Paper Wire Atlanta

Costs and benefits of highly efficient wire cleaning by ultrasound

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Costs and benefits of highly efficient wire cleaning by ultrasound

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Abstract

This paper examines the economic costs and benefits of the use of an ultrasonic wire or tape cleaning system[1]. In the last years, major technology improvements made the use of ultrasound more reasonable for the cleaning of wires. The cavitation of today's high-power ultrasonic processors serves to remove grease, oil, and other contaminations from the surface of the wire. Reduced investment costs and improved performance of these ultrasonic wire cleaning systems made them not only competitive but superior to conventional cleaning methods as for example acid baths.

1 Ultrasonic Cleaning

Ultrasound is well known for its capabilities in the cleaning of metal parts. There are two working principles. Firstly, there is an oscillation of the cleaning liquid itself that causes a movement of the liquid in relation to the parts to be cleaned. Secondly – and more important – is the cavitation caused by high amplitudes.

Cleaning is often a bottleneck in the wire production line. Many companies still clean coils of wire in acid baths. This is an non-continuous batch process – consuming time and chemicals.

Cleaning the wire in line with the other production steps leads to continuous production. Furthermore, speeding up the cleaning often enables the company to make use of the capacity of the rest of the line.

1.1 High-Power Ultrasonic Processors

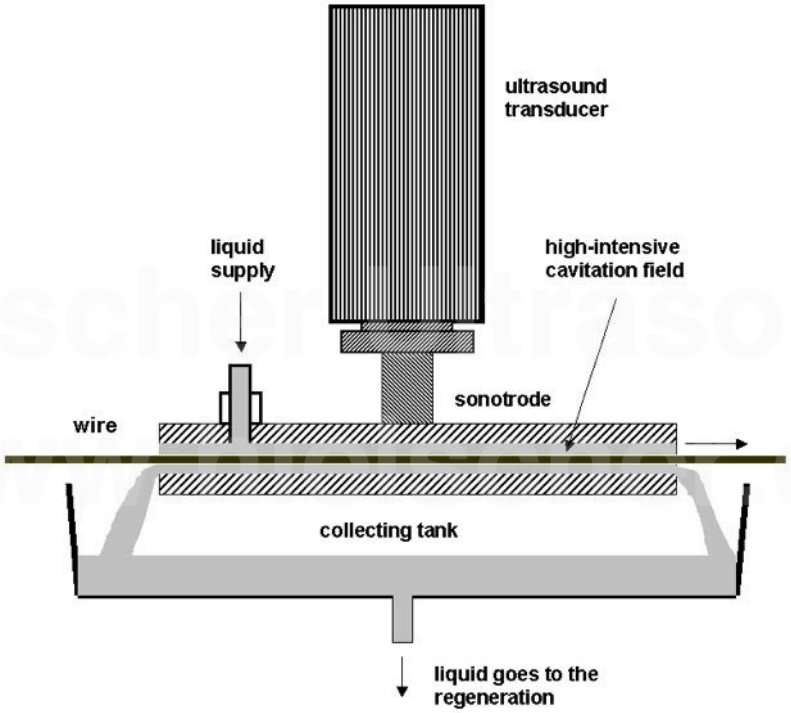
For the industrial wire cleaning powerful ultrasonic processors are needed that can run continuously. High power combination with high efficiency makes high cleaning speeds possible at reasonable costs. Furthermore, these devices should be run-dry protected to ensure that the systems won't be destroyed by a simple error such as a pump failure or the missing maintenance of the liquid tanks. This protection is accomplished by holding the amplitude constant and by this preventing it from rising above critical limits as a consequence of the missing load.

Such high-power ultrasonic processors have been developed and installed in industrial wire cleaning systems by our company. Modules of one, two, and four kilowatts continuous sonic power mark the edge in ultrasonic technology today. They meet industrial requirements in performance, efficiency and reliability.

1.2 Cavitation

Ultrasonic processors generate oscillations of frequencies beyond the audible spectrum. In general, this is 20kHz and higher. Amplitudes differ depending on the devices used. Ultrasonic baths usually operate with amplitudes of up to 4μm.[2] Most megahertz-systems achieve only less than 1μm. Today's high-power ultrasonic systems oscillate at amplitudes of 100μm and more in industrial applications. The high frequency in combination with the high amplitudes causes extreme accelerations, that the liquid cannot follow. Since the forces become higher than the adhesion and cohesion within the liquid and between liquid and oscillating surface, small vacuum bubbles emerge. These bubbles implode after growing to the critical limit of approximately 100μm. This effect is called cavitation. These implosions create

[1] below only referred as wire, although this applies to tape and profiles as well
[2] always referred as peek to peek



Graphic 1 - Wire Cleaning Sonotrode

shock waves and liquid streams of up to 400km/h. These conditions will overcome the surface tension of wire contaminations (drawing oil, lubricants, grease, stearats, resins etc.).
The intensity of the emerging cavitation rises with an increase in amplitude. Furthermore, the cavitation will be stronger for lower frequencies such as 20kHz. Frequencies below 20kHz are not really applicable, since they are within the audible range. With a rise in frequency, the cavitation reduces.

1.3 Sonotrode Design

Since the intensity of the ultrasonic oscillations and the induced cavitation diminishes very fast with the distance from the sonotrode, a low distance between sonotrode and the wire to be cleaned is necessary. The sound intensity equals the ratio between power input and liquid volume. Thus, the intensity increases with an increase in power and with a decrease in liquid volume. Graphic 1 shows a sonotrode design, that maximizes the sound intensity. In this case, the wire is passing a bore hole inside a sonotrode. Similar designs are possible for the cleaning of tapes and profiles as well.

1.4 System Integration

For the application of ultrasonic wire cleaning in the industry the ultrasonic components have to be integrated in a complete system. Such a system consists of the above mentioned high-power ultrasonic processors, liquid circulations and drying. To increase the efficiency, the liquid circulations are supplied with filter cartridges and oil skimmers to extend the maintenance cycles and to reduce the consumption of chemicals. The liquid tanks are installed in double version and change automatically for maintaining the inactive tanks.
Graphic 2 shows a complete tape cleaning system made of stainless steel with high-power ultrasonic processors and tree separate pairs of tanks for the continuous cleaning. The systems can be customized, meeting the requirements regarding wire diameter, cleaning speed, contamination type and required space for set-up.

2 Wire Cleaning System

Besides the technical parameters, costs and benefits are important, when considering investing in alternative wire cleaning systems.

2.1 Costs

The costs of an ultrasonic wire cleaning system are the sum of the investment costs and the operation costs. The initial investment costs result from the purchase price, installation costs, training and required space.
Operation costs include labor, power consumption, maintenance, cleaning liquid consumption and costs of the disposal, pressured air, spares and required space for set-up.

2.2 Benefits

One advantage of the ultrasonic wire cleaning described above is the in-line cleaning. In comparison to the batch cleaning (such as acid cleaning baths) costs are reduced by decrease in necessary operating steps. In addition, the continuous in-line cleaning

Graphic 2 - Tape Cleaning System

reduces the number of interruptions in the production process and with it the costs of stopping and starting the production line after each interruption.
Today's high-power ultrasonic wire cleaning systems serve to clean wires from contaminations at speeds of up to 30m/s. Since cleaning is often the bottleneck, this would increase the production capacity of the entire line and with it the potential output per year.
Another benefit results from the continuous filtering and oil skimming of the cleaning liquid. This serves to hold the cleaning quality at a constant high level. This is particularly important in quality sensitive productions.
In addition, high-power ultrasound saves cleaning chemicals. Thus, costs are reduced for purchasing and disposing the cleaning liquids. Filters and oil skimmers increase this effect by prolonging the utilization time. Better air conditions for the employees are the result of the lower concentration of cleaning chemicals. Together with the low power consumption and the highly efficient use of power and chemicals this is very favorable from an environmental perspective, too.