I. INTRODUCTION

Vanadium carbide coverage has been used in industry to improve the steel properties [1] and there are some studies on VC laser cladding [2]. We will discuss in this work the vanadium carbide deposition by laser cladding on steel surface as intermediary layer for CVD diamond deposition.

The main problems to grow CVD diamond directly on steel surface is related to its quality and adhesion. Transitions metals, as iron, on steel surface catalyzes sp^2 instead of sp^3 bond formation, which leads to graphite growth or CVD diamond film with high amorphous carbon content, reducing its quality [3]. The mismatch between thermal expansion coefficient (TEC) of steel substrate and diamond causes a residual compressive stress state on CVD film after cooling [4]. An intermediate layer is necessary to create a diffusional barrier, both for iron and carbon, and a transition zone able to relieve the residual thermal stress [5]. Vanadium has particular characteristics as high hardness [6], carbides forming ability [7], protect against oxidation [8] and thermal expansion coefficient intermediate between diamond and carbon steel [9].

Laser cladding advantages are rapid processing [10], excellent metals adhesion by melting, ability for treating small surface areas with great precision, preserves bulk original properties and, high degree of automation and controllability of processing [11]. The laser cladding follows two steps: VC powder dispersion on carbon steel surface and; laser focus scans powder surface. The powder absorbs the beam energy, transfer to substrate and forms a melting pool by heat conduction. Once laser focus moves on, substrate spreads heat around causing coating rapid solidification. This study comprises laser cladding sintering parameters and construction of a multi layer able to improve diamond film adhesion and quality. The diamond films were deposited in a hot filament chemical vapor deposition (HFCVD) reactor. We characterized the samples by X-ray diffraction, SEM-FEG microscopy and Raman spectroscopy.

II. EXPERIMENTAL PROCEDURES

In the two step laser cladding, VC powder (25g) dispersed with CMC (Xg) in ethanol was air sprayed on surface and irradiated by laser. Experimental deposition was conducted varying laser resolution from 300 to 900 DPI and scanning speed from 100 to 500 mm/s^2 for just one heating cycle (NHC). Substrate selected was the...
AISI D6 steel because of its composition. Each step was repeated to form the multi-layer up to 6 overlapping VC layers. After laser cladding vanadium carbide (LCVC) deposition the samples were cleaned in ultrasonic acetone bath.

Diamond seeding of LCVC coatings improved CVD diamond nucleation. Once introduced in the HFCVD reactor, the diamond deposition was conducted with the following parameters: 3% of CH4; total flux of 100sccm; pressure 50 torr; work distance of 5mm; substrate temperature at 700 °C and; 3h deposition time.

III. RESULTS AND DISCUSSIONS

The best condition for LCVC deposition was 600 DPI and 100mm/s², forming the VC phase (Fig.1). Even though overlapping layers the VC phase kept the same. A homogeneous and continuous LCVC coating was obtained with four layers overlapped (Fig.1).

Figure 1 The LCVC coating: a) SEM surface image; b) surface mapping; and c) phases.

LCVC deposition in multi layers shows a limit to increase cross-section thickness around 28 μm (Fig.2). We noted LCVC cracks and partial delamination with five layers and complete delamination with six layers.

Figure 2 The LCVC cross-section: a) SEM image; b) mapping; and c) thickness increase.
In this way, diamond growth was performed just only over samples with until four layers. The cross-section thickness with one layer was around 7 μm and with four layers was around 25 μm (Fig.2). The cross-section mapping presents the heat affected zone (HAZ) located between LCVC film and substrate bulk (Fig.2). Diamond compressive stress state could be mitigated increasing cross-section thickness (Fig.3). The Raman shift reduction about 4.59 cm$^{-1}$ and it means tension relives about 2.6 GPa calculated by Ager and Drohy expression [12]. However, the Raman peak centered at 1585 cm$^{-1}$ evidences the high presence of graphite sp$^2$ bonds on diamond film. As the layer became thicker some cracks appeared on LCVC coating surface and it perhaps had been favorable for iron migration to diamond deposition reaction zone reducing the diamond film quality.

**Figure 3** The HFCVD diamond: a) morphology and b) Raman Spectra.

**IV. CONCLUSIONS**

The laser cladding showed to be a promising technique for vanadium carbide deposition. The growth was of 6.3 μm thick film per overlapping layer and a cross-section thickness about 25.4 μm was enough to mitigate diamond compressive residual thermal stress. However, the diamond quality decrease because of increasing cracks in overlapping 4 LCVC layers. The laser cladding process development may allow getting thicker LCVC film and cracks free. In this way, it can reduce thermal stress and increase diamond quality that are the goals for a high performance cutting tool fabrication.

**III. REFERENCES**


