Journal of Modern Processes in Manufacturing and Production, Volume 9, No. 2, Spring 2020

The Milling of Metalsthrough Adaptive Neuro-FuzzyInference System (ANFIS) for non-touch Measuring of the Temperature to Reduce Coolant

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Received: March 16, 2020; Accepted: May 23, 2020

Abstract
In this paper, an innovated method is used for cooling Milling zone of Stainless Steel via Adaptive Neuro-Fuzzy Inference System (ANFIS) using non-touch laser thermometer for non-touch measuring of the temperature. This method is economically appropriate because of its optimization in using coolant. In comparison to the ways which were designed to optimize the ratio of coolant, this method is the best due to its intelligent, fast and trained system via ANFIS .In this method, not only the designing of the ANFIS and using the non-touch laser thermometer makes the cooling process fast but also the accuracy of the system is improved in comparison to the previous designs according to the results in different statistics criteria including MSE, NMSE, R2 and MAPE, which were calculated.

Key words
Milling of Stainless Steel, Cooling System, ANFIS, Optimization

1. Introduction
Heisel (1998) used water for the first time to cool grinding operations; a significant increase on tool life was experienced. From that time, a large variety of coolant fluids have been used for this purpose [1-6]. Oil-based fluids can be emulsified in water (containing 1 to 20% of oil) or used pure, without any water addition. Using pure oil, mainly because of its lubricating properties, has been a very common procedure. Pure oil better lubricates which drastically reduces the heat due to friction at interfaces and helps to produce better finishing surface. Additionally, grinding force is also reduced, leading to less power consumption for the whole grinding process [7-10]. This is also one of the main reasons for the use of grinding fluids with lubricating capacity. Furthermore, extreme pressure additives can be applied in order to reduce the possibilities of adhesion at toolchip interface. Forces and power consumption in low speed machining processes,such as grinding, broaching and tapping are the most influenced by the lubricating properties of the grinding of fluid. For these kinds of processes, the temperature at the chip formation zone is relatively low and lubricating properties become more significant. Lower power consumption corresponds to a good lubrication fluid and it is usually the first choice in industry.In contrast, high speed machining processes, such as turning and grinding, produces high temperatures at chip tool interface, which makes the cooling properties more important for a grinding fluid [11-17]. Recently, minimizing the use of grinding fluid has become a very important issue. Two techniques have been intensively

tested: dry grinding, also known as ecological machining, and grinding with a Minimum Quantity of Lubricant (MQL), where a very low amount of fluid is used.The MQL name is given to the process of pulverizing a very small amount of oil (less than 30 ml/h) in a flow of compressed air [38-45]. Some good results, in terms of tools life, have been obtained with this technique. Braga, et. al. used this technique on grinding. The authors concluded that MQL could reduce the temperature on the chip formation zone, maintaining it at levels low enough to avoid tool material deterioration [46-51]. Similarly, tapping often uses grinding fluids and it is believed to benefit the process in many ways, such as force and temperature reduction and also in improving thread quality. In addition, the application system may significantly affect the temperature at the grinding zone. Tests to define the temperature values and of the heat flow in grinding and tapping processes have been carried out with several methodologies. The use of pyrometer is simple and has a good accuracy to define temperature and heat flow together with analytical mathematical models.An innovated method based on using fuzzy logic and infrared pyrometer sensor for cooling of a grinding were designed by M.Hajian and partners. However, the design was so reasonable due to the usage of fuzzy logic but also in pure fuzzy logic design, the fuzzy sets were chosen by the designer. In this article, an intelligent system was designed via ANFIS for cooling the Milling of Stainless Steel which automatically would choose the fuzzy sets and rules. As a result, the accuracy and the speed of cooling system was increased drastically. A method based on using ANFIS for cooling for the “Pride “crankshaft grinding was designed [18-21].

2. The Structure of Gaining Experimental Data of Milling of Stainless Steel

Coolant is necessary to decrease the friction between the work piece and the tool. The type of the coolant, which is mostly mixture of water and soft soap for ordinary steels.To train and design the Adaptive Neuro-Fuzzy Inference System (ANFIS) for cooling the Milling of Stainless Steel using non-touch laser thermometer, experimental reliable andaccurate data of the temperature and its current flow rate of coolant was needed.

Figure1. The schematic view of the Stainless Steel work piece

Figure2. The schematic view of the machined work piece

Second, the work piece was grinded by the crankshaft grinding machine in a regular process in which the diameter of the piece was decreased for 5mm in several passes, each pass 0.4mm. During the milling of Stainless Steel, the temperature and the flow rate of coolant were measured using a non-touch laser thermometer in three different specific points in the milling zone (Figure 3), which makes the experimental data extremely reliable and accurate.

Figure3. The schematic view of a non-touch laser thermometer

To measure the flow rate of the coolant in the milling of stainless steel, a circular plate was designed, divided to 32 parts, each part 5.625degree equals 0.03 liter per seconds of coolant, and installed on the coolant valve to measure the ratio of the coolant flow in accuracy of 10^{-3} (Figure 4).

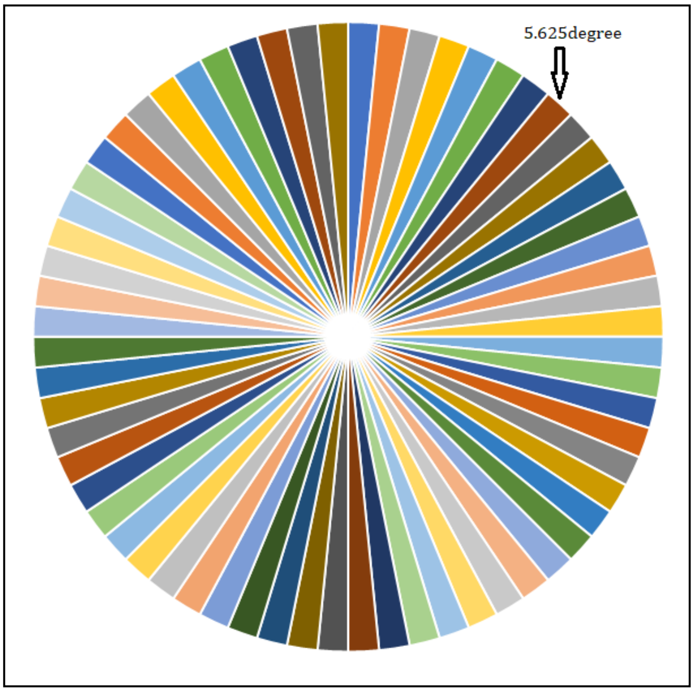

Figure4. The divided plate as a gage to measure the flow rate of coolant

The measured experimental data of temperature-flow rate of coolant are shown in Table1.

3. ANFIS for Cooling the Milling Zone of Stainless Steel using the Experimental Data

Adaptive Neuro-Fuzzy Inference System is using both Artificial Networks and Fuzzy logic in which it would capable ANFIS to be extremely fruitful for designing the controlling systems. In addition, ANFIS has the super practical attenable properties such as: generalization, trainability, robustness, and optimization.

In this study,ANFIS was trained using the experimental data of temperature-flow rate of coolant which was capable of intelligently infer If-Then fuzzy rules according to 2 inputs (temperature and flow rate of coolant) and eventually, defuzzicate the output(increasing or decreasing amount of coolant).

To design the best ANFIS by making comparison, 6different ANFIS were trained and designed, for intelligently cooling the crankshaft the stainless-steel milling zone, in Matlab software:

1-ANFIS using 3 fuzzy sets for each input (M3)

2-ANFIS using 4 fuzzy sets for each input (M4)

3-ANFIS using 5 fuzzy sets for each input (M5)

4-ANFIS using 6 fuzzy sets for each input (M6)

5-ANFIS using 7 fuzzy sets for each input (M7)

6-ANFIS using 8 fuzzy sets for each input (M8)

By the way, the inputs are temperature and the current flow rate of the coolant and the output is the increasing or decreasing amount of the flow rate of coolant.

The trained and designed ANFIS using 5 fuzzy sets is shown in Figures 5 and 6, for instance.

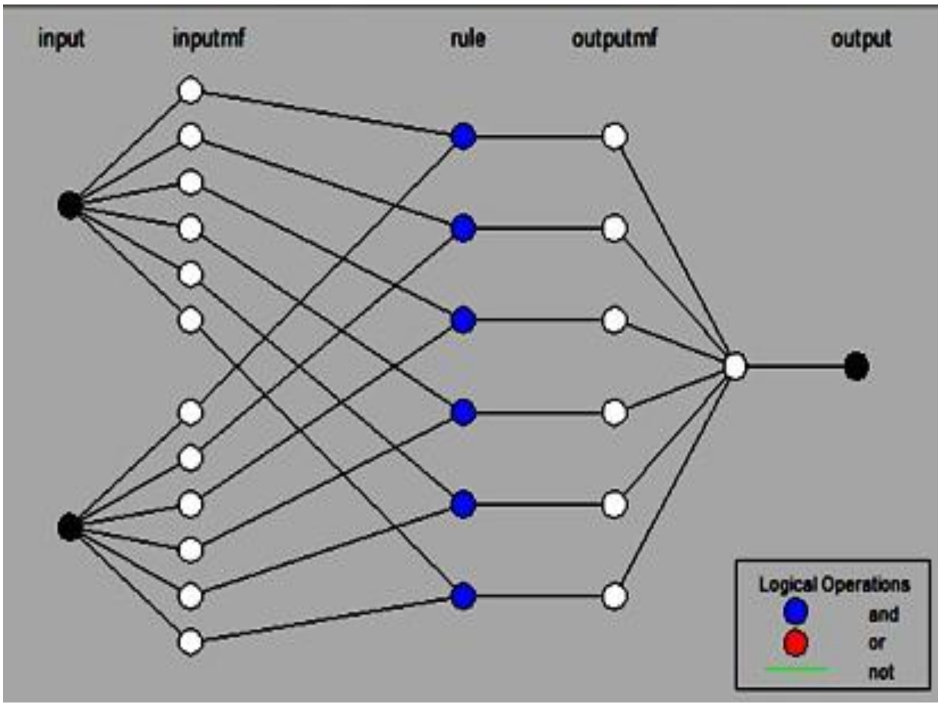

Figure5. The structure of ANFIS using6fuzzy sets designed inMatlab software

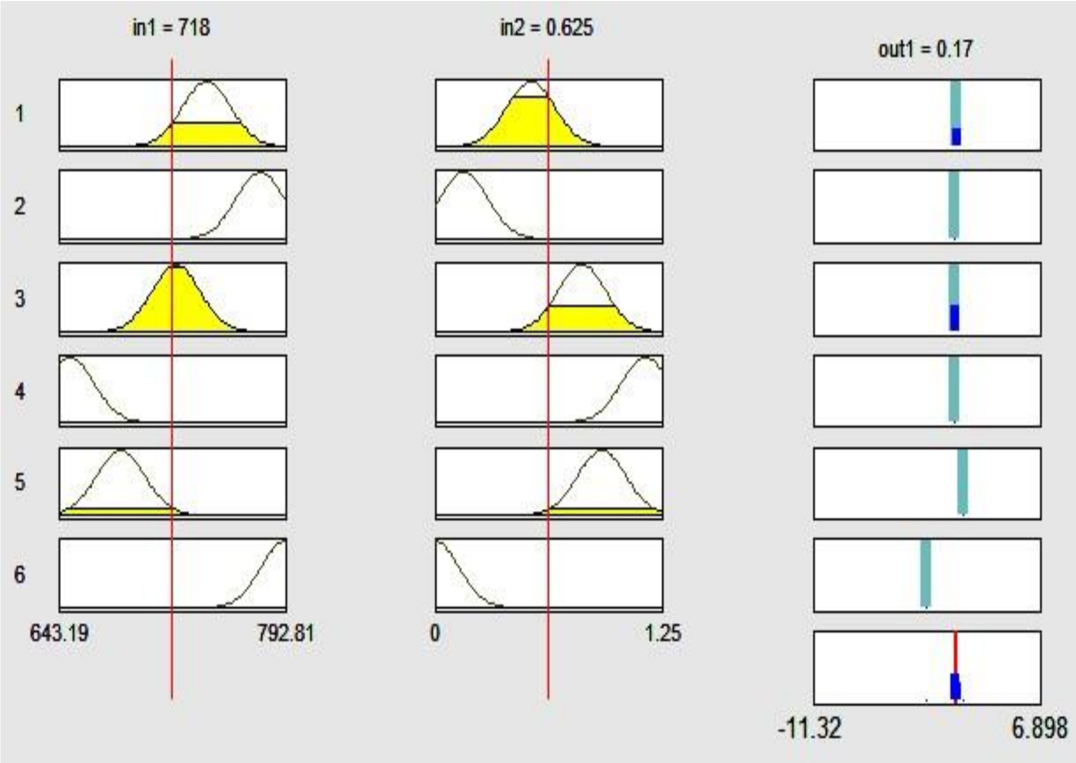

Figure 6. The inferred rules by the ANFIS using6fuzzy sets designed in Matlab software

Finally, the designed ANFISs were compared calculating different statistics criteria including MSE, NMSE, R2 and MAPE (Table 2 and Figure 7).

Table2. The result of comparing different ANFISs according to statistics criteria

MAPE	R^2	NMSE	MSE	Model of ANFIS
3.82	0.869	0.132	0.014	M3
4.35	0.837	0.164	0.015	M4
3.29	0.801	0.084	0.019	M5
3.20	0.916	0.024	0.013	M6*
4.62	0.813	0.173	0.016	M7
3.73	0.824	0.183	0.017	M8

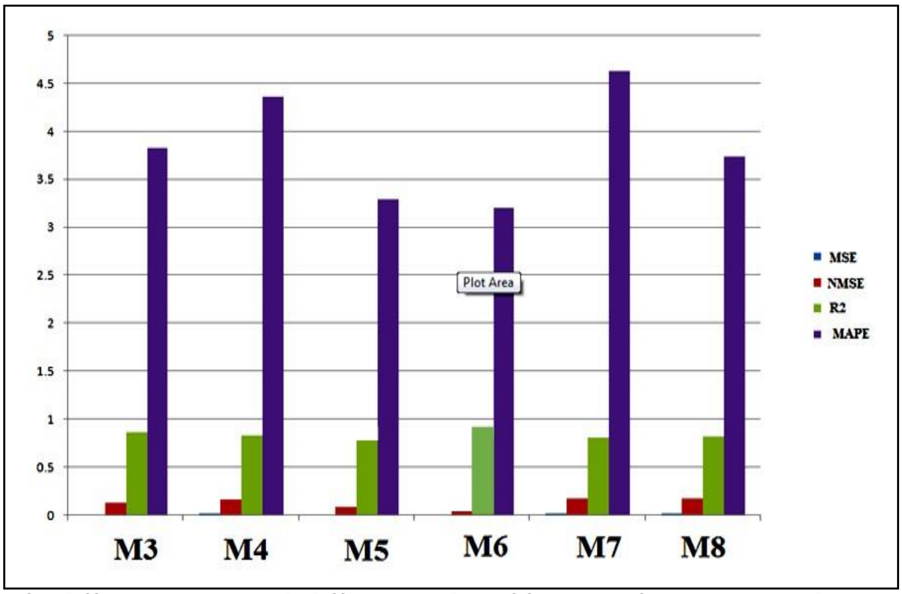

Figure7. Diagram for different ANFISs with different number of fuzzy sets for2inputs according to statistics criteria

As a result, it was shown the best ANFIS for cooling the stainless-steel milling zone is the one using 6 fuzzy sets for each input.

4. Conclusion

In this article, an innovated method for cooling the cooling the stainless-steel milling zone via ANFIS using a laser thermometer was presented. Different ANFISs were designed by 3, 4, 5, 6, 7, 8 fuzzy sets, however, it was reached that the best one was ANFIS using 6 fuzzy sets. In this case, not only the cooling of crankshaft grinding process is intelligent and faster but also it is more accurate in comparison to the previous designed systems.

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