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Research article

Finite Element Method Analysis in Simulation of Induction Heater Using Helical Coil Method

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A B S T R A C T

The problem of corrosion is very common in aircraft structures. This phenomenon happens because the two different types of material are in contact under moisture or water. During the operational hours of the aircraft structure, this corrosion is identified during the maintenance activity. To study the corrosion removal using the helical coil method, the simulation of the corrosion removal in bolt and nut joints is conducted in this research. The aim of the analysis, i.e., to get the optimum electric current and frequency for induction heaters to heat stainless steel nuts that cannot be opened or the threads are stuck. The study was carried out so that the stainless-steel nuts reached a temperature of 400°C in one minute. Several variations of the electric current are carried out with magnitudes, namely 30 A, 40 A, and 50 A, and frequency variations of 300 kHz, 400 kHz, and 500 kHz. Based on the electric current and frequency variation, the optimal electric current and frequency are generated to heat a stainless-steel nut that cannot be opened or the screw is stuck at 50 A and 500 kHz with a temperature of 394°C in one minute.

1. INTRODUCTION

Fasteners are widely used in aircraft to join one of the components/skin to others. Common fasteners are used in aircraft, for example, bolts, nuts, washers, rivets, and screws. Bolt and nut components are connection components to join aircraft parts that are easily disassembled and reassembled. This type of fastener is widely used because these components are relatively safer when replacing, repairing, or maintaining [1]. Stainless Steel is a type of steel material that is resistant to the effects of rust or oxidation. According to a report from the FAA, almost all parts of the aircraft use stainless steel material, including fastener components. This material is widely used in aircraft nuts because it does not require coating or coating as an anti-rust [2]. Fasteners in Nomad N22 aircraft are one of the examples of fasteners used in aircraft, as shown.

Figure 1. Fastener in Nomad N22, Politeknik Negeri Bandung

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Induction heating is a device with a heating system that uses the principle of magnetic field induction. This tool can generate heat due to eddy or central currents whose circular direction contains a magnetic field penetrating the object. An induction heating process in which the heated workpiece is placed in the middle of a spiral coil is called induction heating with the helical coil method. This heating method is not in contact with the heater, but what is used as a heat-producing medium is the magnetic field wave generated from the coil [3]. In fasteners, it is common for threads to get stuck and cause components to lock together so that the connection cannot be removed, especially for bolts and nuts. This is due, among other things, to the occurrence of an electrochemical reaction that causes the creation of corrosion in the threaded part of the component so that the movement of the component is locked.

The method for overcoming stainless steel nut threads that are locked or cannot be opened is by using heating. The nut heating method often used in MRO is using a heat gun. A heat gun is a heating tool to open fasteners with hot air produced. These heaters usually use two temperature modes: up to a maximum temperature of 400°C and 600°C. However, the hot air generated may not be focused on the nuts but on the surrounding components [4].

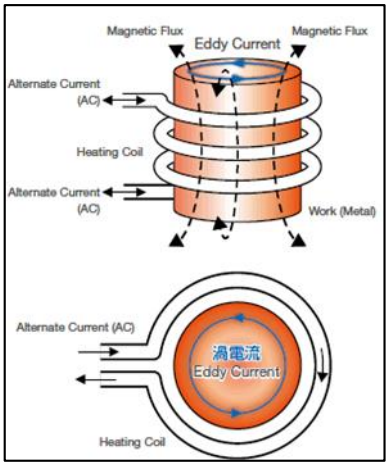

Figure 2. Induction heat principle [5]

Due to some electromagnetic phenomena, the current distribution in the coil and the workpiece is not uniform. The non-uniformity of this heat source causes the workpiece temperature profile to be non-uniform, which is caused by several factors, namely the skin effect, the proximity effect, and the ring effect. This effect plays an important role in understanding the phenomenon of induction heating [5]. Figure 2 shows the illustration of the induction heat principle. The figure shows that alternate current (AC) passes through to the heating coil so that an eddy produces current magnetic flux. The example of the helical coil is shown in Figure 3.

Figure 3. Helical Coil [3]

2. METHODOLOGY

In this research, the process of obtaining an analysis of the helical coil method to loosen the corrosion nut /bolt using the finite element method is shown in Figure 4.

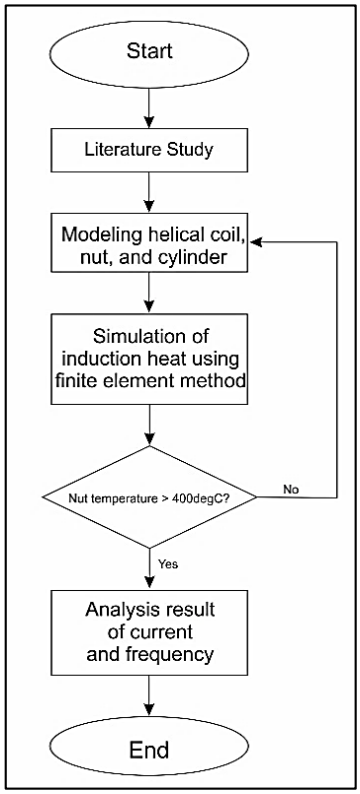

Figure 4. Research methodology flow chart

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2.1. Related Works

The method for overcoming stainless steel nut threads that are locked or cannot be opened is by using heating. The nut heating method often used in the Maintenance, Repair, and Overhaul of aircraft (MRO) is using a heat gun. A heat gun is a heating tool to open fasteners with hot air produced. These heaters usually use two temperature modes: up to a maximum temperature of 400°C and 600°C. However, the hot air generated may not be focused on the nuts but on the surrounding components.

2.2. Problem Definition

The current in calculating the eddy current loss and converting this heat loss in a certain time is a complicated or complex problem. Problems like this are often called multiphysics problems because they contain electromagnetic and thermal studies. Computer simulation techniques are needed to get the desired current, frequency, and time to increase the temperature of the stainless-steel nut. One of the numerical techniques used to study electromagnetic problems is the finite element method. Therefore, in this research, the study of induction heaters with the helical coil method using the finite element method was conducted, where the purpose of this research is to obtain optimal electric current and frequency on induction heaters to heat a stainless-steel nut whose screw is stuck to a temperature up to by 400°C in one minute.

2.3. Method

As shown in Figure 4, the methodology of the research starts with the literature study for the scope of the technology to loosen the nut by using a helical coil and other methods. Followed by collecting material data of nuts in the aircraft structure, i.e., Nomad N22 Politeknik Negeri Bandung and helical coil data. Modeling nuts and helical coils by using Solid Works is the next step in this research.
As a result of the modeling, the simulation was run by using the finite element concept, i.e., Solid Works. The final purpose of the research is to obtain the current and frequencies to the optimum values when the heating temperature is 400°C.

3. RESULT AND ANALYSIS

The analysis of the induction by using the helical coil method is conducted by variating the temperature and time. Figure 5 shows the variation of the frequencies (300 kHz, 400 kHz, and 500 kHz) and current value, i.e., 30 A, 40 A, and 50 A, as a function of time and temperature.

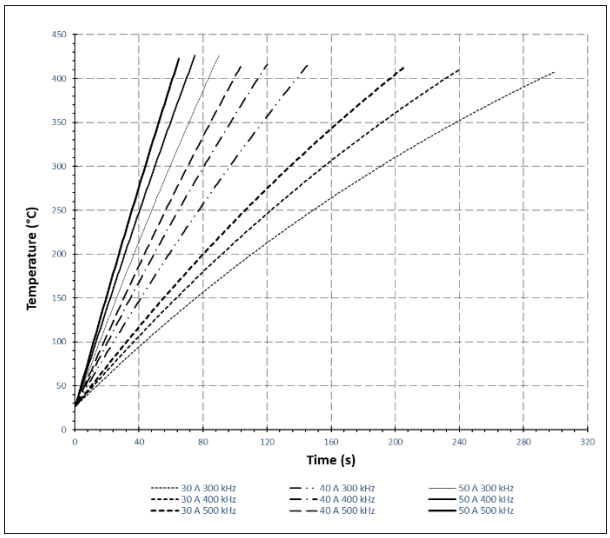

Figure 5. The variation of frequencies and current value as a function of time and temperature

In Figure 5, it is shown that to reach the temperature to the value 400°C, the current value of 30 A needs a time of more than 200 seconds. Meanwhile, for the current value of 50 A, it needs time for about 60 seconds. Increasing the current value makes the heat induction faster to reach 400°C temperature.

The variation of the frequencies, as shown in Figure 5, also affected the time of the induction heat process to reach 400°C temperature. The higher the frequencies, the time to reach 400°C temperature also increases.

In Table 1, it can be shown that for the induction heat process in 60 seconds, the temperature reach is variated and affected by current values and frequencies. It also shows that the increase of the frequencies will also increase the reach of the temperature.

The effect of the current value is also shown in Table 1 that the increase of the current value

significantly increases the temperature. For the current value of 50 A and the frequencies of 500 kHz, in 60 seconds, the temperature reaches 394ºC. Meanwhile, for the current value of 30 A and the frequencies of 500 kHz, in 60 seconds, the temperature only reaches 159.3ºC.

Table 1. Simulation of induction heat by using a helical coil in the variation of frequencies and current value in 60 second

Current Value (A)	Frequency (kHz)	Temperature (ºC)
30	300	126.2
	400	143.9
	500	159.3
40	300	203.2
	400	234.7
	500	262
50	300	302.1
	400	351.4
	500	394

4. CONCLUSION

The study of the effect of current values and frequencies was conducted in this research. The optimum current value and frequencies studied in these results are 50 A and 500 kHz to reach the temperature 400ºC in 60 seconds. Future research will be continued by manufacturing the helical coil induction and experimenting with the variation of current values and frequencies.

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NOMENCLATURE

I	electrical current, A
N	number of coil, n
Hz	frequency, hertz

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