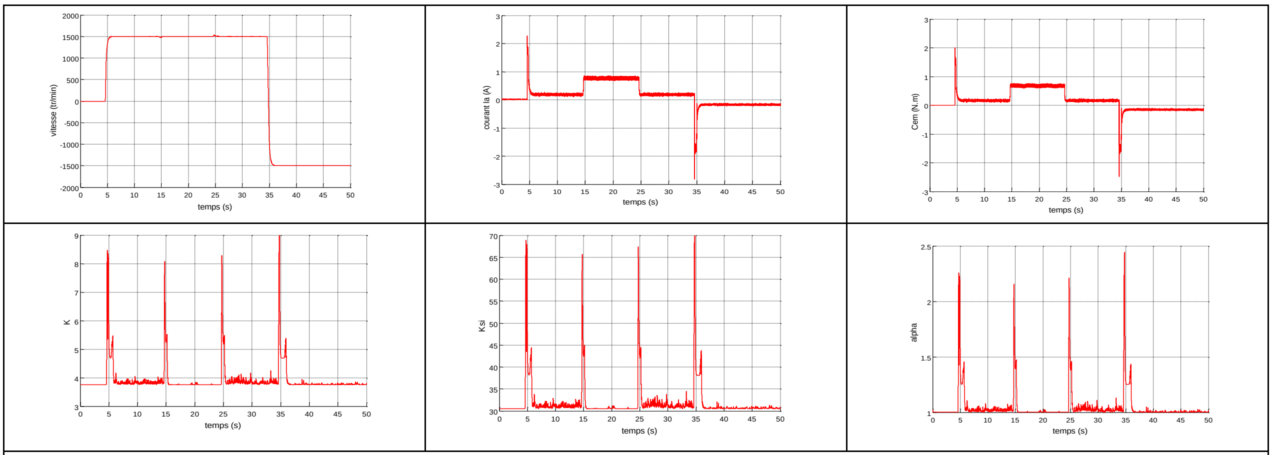


Fig.7. : Experimental results of the fuzzy sliding control (1rst approach)

4.2.2.second approach fuzzy sliding mode control

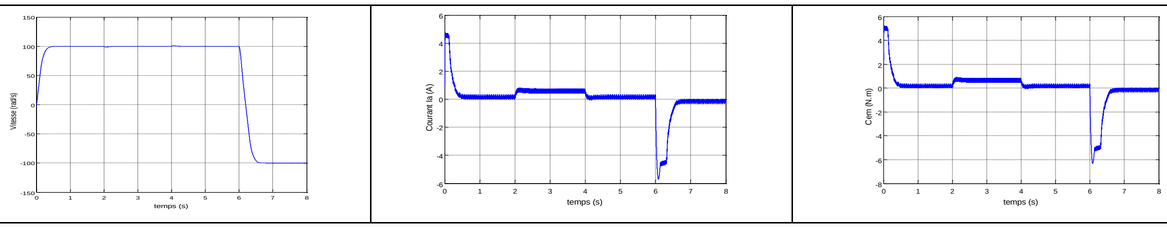


Fig.8. Dynamic behavior of the sliding fuzzy control (2st approach)

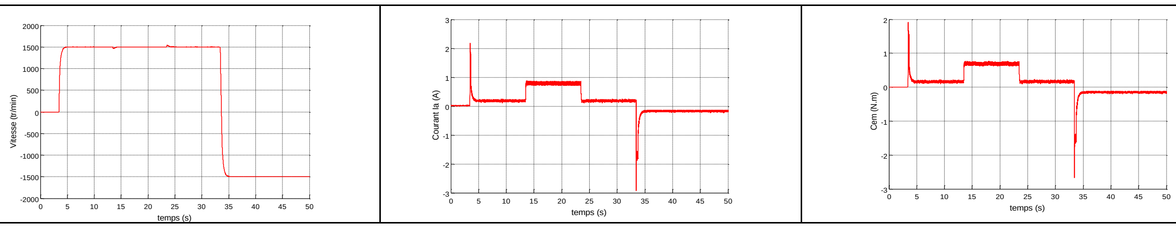


Fig.9. Experimental results of the fuzzy sliding control (2end approach)

4.2.3. Comparative chattering result

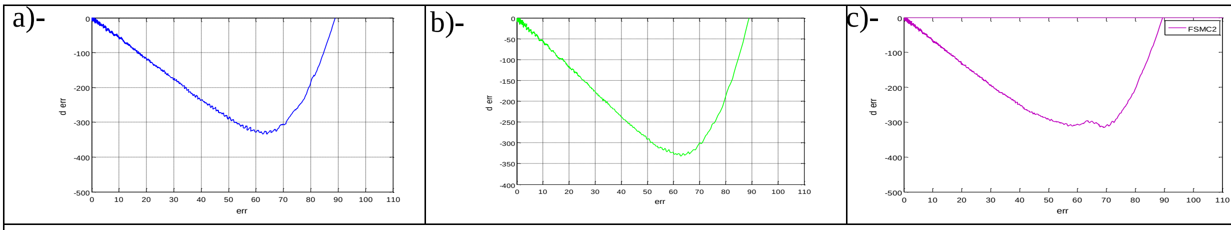


Fig.10. Experimental result of chattering phenomenon (a-SMC, b-1st approach and c- 2 scd approach)

5. Conclusion

This paper presents a new hybrid between fuzzy logic and sliding mode control. The aim objective of this hybrids is reduced the chattering phenomenon. In the first hybrid, the FLC have been generated the equivalent control parameters K and Ksi. In the second hybrid, the discontinuous part will be changed by FLC proposed. The result obtained has been showed in figure (6), (7), (8), (9). The FSMC have a fast response without overshot, robustness against external load disturbance and parameter variation. This article demonstrated experimentally that the application of these hybrids give a great robustness and best effectiveness of the hybrid strategies have been verified by simulation and real-time Implementation.

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