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Full Length Research Paper

Effect of welding parameters in flux core arc welding (FCAW) with conventional and pulsed current in the efficiency and fusion rate of melting coating

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This study was conducted over the welding parameters associated with three levels of pulse to lead to important data for the deposition of metal on martensitic stainless steel, through tubular electrode EC410NiMo MC – ESAB by the conventional and pulsed flux core arc welding (FCAW) process in SAE 1020 steel. Were applied three current levels, 170A, 200A e 230A with welding speed of 300 mm/s, 350 mm/s and 400 mm/s, respectively and distance torch tip-piece of 30, 33 and 36 mm to obtain the necessary cords for evaluation. The results showed that the main effect of welding parameters are: the increase in the welding speed and the amperage of the arc tend to increase the fusion rate when we pass from level +1 to -1, for the conventional current and reduced for the pulsed current when evaluating the level -A to +A. However, the efficiency decreases with the increase of welding speed for both processes: conventional and pulsed current, but increases with increasing amperage of the arc when evaluating the level -1 to +1 for conventional and - A to +A only for pulsed process. Also, we observe that the efficiency in both cases with conventional and pulsed current decreases as we increase the distance nozzle/piece. The spectra emitted by the accelerometer showed greater stability of the voltage and current process, but an important instability in the acceleration applied to the three current levels.

Key words: Fusion rate, accelerometer, tubular electrode, welding speed, pulsed flux core arc welding (FCAW).

INTRODUCTION

Fluxed cored arc welding (FCAW) is one of the current processes that have fundamental differences with the metal inert gas (MIG) process, for example, it offers more flexibility in the composition of the alloy, while also allowing higher deposition rates of wire and a greater arc stability, although the efficiency of the MIG process is normally higher as reported Shoeb et al. (2013). Welding with flux cored wire (FCAW) is a process where fusion is

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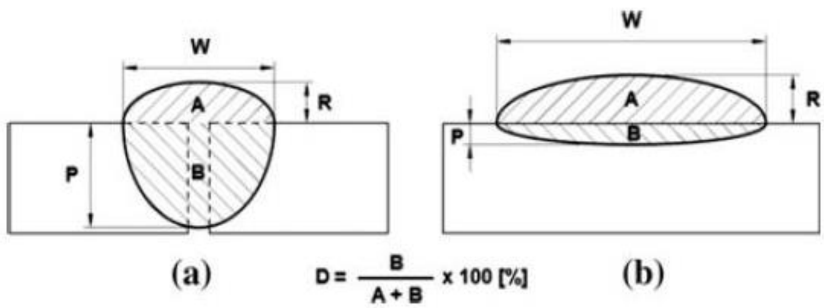

Figure 1. Desired weld bead geometry: (a) union joint (typical applications) and (b) cladding as shown in Gomes (2012).

produced by the action of an electric arc established between the work piece and the consumable wire continuously fed. The protection of the deposited metal and the weld pool are given by the decomposition of the internal flow of consumable wire, and can be further aided by a shielding gas, usually CO_2. For stainless steels, the use of argon mixture with 2% oxygen was recommended which has a slightly oxidizing behavior.

The internal flow of the wire is composed of a mixture of several minerals and organic substances with defined functions as reported by Bracarense et al. (2012). Consumables commonly use in this welding process are usually manufactured with a diameter between 1.0 and 3.2 mm and the geometric cross-sectional configuration can simply be a tube or more complex configurations/metal flow in its cross section (Figure 1).

With the advancement of new technologies, especially electronic sources to manufacture the welding arc, made possible the use of pulsed current for welding processes MIG/MAG, TIG and Flux Cored. Recent studies show that pulsed current can easily weld in all positions and to obtain higher deposition rate when compared to conventional current second (Mohamat et al., 2012).

Another important factor is the use of an average low current welding current used compared to the same conditions with a conventional source, providing less distortion in the pieces. It has been observed that the use of pulsed current provides a reduction in the amount of fumes and spatter by controlling the welding parameters during crude refining and solidification structure of the weld, allowing the decrease of solidification cracks.

When using pulsed current, there are many factors responsible for maintenance of the welding operation. In this sense, it becomes quite complex task of selecting appropriate to the needs of the electric arc welding parameters, the economic advantages, the weld quality and mechanical properties (Sathiya et al., 2012).

Generally, the electrical parameters involved in welding with pulsed current are defined by the peak current (I_p), the base current (I_b), the peak time (t_p), time base (t_b), and the feed speed the wire, welding speed and welding voltage.

The welding coating is employed not only in the recovery of pieces of worn equipment, but also in the manufacture of new products and industrial processes. In welding, the coating on the main aim is to get a welding bead at the lowest possible dilution yielding the morphology of the bead low penetration and the largest possible increase in width for better process efficiency.

Among the materials commonly used for coating, the martensitic stainless steel has important application for resisting corrosion and high-temperature service, it has excellent ductility and mechanical properties appropriate for high temperature and they are easy to be welded. Stainless steels are considered high alloy steels usually containing chromium, nickel, molybdenum in its chemical composition. The alloying elements particularly chromium, gives excellent corrosion resistance when compared to carbon steels. These steels are oxidized, that is, the chromium present in the alloy oxidizes in contact with oxygen in the air, forming a very thin and stable film of chromium oxide. For the oxide, film is effective in protecting against corrosion; the minimum content of chromium should be around 12% according to Ananthan et al. (2012).

Therefore in this study, the influence of important variables such as welding speed, the average amperage arc distance and the tip of the torch-piece was studied in order to determine the efficiency of the processes for both conventional current as for pulsed current controlling the rate of fusion as reported by Kumar et al. (2012).

MATERIALS AND METHODS

The base metal was a steel plate AISI 1020 (185 × 63.5 × 12.7 mm) and for the coating, the EC410NiMo MC 1.2 mm in diameter electrode wire with the shield gas, a mixture of argon and oxygen 2% was used. The chemical composition of the base metal and filler are shown in Table 1.

To perform the welding, a test bench consists of a welding source, a turtle welding and modular data acquisition system with ammeter, voltmeter, accelerometer and thermocouples was used. Figure 2 shows a view of the test bench used during the performance of the weld beads.

Welding is normally limited to the flat and horizontal positions with large diameter wires. Smaller diameter wires are used in all positions. A layer of solidified slag is left on the weld bead that must

Table 1. Chemical composition of base metal and filler metal.

Material	C	Mn	P	S	Si	Ni	Cr	Mo
AISI 1020	0.18/0.23	0.30/0.60	0.03	0.035	0.10/0.30	0.15	0.15	…
EC410NiMo	0.027	0.590	0.024	0.006	0.44	4.86	12.5	0.43

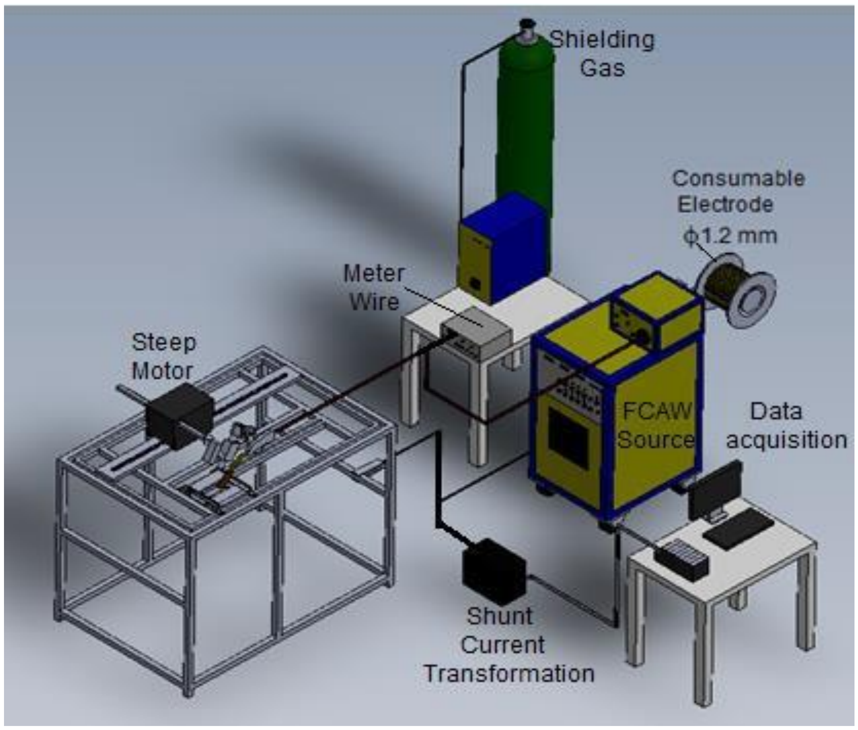

Figure 2. Layout of the test bench.

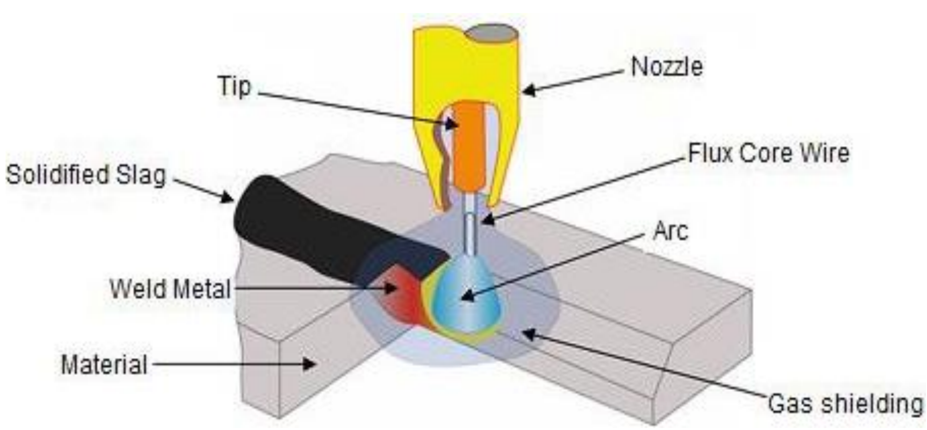

Figure 3. Schematic flux cored arc welding process.

be removed after welding as showed schematically in Figure 3.

The FCAW parameters examined are the welding speed, amperage, distance from torch tip - piece, and the pulse frequency. To define parameters in the FCAW process in previous studies, Om and Pandey (2014) observed that the limit of each variable must be prefixed. Thus, by analyzing previous studies and considering the objectives of this study, the limits of each variable were prefixed. Then, preliminary tests were performed to find the extreme levels for each variable, thus determining whether the process occurred under such conditions. Table 2 shows the parameters and their levels, set at the end of the preliminary tests. Before they were welded, all specimens were subjected to a process of abrasive blasting with steel grit angle G-25 S-280, with hardness D, according to SAE J444 (1993),

Table 2. Parameters applied and maintained constant levels during welding.

Parameter	Level
Polarity of the electrode	CCEP
Protective gas	Argon+2% O_2
Gas flow	18 L/min
Torch angle	90°
Welding position	Plane
Interpass temperature	150°C
Number of cords	11
Peak current (Ip)	350 A
Peak time (tp)	0.01 s

Figure 4. View of the accelerometer model KS80D.

Table 3. Variables and their levels welding.

Variable/level	-1	0	1
Current average (A)	170	200	230
Distance nozzle/piece (mm)	30	35	40
Pulsation frequency (Hz)	18.18	20.00	22.22
Welding speed (cm/min)	30	35	40

for which obtain a surface free of grease, oil and other contaminants. The equipment used in the blast was the case with suction CMV, model GS-9075X.

During welding of the cord sensors (voltmeter, ammeter, thermocouples and accelerometer) to obtain the necessary analyzes and a better interpretation of the results were used. In the acquisition of the temperature control part and interpass temperature two commercial type K thermocouple with a diameter of 3.00 mm, which has a measuring range from 0 to 1350°C were used.

To enable it to monitor the interpass temperature, which is 150°C prior to welding of the samples, were heated in a muffle furnace NT-380 at a temperature of 200°C. When the specimens reached this temperature, they were taken to the welding device for positioning and temperature control via thermocouples.

When this temperature decreases to 150°C welding is performed by monitoring, and this procedure was used in all tests as suggested by Kovacevic and Huang (2011). The welding device was constructed to maintain good contact between thermocouple/specimen; it features an adjustable spring in order to maintain this contact.

To weld properly, a piezoelectric accelerometer industrial KS-80D of MMF Industries as shown in Figure 4, which has a frequency range from 0 to 22000Hz, temperatures of between -20 to 120°C and with magnet stainless steel was used. It is observed that the temperature of the welding part is greater than the operating temperature of the accelerometer which was 90°C and which has been placed laterally on the welding.

Development of L9 matrix

The welding tests were performed aiming to relate the levels applied to the respective variables as shown in Table 3. From the choice of these 4 variables mentioned and 3 levels for each test, we determine parameters that were entered into the MINITAB software with an L9 TAGUCHI matrix according to Palanni et al. (2006) and Aghakhani et al. (2011), which resulted in the parameters in conventional and pulsed current to be applied during the welding trials as shown in Tables 4 and 5, respectively.

RESULTS AND DISCUSSION

In this research, the effect of the main welding parameters on the fusion rate and efficiency of the

Table 4. Data generated by the MINITAB software L9 Taguchi matrix for tests with conventional welding current.

Tests on conventional current			
Experiment	**Welding speed (mm/min)**	**Distance nozzle/piece (mm)**	**Current average (A)**
1	300	30	170
2	300	35	200
3	300	40	230
4	350	30	230
5	350	35	170
6	350	40	200
7	400	30	200
8	400	35	230
9	400	40	170

Table 5. Data generated by the MINITAB software L9 Taguchi matrix for tests with pulsed welding current.

Tests on conventional current				
Experiment	**Welding speed (mm/min)**	**Distance nozzle/piece (mm)**	**Pulsation frequency (Hz)**	**Current average (A)**
1	300	30	18.18	170
2	300	35	20	200
3	300	40	22.22	230
4	350	30	20	230
5	350	35	22.22	170
6	350	40	18.18	200
7	400	30	22.22	200
8	400	35	18.18	230
9	400	40	20	170

welding FCAW process of level -1 to level +1 was investigated (Gomes et. al., 2012). The results show that the main effect of welding parameters are: the increase in the welding speed and the amperage of the arc tend to increase the fusion rate as noted by Chotěborský et al. (2011) when we pass from level -1 to +1, for the conventional current and reduced for the pulsed current when evaluating level -A to +A, as shown in Figure 5. However, the efficiency decreases with the increase of welding speed for both processes, both conventional and pulsed current but increases with increasing amperage of the arc when evaluating level -1 to +1 or –A to +A, second (Figure 6). Also, we can observe that the efficiency in both cases with conventional and pulsed current decreases as we increase the distance of nozzle/piece.

The spectra of Figures 7 and 8 show a behavior definition of important signals in the acceleration, arc voltage and welding current, respectively (Li et al., 2010). All spectra were observed initially, that there was an unstable initial pulse due to the gas flow (acceleration of initial the gas exit) for all parameters (acceleration, arc voltage and welding current).

In the spectra emitted by the accelerometer, we can see the current and open circuit voltage of both processes, conventional pulsed current, open acquisition system, displacement of torch, and thus deposition of weld metal.

Conclusions

This work has presented an application of the parameter of the Taguchi method in optimization of the FCAW parameters. A three-factor of the three level Taguchi experimental design was used to study the relationships between the fusion rate and the five controllable input welding parameters such as, welding current, nozzle/piece distance and welding speed. The following conclusions can be drawn based on the experimental results of this research work:

1. It appears that the Taguchi method is important for the optimization of the welding parameters of FCAW, favoring the control of welding data more easily;
2. The wire feed rate, welding voltage and distance torch

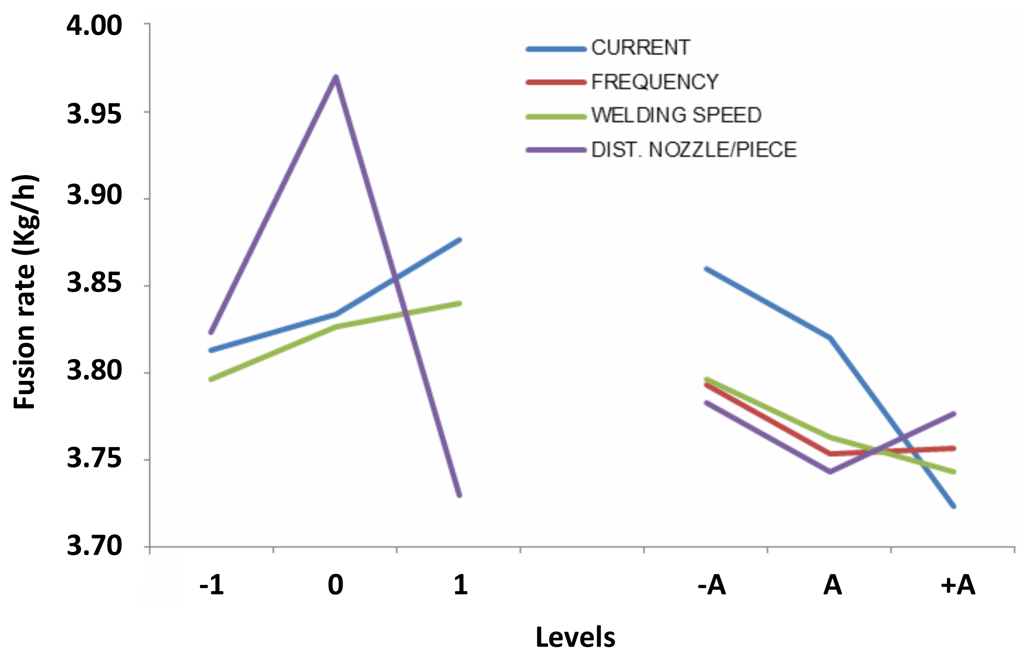

Figure 5. Influence of parameters on the fusion rate (Kg/h) in conventional and pulsed current.

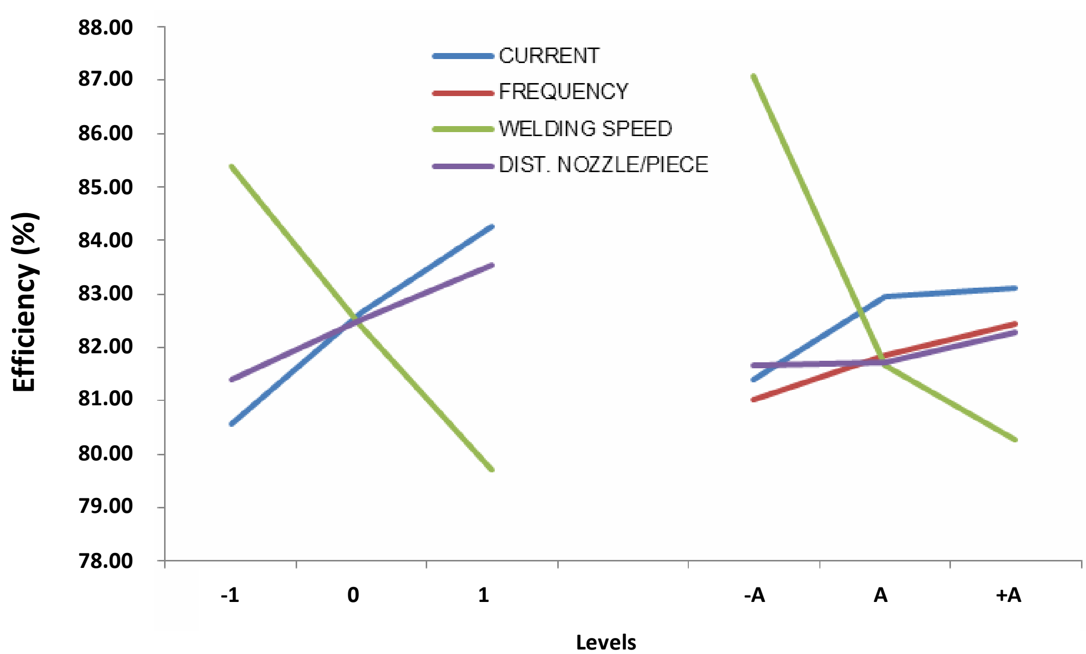

Figure 6. Influence of parameters on the efficiency (%) in conventional and pulsed current.

tip-piece have a significant effect on the fusion rate and efficiency, e.g, the welding speed and the arc amperage increase the fusion rate for the process of conventional arc and reduces the process to a pulsed arc;

3. The spectra emitted by the accelerometer showed a very stable voltage and current process, however showed some instability in the acceleration applied in the three stages amperage (170 A, 200 A and 230 A);

4. Increasing welding current value influenced the depth of penetration increased. Other than that, the factors that can influence the value of depth of penetration are arc voltage and welding speed.

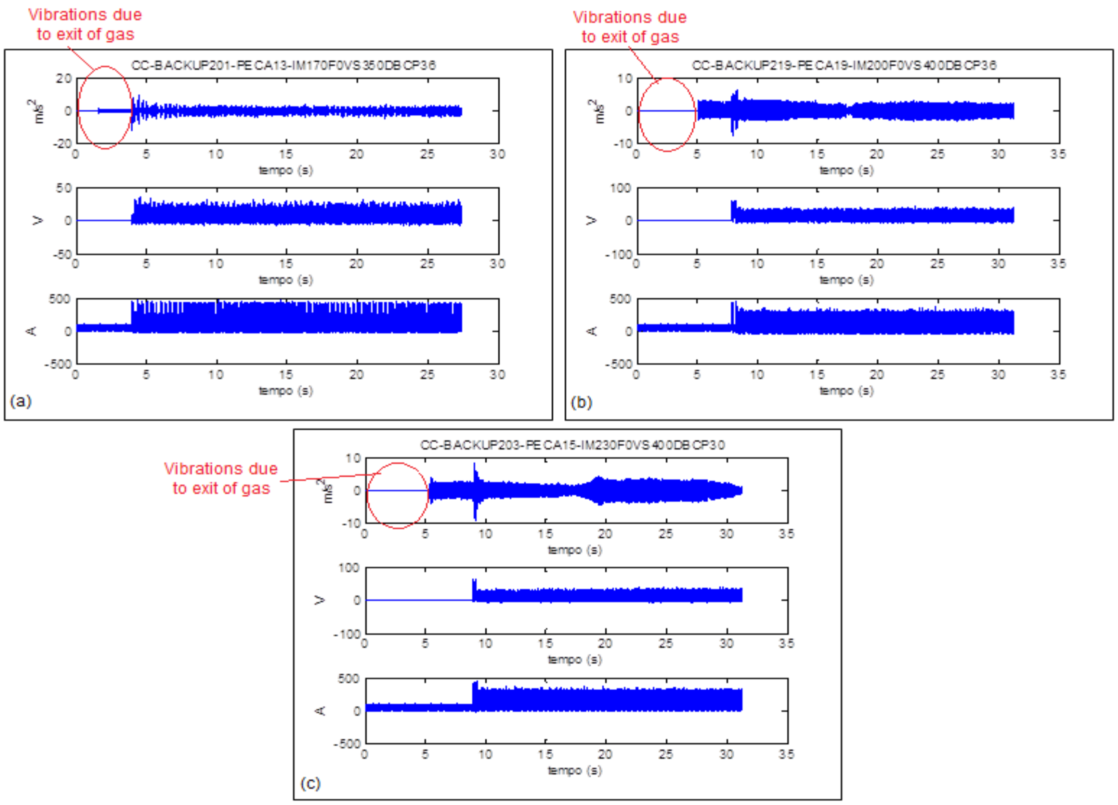

Figure 7. Pulse spectra emitted by accelerometer at (a) 170 A, (b) 200 A and (c) 230 A in conventional current.

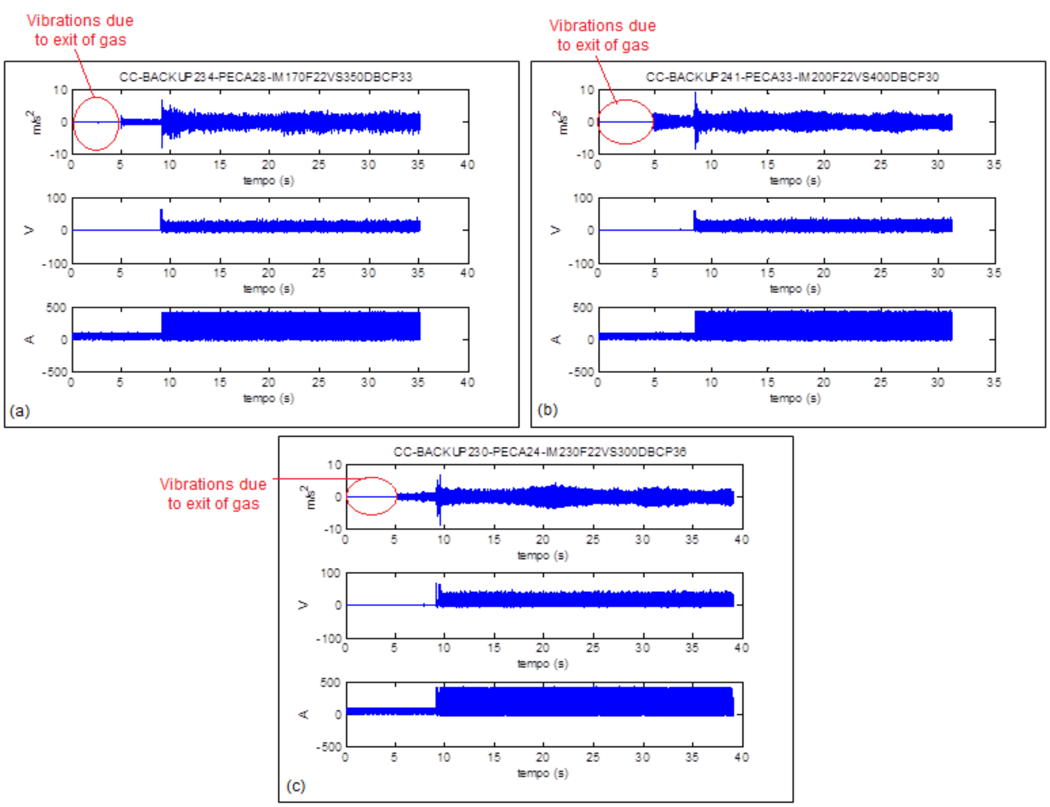

Figure 8. Pulse spectra emitted by accelerometer at (a) 170 A, (b) 200 A and (c) 230 A in pulsed current.

Conflict of Interests

The authors have not declared any conflict of interests.

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