Residual Stress in Ground WC-Co Coatings

M. Jalali Azizpour, H. Mohammadi Majd

Abstract—High velocity oxygen fuel (HVOF) spray technique is one of the leading technologies that have been proposed as an alternative to the replacement of electrolytic hard chromium plating in a number of engineering applications. In this study, WC-Co powder was coated on AISI 1045 steel using high velocity oxy fuel (HVOF) method. The sin²ψ method was used to evaluate the through thickness residual stress by means of XRD after mechanical layer removal process (only grinding). The average of through thickness residual stress using X-Ray diffraction was -400 MPa.

Keywords—Grinding, HVOF, Thermal spray, WC-Co.

I. INTRODUCTION

Thermal spraying is a promising method replacing the hazardous chrome plating in the finishing industry. This method has demonstrated to have superior wear and fatigue properties when compared to hard chromium using cermets e.g. tungsten carbide-cobalt (WC-Co). High velocity oxy fuel (HVOF) coatings have exhibited wear resistant WC-Co coating with high density; superior bond strength and less decarburization than many other thermal spray methods. This is attributed to its high particle impact velocities and relative low peak particle temperature. Over the last years, the substitution of hard chromium plating has been promoted due to the new legislation concerned to hazardous wastes of galvanic Industries. In high velocity oxy fuel (HVOF) thermally spraying powder particles are accelerated in supersonic velocities toward the substrate (Fig. 1).

Thermal spray technology has been proposed as an alternative to hard chromium plating showing in some applications promising results. For instance, one requirement for tungsten carbide coatings is to have better wear and fatigue properties than hard chromium when applied in aircraft manufacturing [1], [2].

Thermal spraying with high velocity oxygen fuel (HVOF) has been very successful in spraying wear resistant WC–Co coatings with higher density, superior bond strengths and less decarburization than many other thermal spray processes. This is attributed mainly to its high particle impact velocities and relatively low peak particle temperatures [3], [4].

As a class of hard composite materials of great technological importance, WC–Co powder cemented carbides are widely used by various thermal spray processes to deposit protective coatings in a large variety of applications such as power plants, oil drilling, turning, cutting and milling, where abrasion, erosion and other forms of wear exist.

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are accelerated. Decarburization of WC has been reported in the literature to affect the coating hardness and wear resistance [2]. In the work of Stewart et al. [4], it has been established that the formation of W2C upon splat quenching is caused by dissolution of WC in Co matrix whereas the formation of elementary W depended on the composition of the starting powder. Yang et al. [5] showed that larger degree of WC decomposition is correlated to a smaller carbide grain size in the starting powder. Other forms of W-Co-C may also be present in the matrix in the form of WxCoyCx which are not detected by the XRD method due to their low content or high dispersion in the coating.

B. Residual Stress

For WC-12Co multiphase coating, the determined stresses by X-ray diffraction concern only the dominant phase(WC), which can be taken as the residual stresses on the surface of the coating [5]. The strains in the samples were measured using peak position (2θ=133.48°) of WC. Positive and negative tilts were applied over the full range for sin²ψ=0 up to 0.8 with step of 0.1.

The analysis results of the residual stresses in the WC phase at the surface of the as-coated and ground samples indicated a linear dependency of strains and d-spacing versus sin²ψ. Thus, it was assumed that the coating is under an equibiaxial stress state with σ22=σ33 and σ11=0. Because the penetration depth of X-ray in WC-Co is very small (~2-5μm) [5] the resulting measurements refer specifically to surface of WC-Co coating thus only plane stresses were measured. As the measured strains for (ψ<0 and ψ>0) is linear function of sin²ψ, the shear stress components were negligible. So the residual stress can be obtained from the slope of strain-sin²ψ plot:

\[ \sigma_\phi = \frac{mE}{(1+v)} \]  

The stresses were measured in different thickness after layer removal by grinding. The results show the similar values for different layers seem to be independent of coating residual stress state. Fig. 4 shows the ϵ-sin²ψ for different thickness. Residual stress through the coating thickness is showed in Fig. 5 the average of residual stress generated by grinding thickness was ~400 MPa.

IV. CONCLUSION

Specification, composition and present phase samples coated using high velocity oxy fuel thermally spraying process has been investigated. Metallurgical and mechanical investigations were employed for this purpose. The results show the huge compressive residual stress which seems independent from residual stresses exists in as coat material.
REFERENCES


