The Control Process of Nitinol Alloy Drilling through Fuzzy Logic

Sayed Ali Mousavi[1], Mohsen Hassani[2], Saeid Saki Entezami[3]
1- Islamic Azad University-Najafabad Branch/Department of Mechanical Engineering-Najafabad-Iran
Email: sayedali_mousavi@yahoo.com
2- Islamic Azad University-Najafabad Branch/Department of Mechanical Engineering-Najafabad-Iran
Email: m.hasanee@yahoo.com
3- Islamic Azad University-Najafabad Branch/Department of Mechanical Engineering-Najafabad-Iran
Email: saeed.s.entezami@gmail.com

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ABSTRACT:
The Nitinol alloy is considered as an outcome of the modern engineering and because of its great mechanical properties and memorizing capability is at the service of some advanced technologies, such as the medicine, robotics, army, etc. This article reviews and controls the drilling operation of the Nitinol alloy with Fuzzy logic methods. The machining conditions of the alloy are regarded as far as possible, and the Fuzzy logic are comprehensively and consecutively considered regarding the drilling main parameters. The tool diameter and cutting depth are experimented from 1 to 30, and 0.25 to 3 mm, respectively. The cutting speed is set on 20-50m/min and the spindle speed is classified on 20-6000 rpm. Of all the influential parameters, the temperature is considered and the results are revealed based on the mechanical properties of the alloy and the technological advancements.

KEYWORDS: Nitinol Alloy, Drilling, Memory, Fuzzy Logic.

1. INTRODUCTION

Memorizing capability alloys (SMA) are of a great importance in advanced applications because of their extraordinary characteristics. To provide new areas of application, the machining science of such materials are necessary and there is a vital need for economical machining operations. Nickel-based memorizing capability alloys (Nitinol) shows the greatest memorizing capability effect and they are mainly used in medicine, robotics and army industries. Memorizing capability alloy applications, especially in robotics, is greatly increasing compared to other engineering sciences. These alloys have the extraordinary effect of piezoelectricity and proper mechanical characteristic [1]. Strain hardening and the unusual behavior of piezoelectricity, high viscosity and toughness have led to the complexity of the machining operation of memorizing capability alloys. The main barrier for using and applying the Nitinol is their high toughness and low machinability. Nitinols are the alloys with late oxidation, high flexibility and elasticity. In order to meet these problems while machining the Nitinol, the new technique of machining control is applied. In this study, fuzzy logic control is added to the machining to optimize the process. This technique leads to the successful cutting process of some materials with low machinability, such as high strength alloys used in aero-space industries, super alloys and their compositions, compared to the traditional machining methods. Literature reviews reveal that the common machining of memorizing capability alloys is only done through the references [2]. In these references, the results of turning, drilling, and deep drilling of memorizing capability alloys are provided. Successful applications like presenting machining condition [5,6], machine control [7], total machinability assessment [8], small diameter drilling control system [9] are also provided through applying fuzzy theory in the machining operation of the metals.

2. DRILLING OPERATION

In this section, the most important discussion is about the alloy behavior in drilling. To attain proper results, some special softwares are used, such as Corel, Art Cam, and Sheet cam which are programmed and commanded by the operator.

2.1. Nitinol alloy drilling process

In this process, the drilling quality has a direct relation with the physical characteristics of the drill. The fracture of these tools due to their natural and asymmetrical designing from the cutting edge , and the applied force radius through SMA in the guiding pad are unpredictable and by continuing the drilling and adhesion increase, the probability of fracture or fatigue of the drill increases.

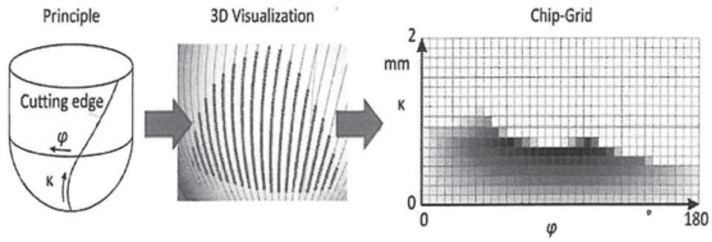

Fig1. The reformed algorithm and tool conformity [3,4] .

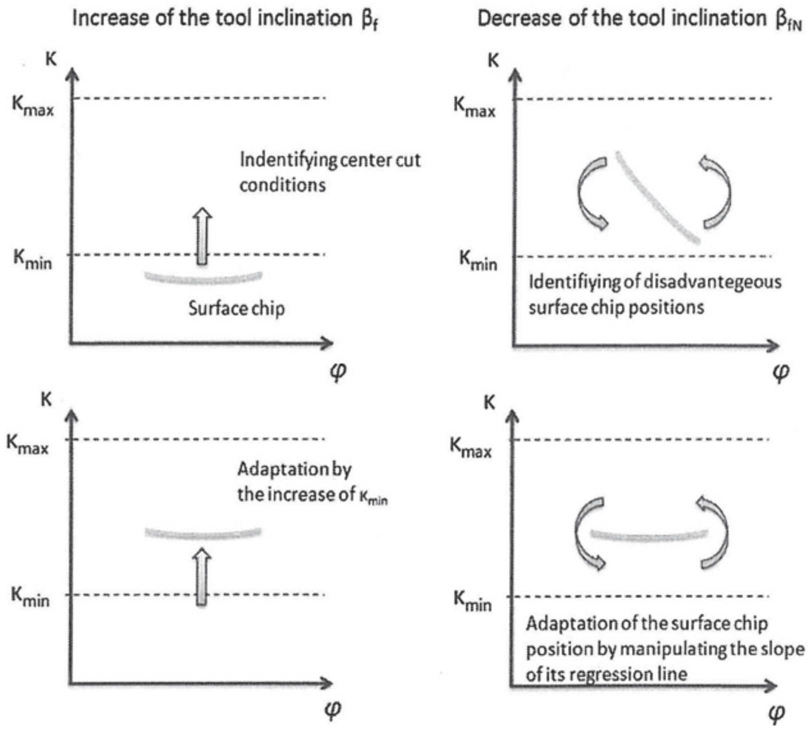

Fig2. The φ angle dependence to Kmax, Kmin.

Cutting speed is also of a great importance. In faster speed, need more control by the software and in low speeds, the probability of tools fracture is more [3,4].

2.2. Machinability

Niti, the main group of memorizing capability alloys, have a high flexibility and suitable strength against creep, fracture and good resistance to wearing which lead to their vast applications. The flexibility of Nitinol before fractur is 50% strain, but strain hardening and unusual piezoelectricity toughness and high adhesion and its machining has become more difficult and new methods like laser machining and electric discharge machining (EDM) are used. The scans reveal different placement angles independent from heat treatment, and heat change phase and cooling down, and according to DSC test , it is found that in this operation, the undeformability of the work piece is trustworthy.

3. MACHINING ANALYSIS BASED ON NETWORKED CHIPPING

With optimization algorithm and tool compatibility with the simulated mode, the interaction of tool and materials get intelligently optimized. The NC Chip software is used for simulation and the needed accordance regarding the network and thickness, and the drafting of the cutting edge is demonstrated and provides a scale. Micro single-edge drill with 0.5mm diameter is analyzed and the geometrical conditions from the milling cutting edge are depicted from different angles. This situation and software simulation depict the different chipping conditions and drilling from different angles that are according to the figure, wear surface cutting direction, slop condition, and work piece thickness.

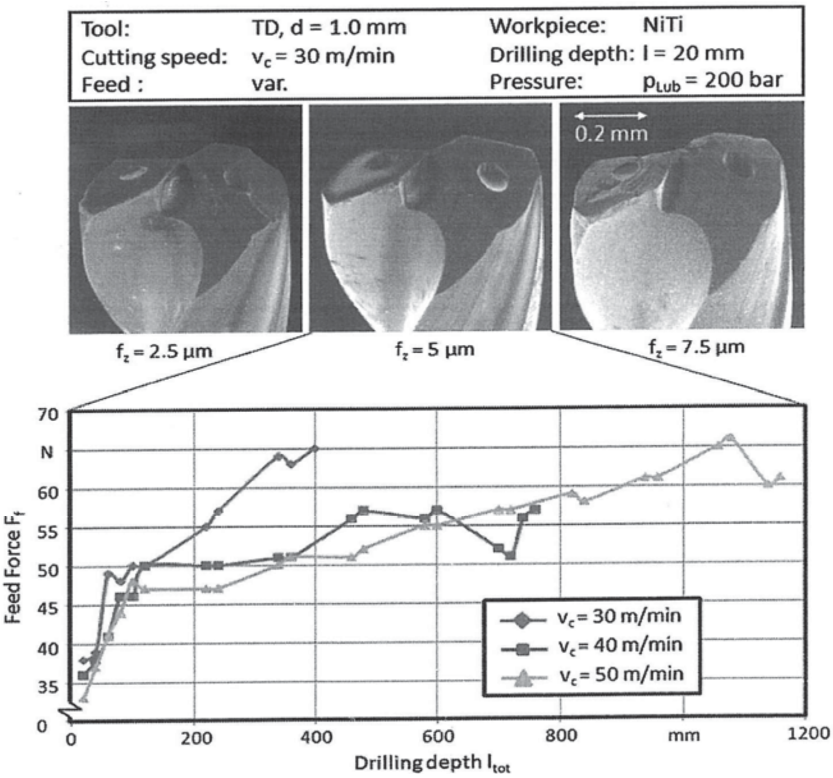

Fig 3. In vivo assessment of drills with SEM and the force effect on drilling depth.

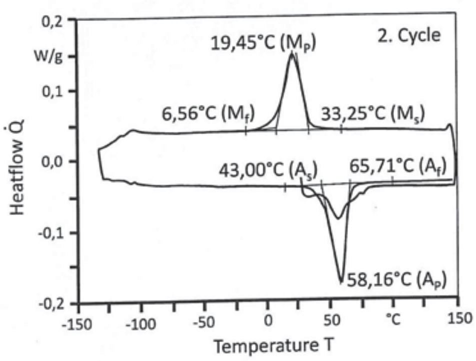

Fig4. The undeformability of Nitinol

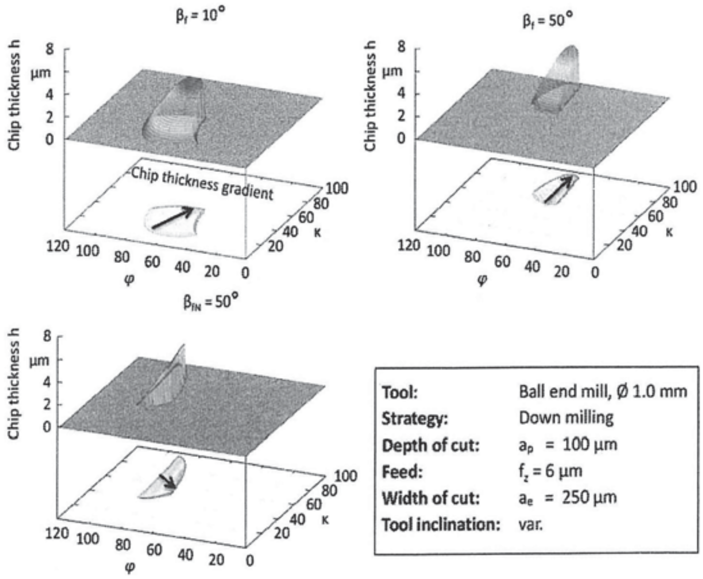

Fig 5. Geometrical condition of milling cutting edge from different angles [3,4].

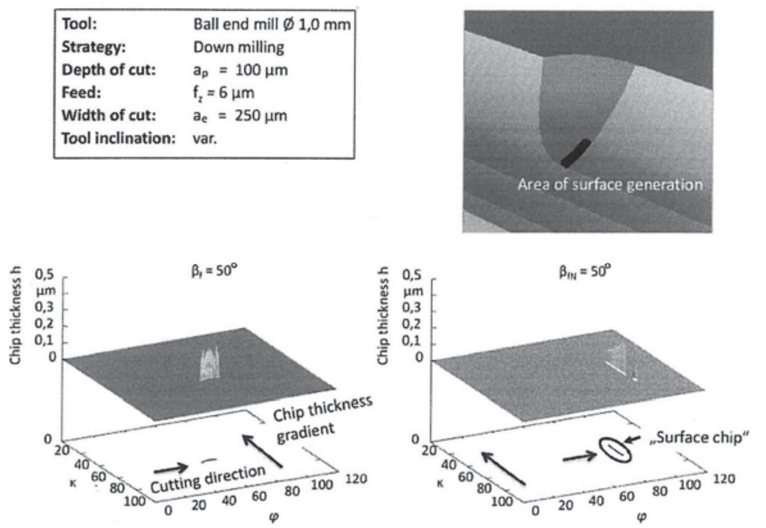

Fig 6. Different drilling states from different angles based on the wear surface, cutting direction, slop condition and work piece thickness.

4. CONTROL SYSTEM

Fuzzy logic has various applications in different fields where in no obvious mathematical modeling of accurate machining system is provided for the given problem. Its great application is also due to nonlinear variable while processing. Machining control fuzzy technique give some commands to the machine such as "decrease the feed speed, if the cutting speed is low and the cooling fluid is too much" and it causes the decision made by the machine to be more comparative. These comparative inputs are considered as a suitable solution because they aren't easy to be formulated. Based on the fuzzy logic flexibility, its application in machining nonlinear operations seems ideal. Machining parameters in controlling fuzzy logic are classified into input and output classes and Fuzzy Tech software does the control task. System structure indentifies fuzzy logic influential current from the input variables to the output ones. Fuzzy modeling in the intermediate input translates the analogue inputs into the fuzzy values. Fuzzy intermediate occurs in the rule blocks which contain the lingual controlling rules. The outputs of these rule blocks are the lingual variables. The non fuzzy modeling task in the output intermediate changes them into analogue values.

Lingual variables for input, output, and meddle variables should be defined. Membership functions are just defined by some given points. In the following tables, all the lingual variables of the system and their related phrases are listed:

Table 1. Lingual variables

Phrase	Parameter
Low,Average,High	Cold condition
Low,Average,High	Pressure
Low,Average,High	Tool diameter
Low,Average,High	Hole diameter
Low,Average,High	Tool type
Low,Average,High	Alloy type
Low,Average,High	Force
Low,Average,High	Depth
Low,Average,High	Cutting speed
Low,Average,High	Feed speed
Low,Average,High	Spindel speed
Low,Average,High	Head drill angle
Very low,Low,Average,High,very high	Feed rate
Very low,Low,Average,High,very high	Spindel rpm

Table 2. Basic variables

Unit	Value	Max	Min	Parameter
Q	50	100	0	Cold condition
mpa	300	450	150	Pressure
mm	15.5	30	1	Tool diameter
mm	15.5	30	1	Hole diameter
--	50	60	40	Tool type
--	50	60	40	Alloy type
N	235	420	50	Force
mm	1.625	3	0.25	Depth
m/min	35	50	20	Cutting speed
m/min	1.625	3	0.25	Feed speed
rpm	3010	6000	20	Spindel speed
degree	105	120	90	Head drill angle
m/min	50	100	0	Feed rate
rpm	3100	6000	200	Spindel rpm

Table 3. Meddle variables

Phrase	Type	Parameter
MBF	input	Cold condition
MBF	input	Pressure
MBF	input	Tool diameter
MBF	input	Hole diameter
MBF	input	Tool type
MBF	input	Alloy type
MBF	input	Force
MBF	input	Depth
MBF	input	Cutting speed
MBF	input	Feed speed
MBF	input	Spindel speed
MBF	input	Head drill angle
COM	output	Feed rate
COM	output	Spindel rpm

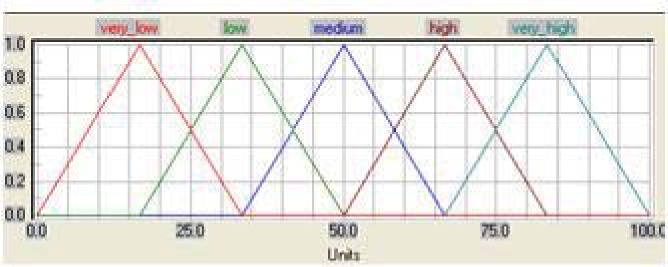

Fig 7. MBF feeding rate

Table 4. The given points of MBF feeding rate

Points (x,y)			Type	Phrase
(33.334, 0)	(16.666, 1)	(0, 0) (100, 0)	Linear	Very low
(33.334, 1)	(16.666, 0) (100, 0)	(0, 0) (50, 0)	Linear	low
(50, 1)	(33.334, 0) (100, 0)	(0, 0) (66.666, 0)	Linear	Average
(66.666, 1)	(50, 0) (100, 0)	(0, 0) (83.334, 0)	Linear	High
(83.334, 1)	(66.666, 0)	(0, 0) (100, 0)	Linear	Very high

The output variable of spindle rpm:

Table 5. The given points of MBF spindle rpm

Points (x,y)			Type	Phrase
(2133.3, 0)	(1166.7, 1)	(200, 0) (6000, 0)	Linear	Very low
(2133.3, 1)	(1166.7, 0) (6000, 0)	(200, 0) (3100, 0)	Linear	low
(3100, 1)	(2133.3, 0) (6000, 0)	(200, 0) (4066.7, 0)	Linear	Average
(4066.7, 1)	(3100, 0) (6000, 0)	(200, 0) (5033.3, 0)	Linear	High
(5033.3, 1)	(4066.7, 0)	(200, 0) (6000, 0)	Linear	Very high

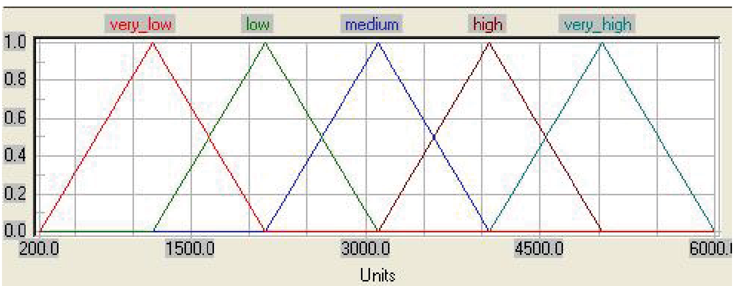

Fig 8. MBF spindle rpm

4.1. Rule blocks

Rule blocks contain the controlling strategies of fuzzy logic systems. Each rule block holds all the rules related to a similar filed. Each field is defined by input and output variables similar to the rules. The degree of support (DOS) is used for weighting the rules based on their level of importance. Rule processes starts with calculating the "if" part. The operand kind of the rule block defines the methods used.

The fuzzy combination finally combines various rules together and at last, one conclusion is obtained.

5. CONCLUSION

In this study the control with fuzzy logic was designed and applied. The designed fuzzy controller has 14 and 2 inputs and outputs, respectively, which the lubricant is also considered. The limitations of all parameters are defined, too. The results have a suitable accordance with the experiments. The final experiment results define the designed system with the controllability and measuring the drilling process with small diameters.

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