Depletion of critical raw elements from surface of superalloy IN100 during hot isostatic pressing

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The critical raw materials (CRMs) are of great strategic importance for development of new technologies and materials in Energy, Transportation and Machinery manufacturing industries. For that reason, substitution or reduced use of CRMs (like Cr, Co, Nb, W, Y, and other rare earth elements) are of great interest. The presence of CRMs is high in case of superalloys, and any loss of material due to processing needs to be minimized. The However, during the hot isostatic pressing (HIP) which is commonly used for superalloy castings due to the almost complete elimination of micro-porosity by a combination of plastic deformation, creep and diffusion; a depletion of CRM elements in the surface layer is observed. The depletion is due to formation of contaminated surface layer and a formation of carbide free zone.

To study process of depletion and formation of surface errors a differently grinded (coarse grinding paper P240 and fine grinding paper P1000) and polished (1 m diamond particles polishing) samples made of superalloy IN100 were used. The HIP process was performed at 1200°C and argon pressure of 1379×10^5 Pa (20000 psi) for 4 hours, while total time of process (including heating and cooling) was 9 hours. The cross-section of samples was metallographically examined on Light Microscope Leitz Orthoplan, and further studied on scanning electron microscope JOEL JSM-6460LV equipped with EDS system INCA Oxford Instruments, at 20 kV.

The results of microstructure examination showed that the thickest contaminated layer occurs for the coarse grinded samples (1,728 m), while the lowest layer thickness was in case of polished samples (0,888 m), Fig.1. Furthermore, EDS analysis revealed that the contaminated layer is consisted of oxides, carbides and nitrides formed due to the diffusion of chemical elements (Al, Ti, Cr, Co, V, Mo) from metal matrix and their reaction with impurities (O_2 and N_2) in HIP atmosphere. The contamination layer is formed in direction of grinding scratches and has a globular form, Fig. 2. Due to carbide diffusion (Fig.3a), a carbide free zone (Fig.3b) is formed with depth of 100 and 42 m for coarse grinded or polished samples, respectively. The most affected elements by depletion are Al, Ti, V, Mo, while Cr and Co mostly remained dissolved in matrix. Finally, in order to minimize surface errors during the HIP process, and in that way to minimize depletion of CRMs a smoother part surface is preferable.

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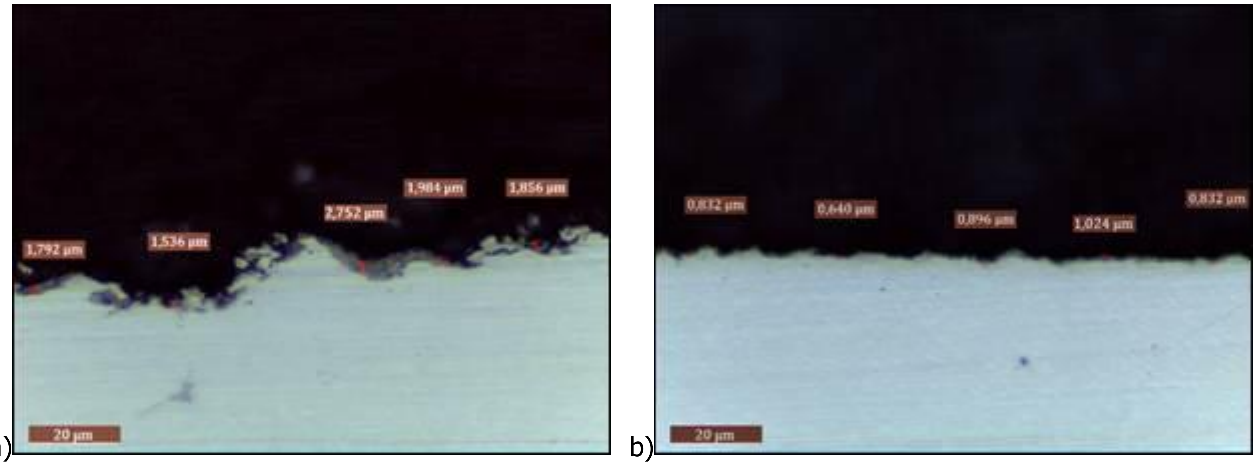

Fig. 1 - LM microstructure of surface contamination layer: a) Grinded surface (P240); b) Polished surface (1 µm)

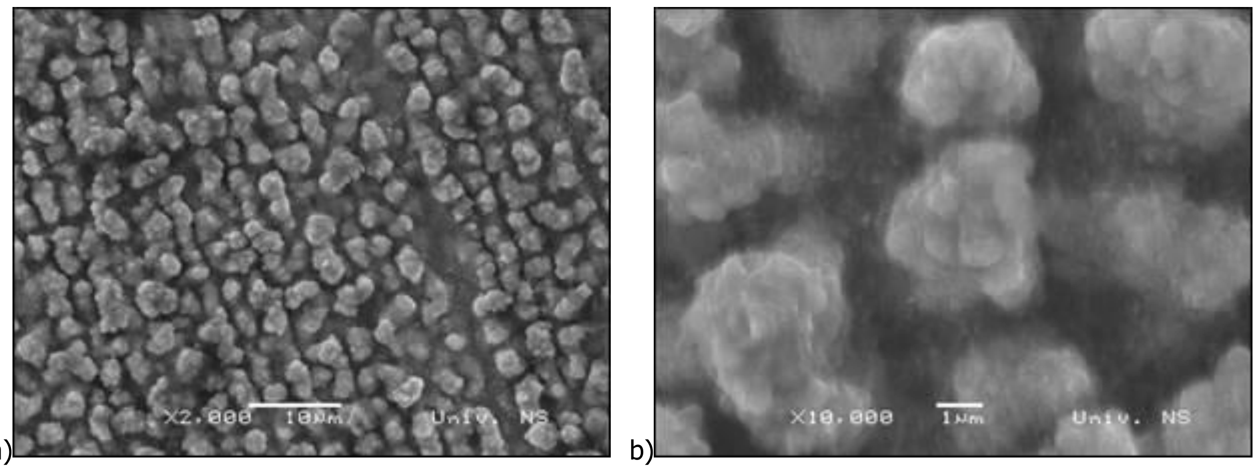

Fig. 2 - SEM microstructure of surface contamination: a) Directional growth of globules on grinding scratches; b) Contaminations globules

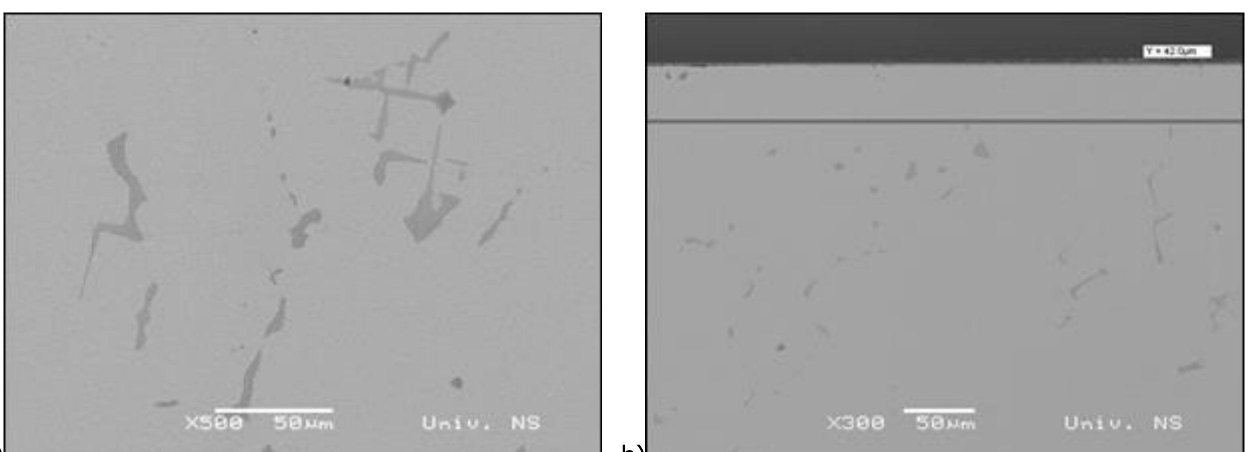

Fig. 3 - SEM microstructure: a) Carbides; b) Carbide free zone