Control noise for coffee roasting

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Summary

In the coffee roasting process, various alerts can be used to individuate the final phase. They are represented for example by the temperature in the roasting camera, by the color of the coffee beans, and by the bean crackling that produces a typical noise.
This acoustic alert is often used by the expert roasting workers, to decide the roasting level of the coffee. After the first crack, half of the coffee beans are roasted. To complete the process, it is possible proceed with a control of the beans color, monitoring the beans temperature inside the machine or/and the roasting time. Another solution is to wait for preset time after the first crack or a second crack that indicates the complete beans roasting. The technician can choose if going out some seconds more for a higher level roasting.
The acoustic signal of this crack can be a resource for the process control and it could be used for an optimization process of the whole system. In the paper, after a review of the proposals to control the coffee bean roasting by means of the crack noise detection, some considerations are presented on measurements made on roasting machines.

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1. Introduction

Today in the processes of the food industry, the aspects linked to the sound emission of the machineries in the production chain are very important. Usually the main aim is the reduction of the sound emissions and the protection of the workers.
Sounds and noises in the food industry are considered negative aspects, their effect is considered mainly the noise pollution to be controlled and, if possible, reduced; however, in some cases, the machinery noises can represent a resource and need attention, because they may be useful to control the process development and to increase the product quality.

1.1 Coffee industry

Starting from the analysis made by P.S. Wilson [1] in 2014, in the last 7 years the exportation from the producing countries has made a 14% growth [2].
Italy is the world's second largest importer of coffee beans (about € 1.4 billion in value) and the second coffee consumer (5.65 kg pro capita), behind only Germany. Green coffee must be roasted and ground, to be processed as beverage. In Italy, there are more than 800 roasters, with 7 thousand workers toasting and grind green coffee imported half from Brazil and Vietnam, followed by India, Uganda, Indonesia and Colombia, and exporting one third of the product [3], representing the third country in Europe for the export. The first four groups in the sector represent about half of the total market.

The coffee beans roasting process employs high energy supply. Due to the diffuse interest to reduce the energy consumption, and the high cost of fuels, the process optimisation becomes more and more a primary need in this field. The roasting process brings the green beans to high temperatures, from 160°C to 240°C, for a time ranging from 8 to 20 minutes, depending on the final product desired and the machine used for the process. Temperature is a parameter that greatly affects the degree of roasting and the coffee aroma. Approximately 40 volatile compounds are considered responsible for aroma: their presence and effects depend on the time-temperature binomial during roasting process and determine the coffee quality [4]
The process can be monitored by means of several techniques that can control mainly beans color, volume, temperature or weight loss that perhaps represents a more objective indicator of the roasting degree [5].

In the artisan roasting process, the color of the beans and the time steps are checked manually by the workers, who constantly control their quality.
The process times are quite longer than in the industrial plants, where times are strictly connected with productivity and money saving is a priority together with quality. The industrial machines work usually with higher temperatures and automatic controls of the whole process.
The artisan roasting process is often controlled not only visually by the beans color that changes during the process, but also by the noise produced by beans. A first emission of noise corresponds to a "crack", when the beans start to release steam and gases at an approximate temperature of 200°C. It can last 1-2 minutes and it is sufficiently loud to be well individuated over the noise level of the whole process. A second "crack" can be heard at the end of the process, when the temperature is around 230°C, due to the emission of additional gases.
After this second event, the artisan can decide to wait a few seconds, based to his experience, to stop the roasting process. The result can vary significantly depending on this little gap, because if the process is not ended properly, beans start to burn.
A research based on the experimental analysis of the crack noise detection in a 0.45 kg capacity coffee roaster with an electrical heating element (1.6 kW) [1], lead to a patent on "Method and Apparatus for Controlling Coffee Bean Roasting" [6]. The control of the process by means of the crack detection may allow avoiding under or over roast the beans due to the difficulty of hearing these cracks and leading to an unusable product.
However, to use properly this technique, deeper analyses must be developed and this research intends to contribute. Therefore some notes on the measurements developed on a 30 kg capacity coffee roaster, gas heated, are presented.

2. Measurements

A coffee roaster, 30 kg capacity, heated by means of gas combustion, was tested to roast a 30 kg batch of green Arabica beans to obtain the product to be ground and sold.
A Brahma digital audio recorder (modified Zoom H2 digital sound recorder [7]) was used to record the noise during the roasting process.
The recorder was placed at a distance of 50 cm from the roaster. The first roasting process was registered from the beginning, when the machine was cold; therefore, the time of the first cycle was longer than usual, lasting approximatively 20 min instead of 15 min.

Figure 1 –Coffee roaster

Figure 2 - Sound recorder

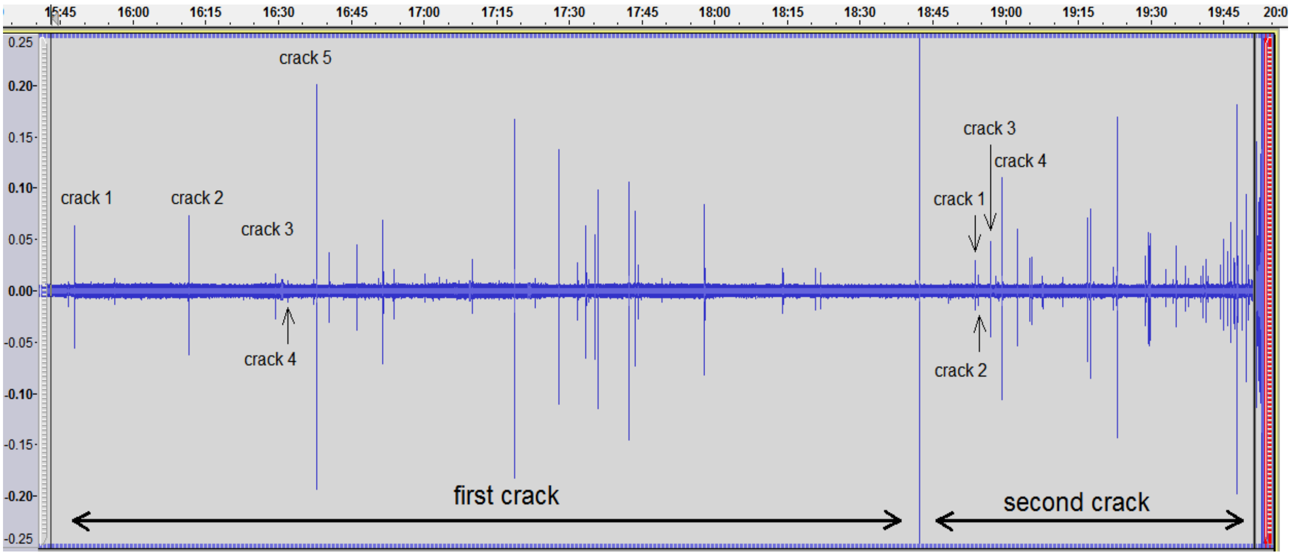

Figure 3 - Sound registration

Figure 4 – First crack

The first crack range started with crack 1 (Fig.4), occurred at 15 min 48 s, crack 2 at 16 min 12 s, crack 3 at 16 min 30 s, crack 4 at 16 min 32 s. The second crack started at 18 min 53 s with crack 1 and continued with crack 2,3,4 and the following ones.

Meanwhile, the roasting expert was controlling the beans colour (Fig.5) and, after 19 min 50 s, he decided to end the process, and opened the machine to cool rapidly the coffee beans to avoid their burning.

3. Results

The first crack spectrum, referred to crack 1, 2 and 3, is represented in figure 6. It can be highlighted that it is characterized by components with frequency higher than 6 kHz, up to 15 kHz. The second crack was not so evident and further measurements are needed to individuate it better. In this case, probably due to the machine characteristics, to the background noise, and to the surroundings, the crack spectrum is more difficult to isolate. Anyway, in fig.7 the spectrum related to the second crack noise highlights a contribution of cracks in the field of 1-2 kHz. The background noise indicated with “noise 2” is more confused probably due to the crack influence.

Figure 5 – Colour check

In previous researches [1], referred to a small size roasting machine, the first crack was found characterized by more low frequency energy, with a spectral peak at about 800 Hz, and a second crack with a flatter spectrum lower in amplitude than first crack up through about 10 kHz, and a spectral peak at about 15 kHz.

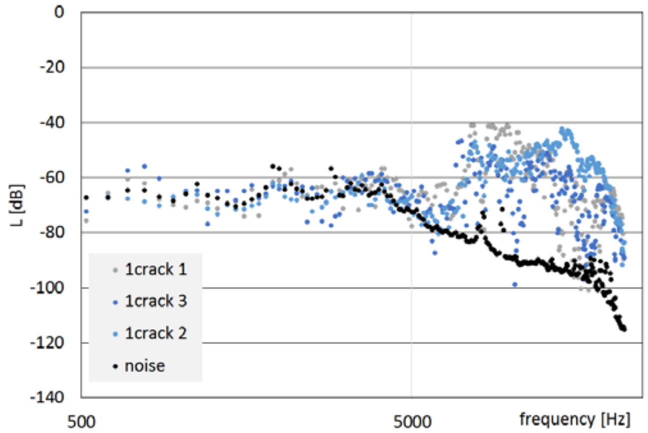

Figure 6 – First crack noise

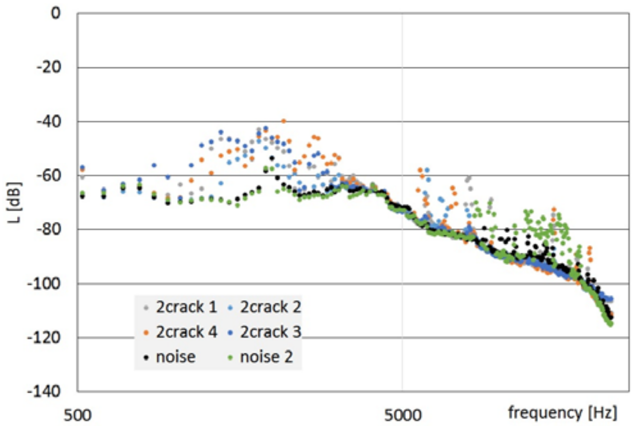

Figure 7 – Second crack noise

4. Conclusions

The control of the coffee roasting process can be demanded to a sound detector that register the coffee beans crack and stop the roasting in the correct times. The crack sound spectrum should be known to automatize and optimize the whole process of roasting and supervision. In this research a medium size machine, was tested and the typical frequency fields are outlined by means of experimental measurements.

The results of the measurements will contribute to develop a better control of the process and to allow the automatic process regulation, timely detection of potential process failures, in the roasting machines, giving additional information related to the single roasting batch, crossing the noise information with color, time, temperature, consumed energy, etc.

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