Cavitation and Electromagnetic Peening processes: development of experiments and predictive modelling

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Peening processes are commonly used to improve the mechanical properties of surfaces and especially introduce compressive residual stresses to improve the fatigue life of mechanical parts. The most classical process is shot peening where shots are mechanically projected on the surface. The induced plastic deformation allows to introduce compressive residual stresses typically up to a few hundred of micrometres. This process is industrially mature and commonly used but suffers a few drawbacks. A first one is the generation of a surface roughness than can be detrimental to the service life of the surface, especially when parts are subjected to a corrosive environment. A second drawback is the difficulty to correctly master the process. Obtaining a uniform treatment on parts with a complex geometry can be challenging and accessibility problems can also sometimes be encountered.

The purpose of this presentation is to introduce two less common peening processes that have different advantages and can help overcoming the aforementioned drawbacks. The first one is the cavitation peening process, illustrated in the following figure. It consists in generating a high velocity water jet (from a 100-300 bar input pressure) in a pressurized chamber (up to a few bar). The shearing forces in the flow lead to the formation of a cavitation cloud. When the induced cavitation bubbles collapse, they generate a pressure pulse, which intensity is increased by the inner pression in the chamber that deforms plastically the treated surface and therefore introduces compressive residual stresses similarly to the classical peening processes. The results in terms of residual stresses are comparable to the classical processes but with a lesser increase in the roughness. Also, the intrinsic nature of the cavitating jet makes it easier to treat complex surfaces. Experiments have been developed in parallel with numerical simulations (coupling Computational Fluid Dynamics and classical solid finite elements simulations) to be able to better understand and to predict the effect of this complex multi-physical process from the process parameters [1-2].

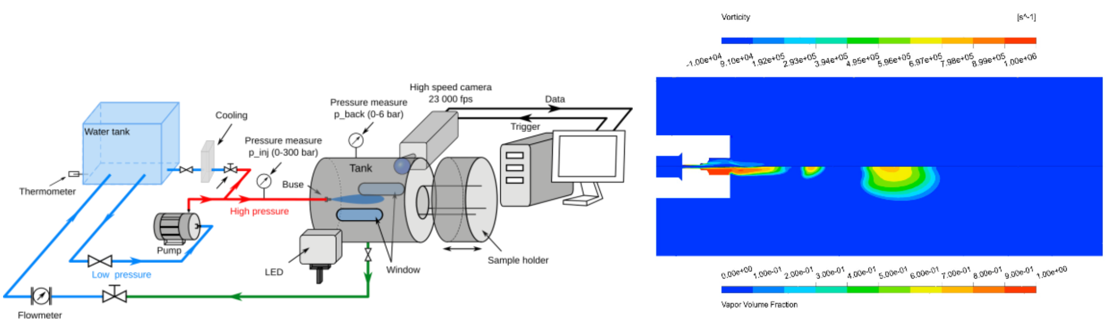

Figure 1 (a) Schematic representation of the Cavitation peening process; (b) example of CFD simulation of the cavitating jet

The second process is the electromagnetic peening process. This innovative process consists in delivering a very high current pulse (typically from 100 to 200 kA during 15 µs) through an inductor. A strong magnetic field is therefore generated inducing Lorentz forces in the treated part. In these conditions those forces are high enough to induce a permanent plastic deformation and similarly to the other processes generate compressive residual stresses. Two major advantages arise: first very little surface modification and thus roughness evolution due to the absence of mechanical contact; second the penetration of the magnetic field allows for a very deep treatment, potentially ten times more than for classical processes. The development of the process is yet challenging due to the strong currents and subsequent mechanical stressed induced. The development of a prototype of the process has yet been achieved and treatments on cylindrical geometries through a large depth have been obtained. In parallel, numerical simulations (couple magneto-mechanical finite elements simulation) of the process have been developed [3] in order to predict the effects of the process as a function of its input parameters and to allow design of inductors for the treatment of specific geometries.

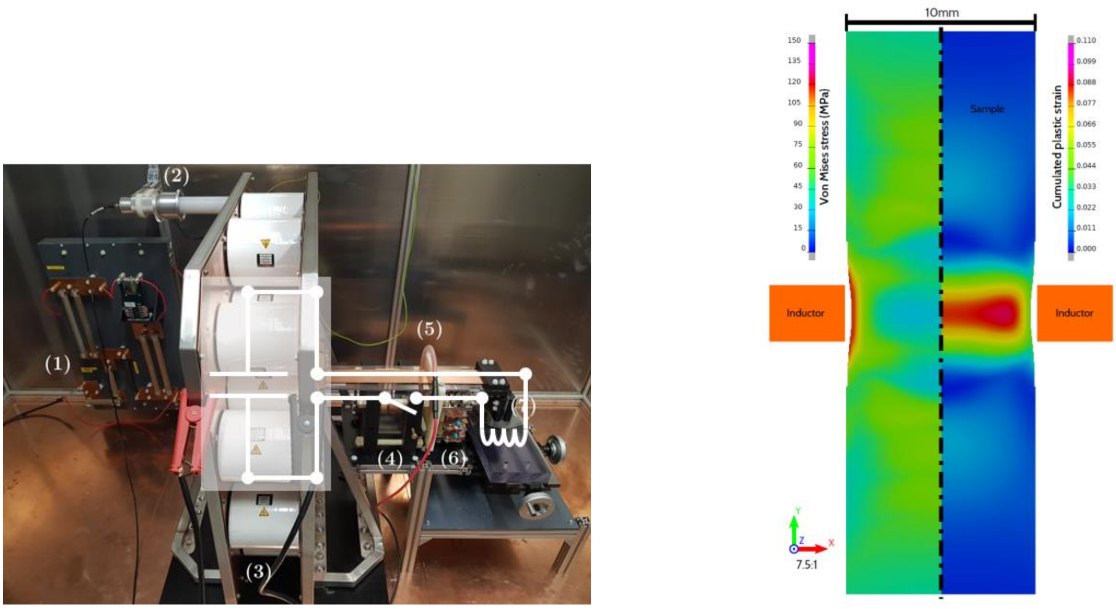

Figure 2 (a) Electromagnetic Peening prototype; (b) Example of numerical simulation of the treatment *via* EMP of an aluminium cylinder.

References :

[1] X. Sedao, M. V. Shugaev, C. Wu, T. Douillard, C. Esnouf, C. Maurice, S. Reynaud, F. Pigeon, F. Garrelie, L. V. Zhigilei, J.-P. Colombier, Acs Nano 10 (2016) 6995-7007.

[1] E. Sonde,T. Chaise, N. Boisson, D. Nelias. , Journal of Materials Processing Technology 262 (2018) 479-91.
[2] Z. Han, C. Mauger, T. Chaise, T. Elguedj, M. Arrigoni, M. El Hajem, N. Boisson, Sensors 21(14) (2021) 4800.
[3] E. Sonde, T. Chaise, D. Nelias, V. Robin, Journal of Applied Physics 123(4) (2018) 045901

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