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NANOCRYSTALLISATION PROCESS BY ULTRASONIC SHOT PEENING

PROCESS PRESENTATION

The main beneficial effects of the Ultrasonic Shot Peening (USP) process are induced by the plastic deformation of the surface work piece. When the treatment parameters are more severe, for instance when the treatment time is increased, the process generates a nanocrystallised surface layer. The core microstructure remains unchanged (see FIGURE 1).

The depth of the nanocrystallised layer depends on the USP parameters but is generally comprised between 10µm and 50µm (FIGURE 1 and FIGURE 2). A transition zone is observed before to recover the initial microstructure grain size. Usually, the total thickness of the affected layer is close to 200 µm (see FIGURE 2).

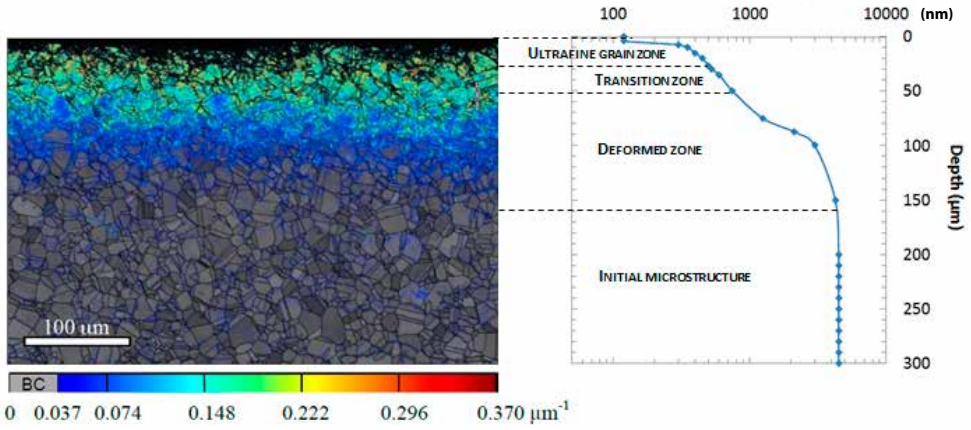

Figure 1. Microstructure evolution after nanocrystallisation by Ultrasonic Shot Peening [1]

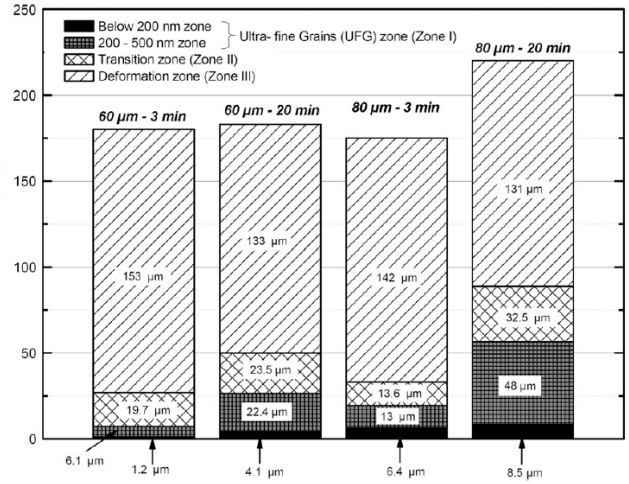

Figure 2. Effects of the Ultrasonic Shot Peening treatment on the affected depth [1]

The interest of the nanocrystallization can be considered as:

- **Surface treatment process:** the desired effect in this case is mainly related to the improvement of the surface mechanical properties of the material,
- **Pre-treatment process:** in this case, the nanocrystallization process is combined with thermo-mechanical treatment (nitriding, chromizing, carburizing). Indeed, the nanostructure increases the diffusion rate of elements such as nitrogen, chromium and carbon.

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MECHANICAL EFFECTS OF NANOCRYSTALLIZATION

The nanocrystallization by USP process enables an improvement of:

- Fatigue limit,
- Surface hardness (FIGURE 3.a.),
- Ultimate strength (FIGURE 3.b.),
- Wear resistance,
- Surface roughness.

Moreover, as a « classical » Ultrasonic Shot Peening treatment, compressive residual stresses appear on the nanocrystallized surface.

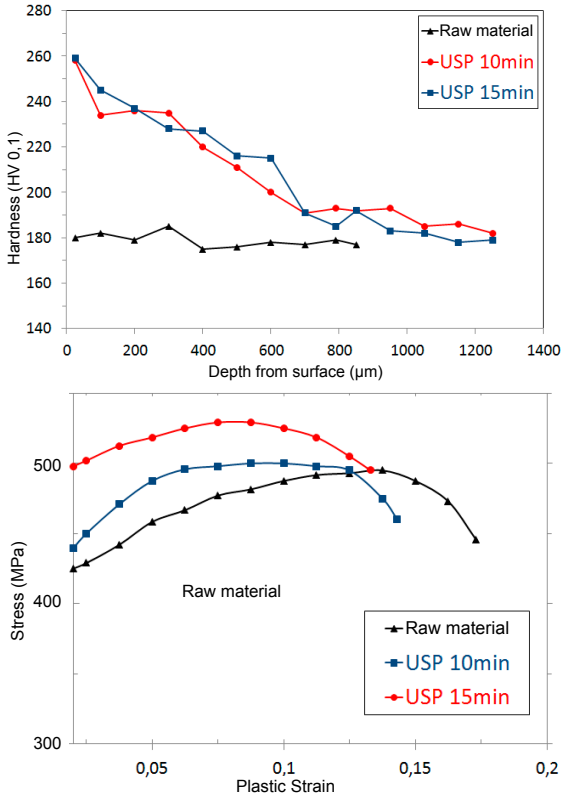

FIGURE 3. Mechanical effects of the nanocrystallization process by USP [3]
a. evolution of hardness in the depth
b. engineering stress-plastic strain curves

EFFECTS ON DIFFUSION RATE

Among the main applications of nanocrystallisation, improving the diffusion rate of atoms such as nitrogen (for a nitriding treatment, for example) is highly studied and adverdised in the literature.
Indeed, the nitriding treatment is widely used in the industry to improve the surface hardness of a work piece

However, to improve the kinetics of diffusion of nitrogen, this treatment is performed at high temperatures (550 °C - 600 °C) for a significant time, which may deteriorate the metal microstructure and properties. The interest of the nanocrystallization process by USP then lies in the optimization (decreased time and / or temperature) of the nitriding treatment. An additional increase of hardness is also observed by coupling both treatments.

POTENTIAL INDUSTRIAL APPLICATIONS

The different applications of nanocrystallization by USP concern various industries (aerospace, automotive, petroleum, machine tool, medical,...). Thus, all parts subjected to high stress and/or friction could benefit from surface nanocrystallized mechanical properties (residual stresses, increased hardness and wear resistance).

The medical field, especially with medical implants, seems to offer a high potential of development for nanocrystallization process by USP. The advantage of the method is both increasing the part fatigue life and facilitating their integration in human body (low rejection rate).
For more information about this specific subject see [4].

As a pretreatment, the nanocrystallization process can be effective in optimizing thermochemical treatments such as nitriding, chromium plating and cementation.

REFERENCES

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