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Impacts of the structure and processing conditions on the voltage arise in machining of gray cast irons

A. Yardimeden [a,*], A. Īnan [b], M. Aksoy [c]
[a] Department of Mechanical Engineering, Dicle University, 21280 Diyarbakir, Turkey
[b] Department of Mechanical Engineering, Faculty of Engineering, University of Fīrat, Elazig 23119, Turkey
[c] Department of Metallurgical Engineering, Faculty of Engineering, University of Fīrat, Elazig 23119, Turkey
* Corresponding author: E-mail address: ayardim@dicle.edu.tr

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Manufacturing and processing

ABSTRACT

Purpose: Machining is one of the most widely used manufacturing processes. The machining of gray cast iron is important because of wide application of these materials in various industries. The machinability studies have been carried out for these materials and it was reported that the amount of graphite in cast irons was one of the influential factor in tool wear during machining. This study is aimed to provide new approach to examine tool life by considering voltage arise during machining of gray cast irons.
Design/methodology/approach: The experimental study carried out to measure voltage values during various machining conditions such as cutting speeds, feed rates and depth of cut. Chemical compositions of the four different gray cast irons were machined and the experimental results were compared to the machining of brass and steel. The selected machining conditions were 0.16, 0.32 and 0.48 mm feed rates, 0.5, 1 and 1.5 mm depths of cut and 125, 250 and 355 rpm spindle speeds, respectively.
Findings: It was observed that the voltage difference was detected during the machining of cast iron specimens. This was due to increase of graphite particles within total intersections. This would lead to conclusion that high graphite particles would increase voltage and this would provide information about tool wear.
Research limitations/implications: Because of being cheap, the usage of cast iron with lamella graphite particles in specific electric circuits to be used in industrial applications need to be further investigated. Also whether or not the cost iron with lamella graphite particles can be used as voltage storage under intensive stress needs to be investigated.
Originality/value: Impacts of the structure and processing conditions on the voltage arise in machining of gray cast irons.
Keywords: Machining; Cast iron; Voltage difference

1. Introduction

The expenses for removing material from a workpiece during machining operations, reach more than US$ 100 billion, yearly in USA. Only four machining processes which are turning, drilling, milling and grinding are responsible for 75% of this value. Therefore the machinability of engineering materials feature an important issue when economic aspects are to be optimized [1].

Machinability can be improved with the proper choices of machining parameters such as depth of cut, feed, cutting speed, cutting fluid, tool insert geometry and tool material or through workpiece material adjustments. Developments in manufacturing involve two aspects: technical and economic aspects. Technical aspects are the possibility of producing a part according to restrictive specifications, the easiness of chip removing and the better performance of chip formation mechanism, etc. The economic improvements can be associated to low wear for the tool, small cutting forces and low energy consumption. This combination can lead to shorter machining times and lower cost per part [1].

Gray cast iron is one of most widely used engineering materials in cast alloys in the world. Low tensile strength, especially low ductility caused by the thick graphite flakes with random orientation has limited its application for many years. Many methods to control the morphology, size and distribution of graphite phase were used to improve the mechanical properties of GCI, such as modification, spheroidising and alloying, etc. [2–6].

Gray cast iron is a ferrous casting alloy, normally characterised by a microstructure of flake graphite in a ferrous matrix. It is essentially a Fe–C–Si alloy containing small quantities of other alloying elements, and the most widely used casting alloy [7, 8].

The microstructure of gray iron usually consists of flake graphite and a matrix of pearlite and/or ferrite, which its mechanical properties, machining performance, etc. mainly depend on. Conventional gray irons have a pearlite matrix and a tensile strength ranging from 140 to 400MPa. The principal means of improving the mechanical properties is to decrease the carbon equivalent, which reduces the percentage of graphite and increases that of pearlite [8].

A recent study has investigated the effect of temperature on the tool life used in brass, steel and cast iron machined on the lathe and the correlation to the voltage rise between the cutting tool and workpiece during machining. It was reported that the amount of graphite in cast irons was one of the influential factor in tool wear during machining [9].

In this study the voltage difference between the workpiece and the cutting tool was measured and analyzed. The correlation, which was recognized through this particular experiment, mediated between the detected voltage difference and workpiece structure, as well as the machining parameters mentioned above are investigated.

2. Experimental work

2.1. Preparation of workpieces

Beside of the brass (%79 Cu, %20 Zn and %1 Pb) and steel (Ç1020) workpieces, four different cast iron workpieces whose chemical compositions was given in Table 1 were prepared at casting workshop of the Middle East Technical University (METU), Metallurgy and Material Engineering Department. The dimension of workpieces were 50 mm x 500 mm (radius x length). The workpieces were then subject to a dry machining process that involved in 0.16, 0.32 and 0.48 mm/min feed rates (s) and 0.5, 1 and 1.5 mm depths of cut (t) for 2 minutes processing time at spindle speeds of 125, 250, 355 rpm (n). The temperature was kept at 1350 °C for all workpieces.

The voltage difference between the cutting tool and workpiece was measured and plotted in real time by a built in plotter. Later on, the pictures of localized fields of workpieces at certain distances from the center of the workpiece, which were considered to be helpful in explanation of the issue, were taken and presented here.

Table 1.
The chemical composition of the workpieces

Workpieces No	1	2	3	4
Elements	Element (%)			
Carbon (C)	2,86	2,52	2,52	3,203
Phosphorus (P)	0,0304	0,0331	0,0309	0,0281
Silicon (Si)	3,23	2,64	1,16	1,02
Sulphur (S)	0,0127	0,0154	0,0281	0,0059
Nickel (Ni)	0,0435	0,0593	1,64	1,61
Manganese (Mn)	0,599	1,13	0,543	0,839

2.2. Experimental set up

The set up used in this experiment is shown in Fig 1. Each workpiece was placed on the lathe with the electrically isolated ends to prevent induced current drift to the workbench. One of the leads of the plotter was fixed to the cutter and the other lead on the workpiece under test such that to continuously contact to the workpiece and move at the same rate as feed rate and direction of the cutting tool. The cutting tool was electrically insulated by using a piece of Teflon insulator. The voltage difference was then recorded in due course of machining for all individual workpieces.

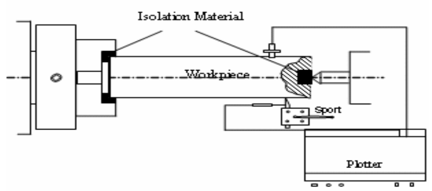


Fig. 1. The schematic representation of the set up

The cutting tool used in the experiment was a high speed steel (HSS) type with 12x12x160 mm^3 dimensions (C % 0.7, W % 0.18, Cr % 0.4-5, V % 1, Co % 5), and the tips of the cutter were prepared according to DIN768 standard. The distance between the tip of cutter and the sport was kept at 20 mm continuously. For each process the cutter tip was sharpened on the TOS–HOSTIVAR sharpening workbench.

3. Results

The workpieces used in the experiment were subject to a dry machining that involved in 0.16, 0.32 and 0.48 mm/min feed rates (s) and 0.5, 1 and 1.5 mm depths of cut (t) for 2 minutes processing time and at spindle speeds of 125, 250, 355 rpm (n), respectively. In due course of machining the voltage produced on each workpiece was recorded. The recorded voltage rates as a function of spindle speed versus both feed rates and depths of cut were respectively figured out for all workpieces used in the experiment. The extremes of voltages measured on all workpieces in response to the variation of machining parameters, s (feed rate, mm/rev) and t (depth of cut, mm) at different spindle speeds can roughly be summarized as follow:

- Steel with d=20mm: the lowest voltage was 3mV at 125 rpm for all s ant t values. The highest voltage was 5mV at 375 rpm for all s values and t=0.5 mm and 1 mm (Figure 3);

- Brass, with d=20 mm: the lowest voltage was 1mV at 125 rpm for s=0.16mm/rev, and for t=1 mm and 1.5 mm. The highest voltage was 5mV at 375 rpm but for s=0.32 and 0.48 (Figure 4);
- Cast iron (No.1 workpiece) with d=50 mm: the lowest voltage was 39 mV at 125 rpm for s=0.16 mm/rev and all t values. The highest voltage was about 55 mV at 375 rpm for almost all s and t values (Figure 6);
- Cast iron (No.2 workpiece) with d=50 mm: the lowest voltage was 25 mV at 125 rpm for s=0.16 mm/rev and t=1.5 mm. The highest voltage was 38 mV at 375 rpm for all s values and t=1 mm and 1.5 mm (Figure 7);
- Cast iron (No.3 workpiece) with d=50 mm: the lowest voltage was 30 mV at 125 rpm for s=0.16 mm/rev and t=0.5 mm. The highest voltage was 45 mV at 375 rpm for s=0.48 mm/rev and t=1.5 mm (Figure 8);
- Cast iron (No.4 workpiece) with d=50 mm: the lowest voltage was 28 mV at 125 rpm for s=0.16 mm/rev and t=1 mm and 1.5 mm. The highest voltage was 52 mV at 375 rpm for s=0.48 mm/rev and all t values (Figure 9);

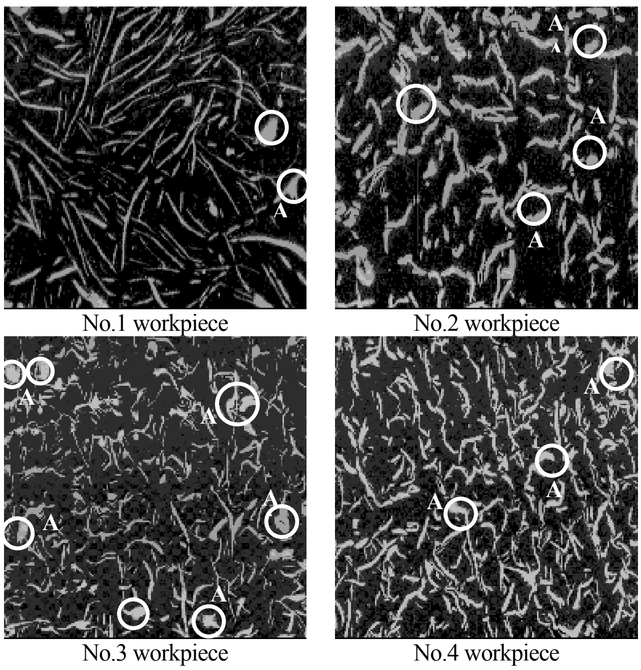


Fig. 2. Microstructure of cast irons

The voltage difference on the four cast iron workpieces corresponding different cut intersections and spindle speeds were also measured and exploited in Figure 5. In this case the voltage extremes were found to be as:

- Cast iron (No.1 workpiece): the lowest voltage was 33 mV at 125 rpm for d=20 mm. The highest voltage was 52 mV at 250 and 355 rpm for d=50 mm;
- Cast iron (No.2 workpiece): the lowest voltage was 17 mV at 125 rpm for d=20 mm. The highest voltage was 27 mV at 355 rpm for d=50 mm;
- Cast iron (No.3 workpiece): the lowest voltage was 23 mV at 125 rpm for d=20 mm. The highest voltage was 43 mV at 355 rpm for d=40 mm;
- Cast iron (No.4 workpiece): the lowest voltage was 15 mV at 125 rpm for d=20 mm. The highest voltage was 48 mV at 355 rpm for d=50 mm.

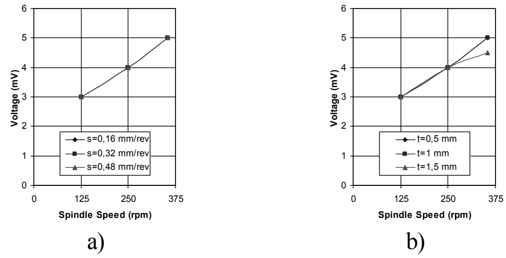


Fig. 3. The voltage variations recorded in response to the processing parameters, s, t and n (spindle speed rates) show for Steel with a) d=20 mm and t=0.5 mm b)s=0.16 mm and d=20 mm

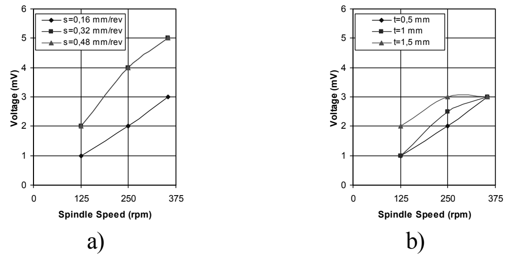


Fig. 4. The voltage variations recorded in response to the processing parameters, s, t and n (spindle speed rates) show for Brasswith a) d=20 mm and t=0.5 mm b)s=0.16 mm and d=20 mm

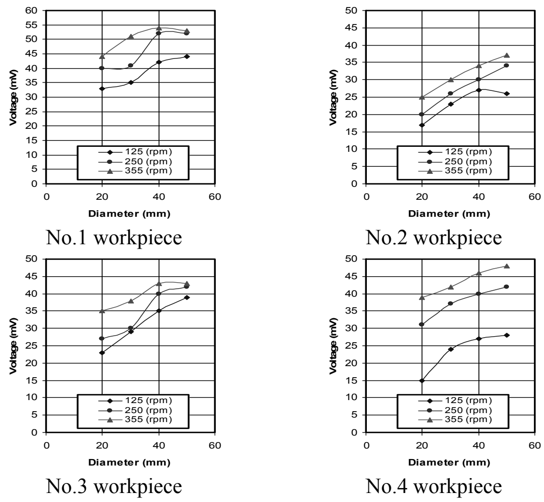
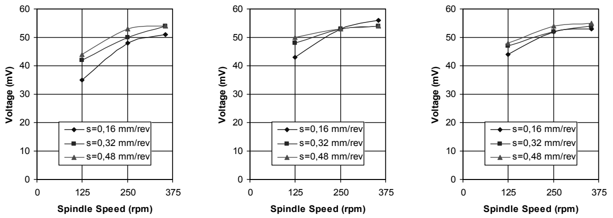


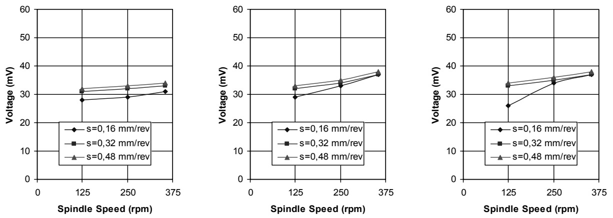
Fig. 5. The voltage variations recorded in response to the processing parameters, spindle speed and the diameter of the workpiece for the four workpieces at t=1.5 mm and s=0.16mm/rev

Furthermore to asses the impact of machining on the microstructure of cast iron workpieces, whose compositions are given in Table 1, the pictures of microstructure of the workpieces, after processing, were taken and are presented in Figure 2. The magnification rate in all pictures was 450X. As seen from the pictures



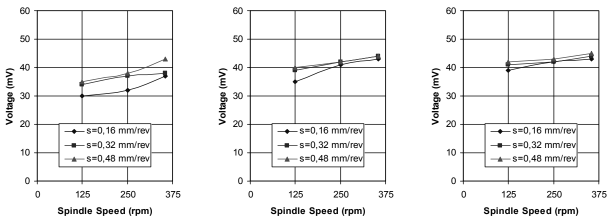
t=0.5mm t=1mm t=1.5mm

Fig. 6. The voltage variations recorded in response to the processing parameters, s, t and spindle speed rates for No.1 workpiece with d=50mm and t=0.5, 1 and 1.5 mm, respectively



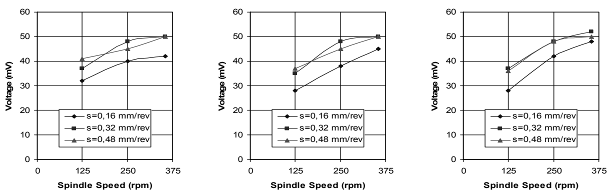
t=0.5mm t=1mm t=1.5mm

Fig. 7. The voltage variations recorded in response to the processing parameters, s, t and spindle speed rates for No.2 workpiece with d=50mm and t=0.5, 1 and 1.5 mm, respectively



t=0.5mm t=1mm t=1.5mm

Fig. 8. The voltage variations recorded in response to the processing parameters, s, t and spindle speed rates for No.3 workpiece with d=50mm and t=0.5, 1 and 1.5 mm, respectively



t=0.5mm t=1mm t=1.5mm

Fig. 9. The voltage variations recorded in response to the processing parameters, s, t and spindle speed rates for No.4 workpiece with d=50mm and t=0.5, 1 and 1.5 mm, respectively

the dimensions, distribution and condensation of the graphite particles have different characteristics. The reason that we have considered for this is the difference in the rates of carbon and differences in alloy elements comprised in the individual workpieces.

4. Conclusions

Based on the result obtained through this experiment the following may be concluded.

1. The cast iron with lamella graphite particles was found to produce voltage by piezo-electric effects.
2. The amount and dimensions of graphite particles as well as the strength of cutting force applied to the workpiece effect the level of the voltage produced. However further studies areneeded.
3. Because of being cheap, the usage of cast iron with lamella graphite particles in specific electric circuits to be used in industrial applications need to be further investigated. Also whether or not the cast iron with lamella graphite particles can be used as voltage storage under intensive stress needs to be investigated.

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