

# Study of metallurgical factors in improving service life of wire drawing carbide dies using cryogenic treatment

Shreyas Sanjay Joglekar and Divyansh Saxena

B. Tech Metallurgical Engineering

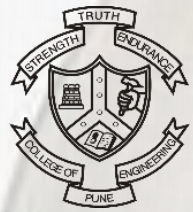
Under the Guidance of

Dr. N. B. Dhokey

Professor and Head

Department of Metallurgy and Material Sciences

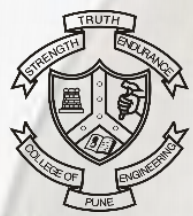
College of Engineering, Pune, India



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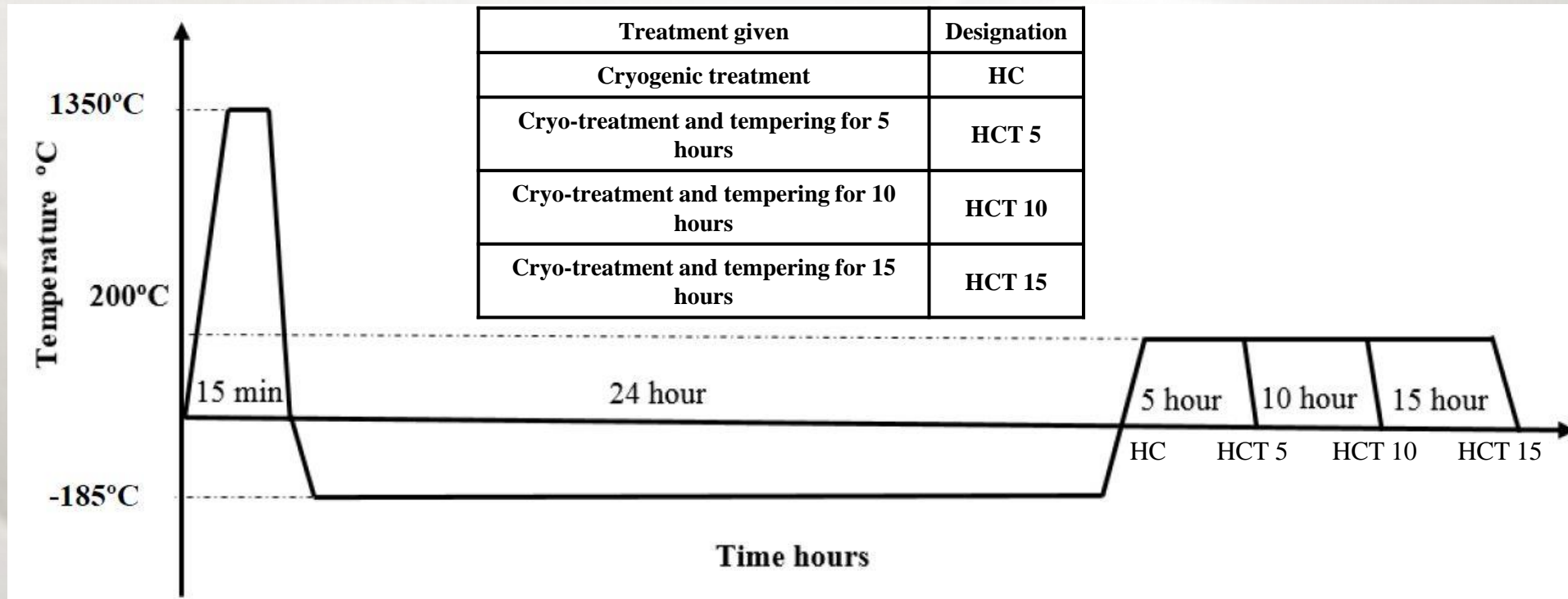
- **Objectives and designed heat treatment cycle**
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# Objectives and designed heat treatment cycle

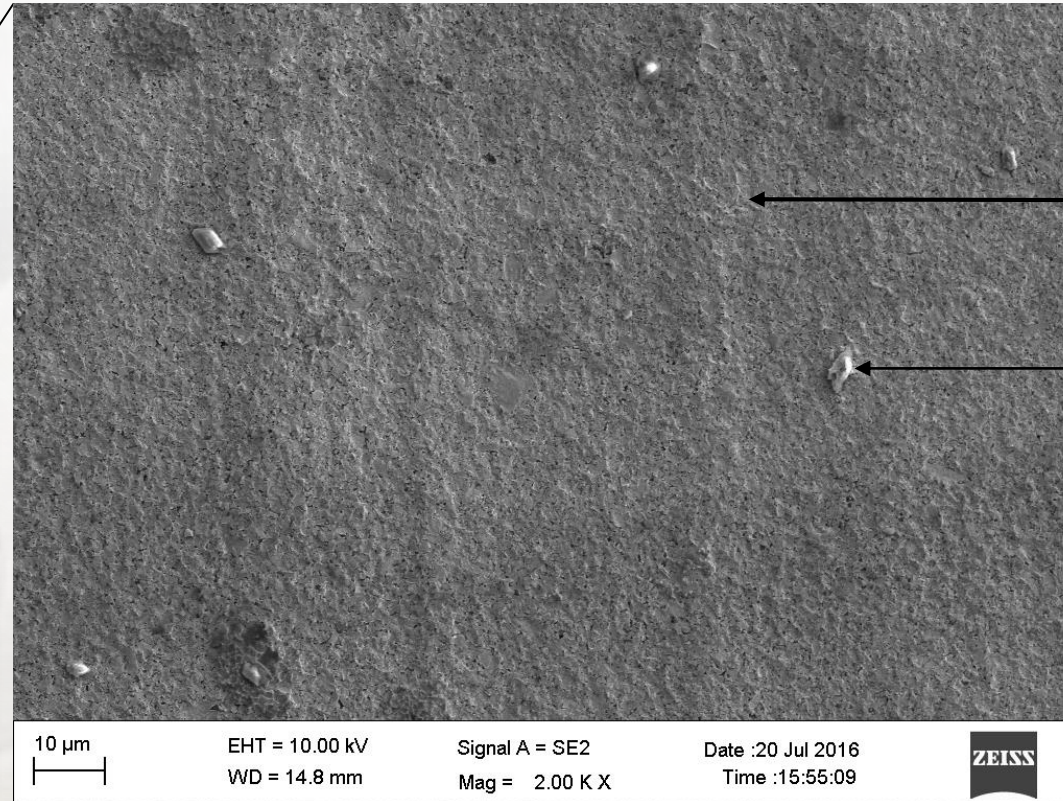


- To study the wear mechanism of carbide dies
- To assess the effect of cryogenic treatment and subsequent soft tempering on abrasion or wear resistant properties of carbide dies
- To predict the possible mechanism behind change in metallurgical and mechanical properties of WC-Co die material



**Figure 1:** Designed heat treatment cycle as a result of literature review

# Experimental observations: Worn out surface analysis

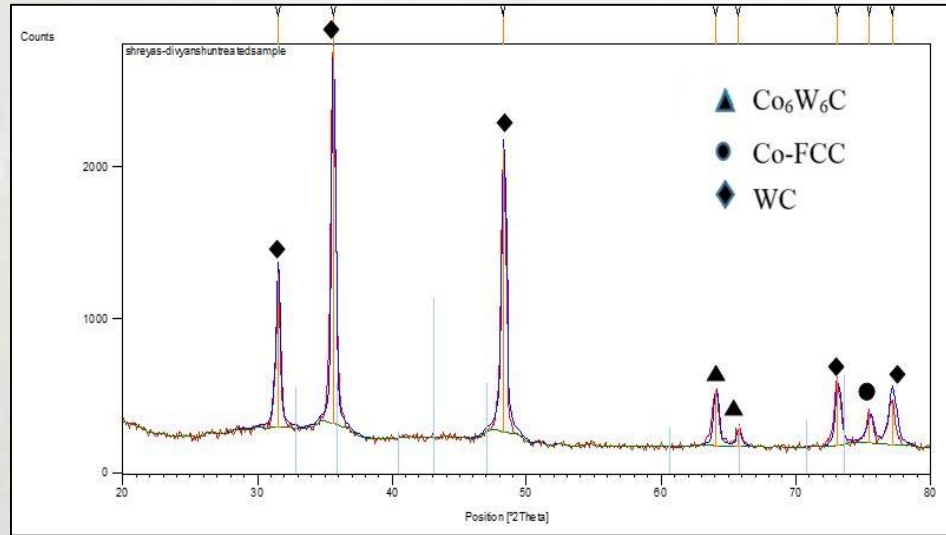


Parallel marks on worn out surface

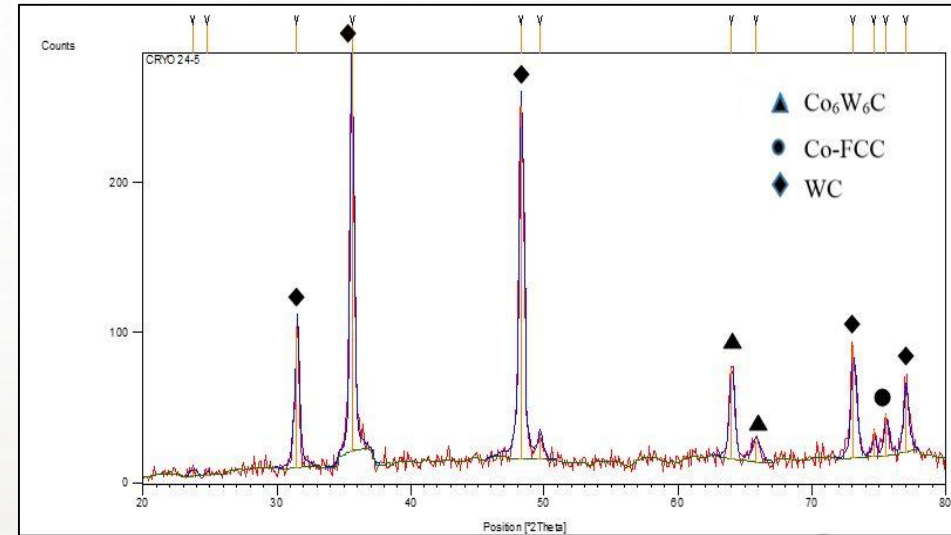
WC Particle

**Figure 2:** Worn out surface of as received used WC-Co die

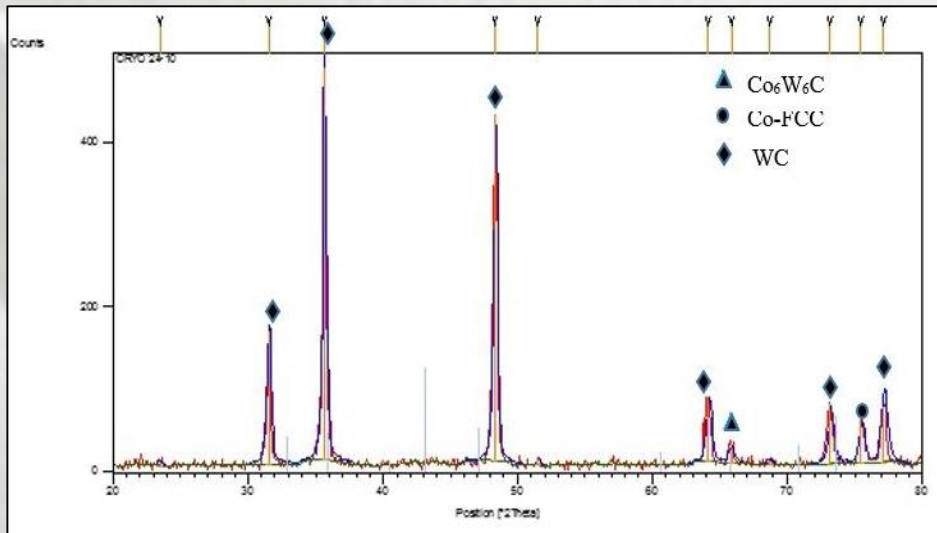
# X-ray diffraction analysis



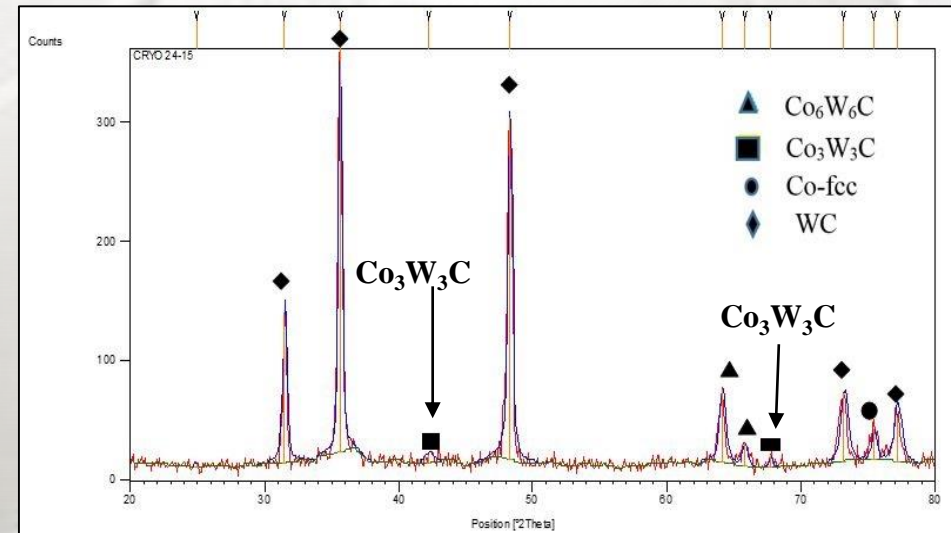
**Figure 3:** XRD pattern of as received sample



**Figure 4:** XRD pattern of HCT 5 sample

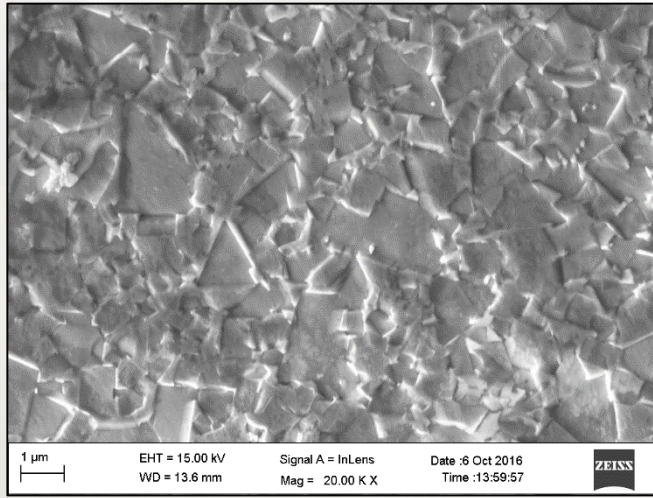


**Figure 5:** XRD pattern of HCT 10 sample

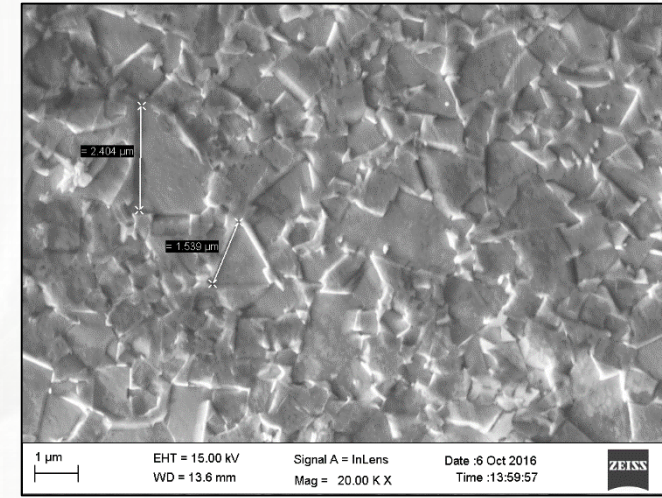


**Figure 6:** XRD pattern on HCT 15 sample showing peaks of  $\text{Co}_3\text{W}_3\text{C}$  phase

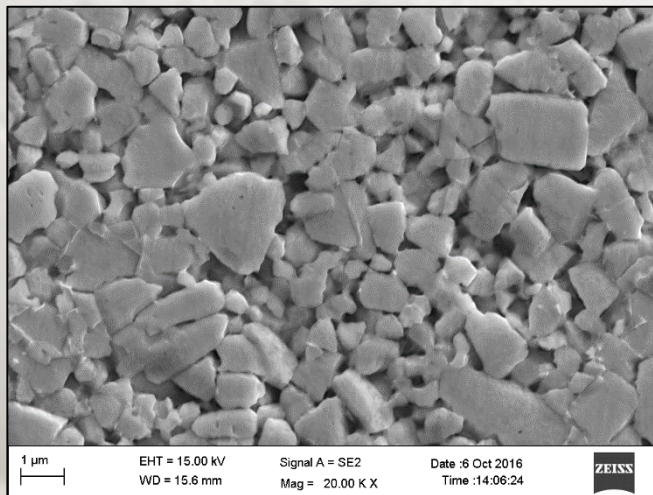
# Microstructures of as received dies



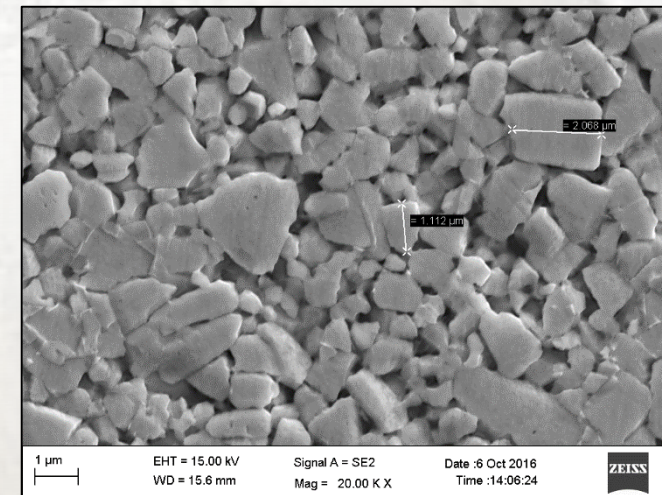
**Figure 7:** microstructure of as-received carbide die (die diameter = 6.15 mm)



**Figure 8:** microstructure of as received die (die diameter = 6.15 mm) showing carbide size

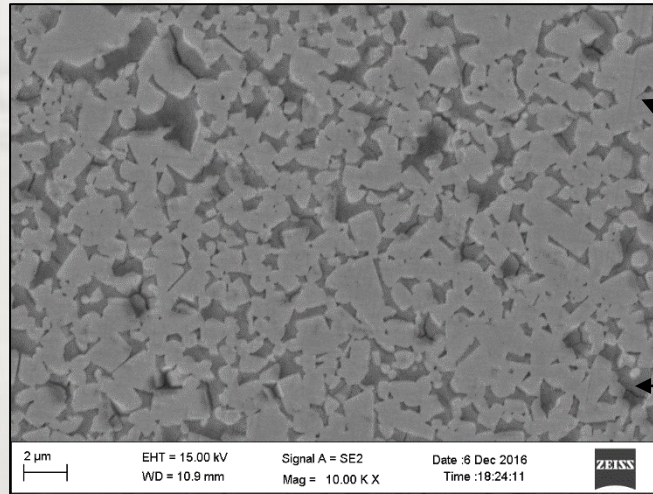


**Figure 9:** microstructure of as-received carbide die (die diameter = 3.46 mm)

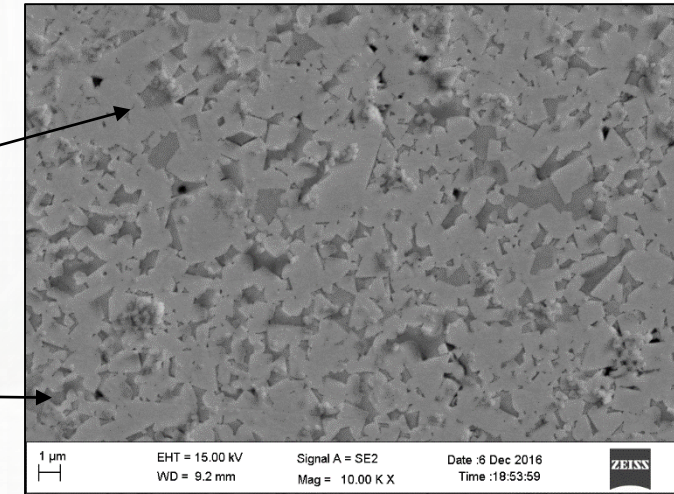


**Figure 10:** microstructure of as-received die (die diameter = 3.46 mm) showing carbide size

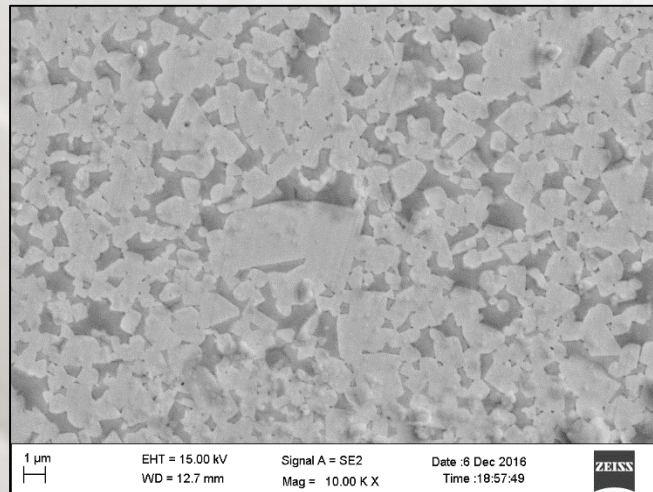
# Microstructures of treated dies



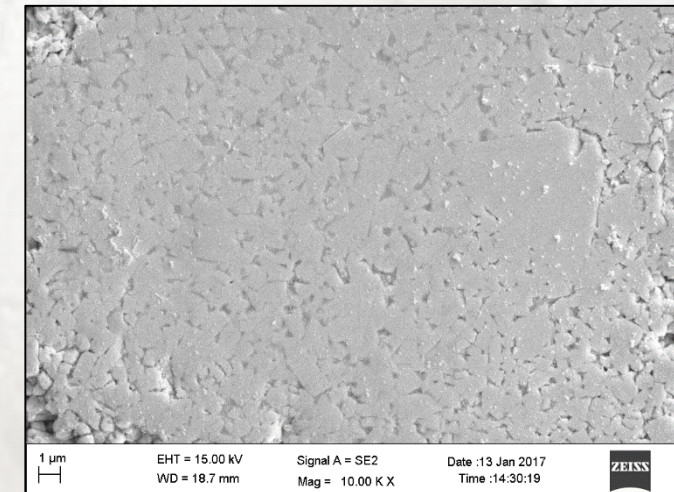
**Figure 11:** Microstructure of HC sample



**Figure 12:** Microstructure of HCT 5 sample



**Figure 13:** Microstructure of HCT 10 sample

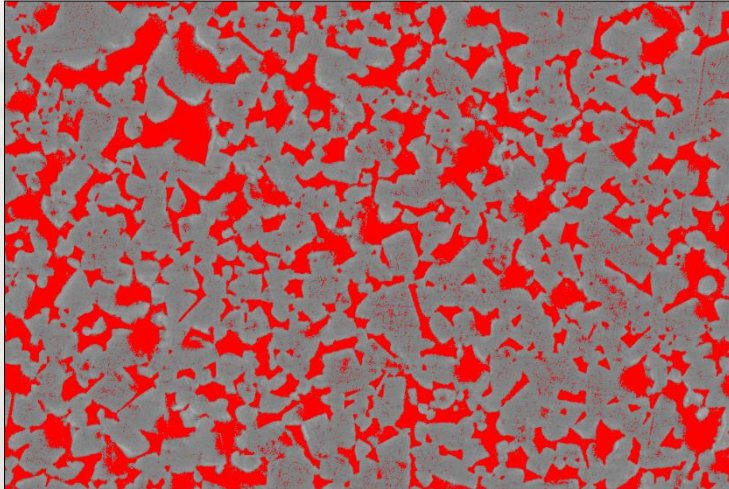


**Figure 14:** Microstructure of HCT15 sample showing sharp decrease in binder content

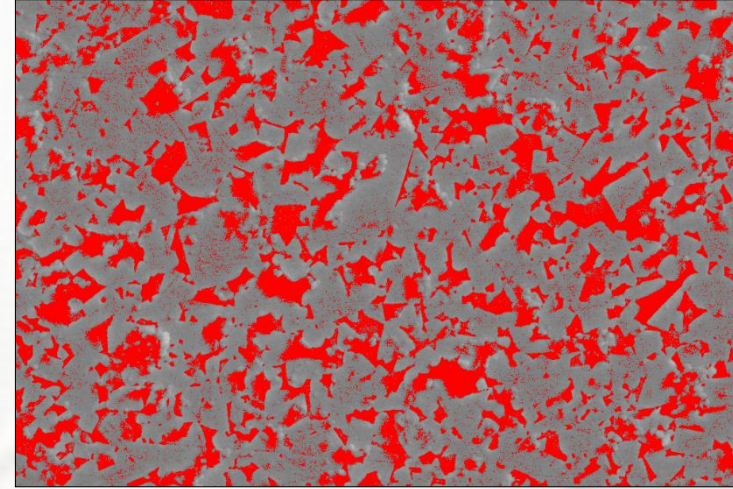
WC particles

Co

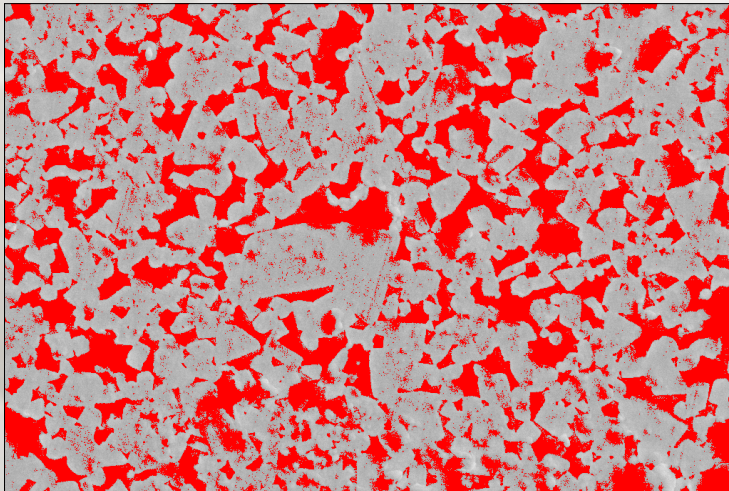
# Phase analysis



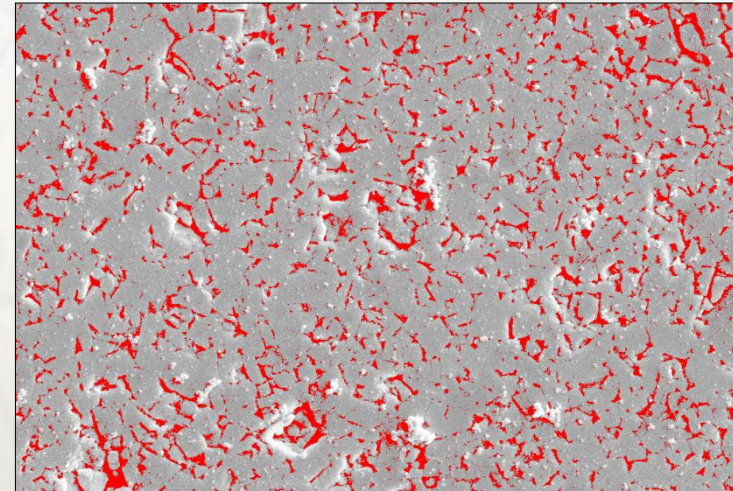
**Figure 15:** Phase analysis of HC sample with binder shown in red colour



**Figure 16:** Phase analysis of HCT 5 sample



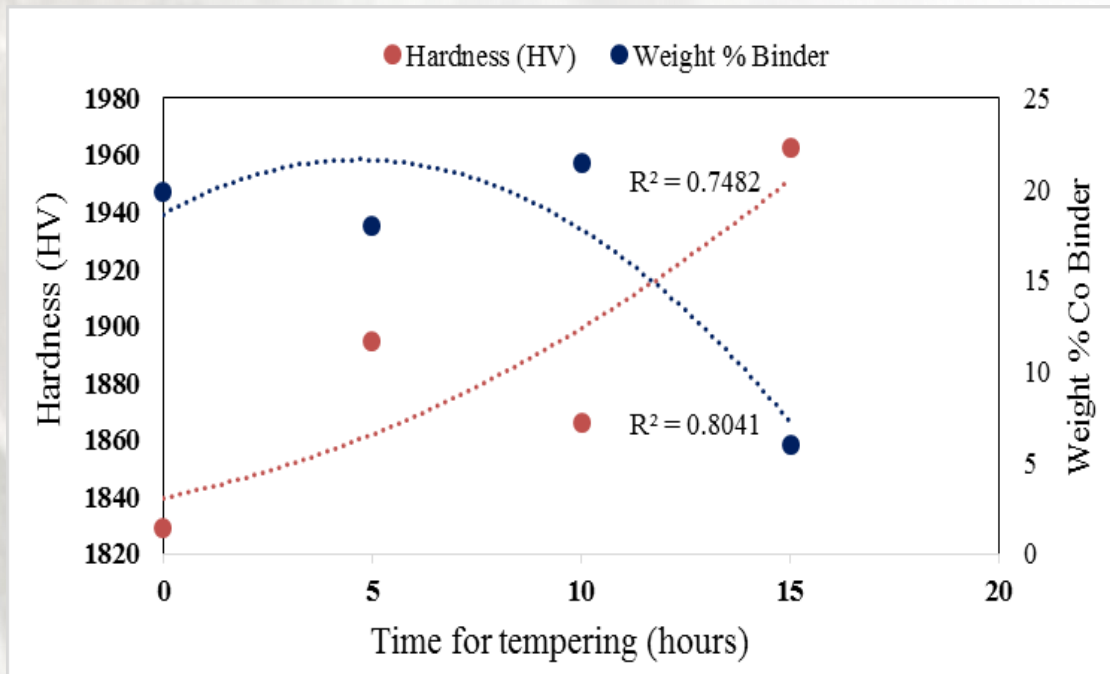
**Figure 17:** Phase analysis of HCT 10 sample



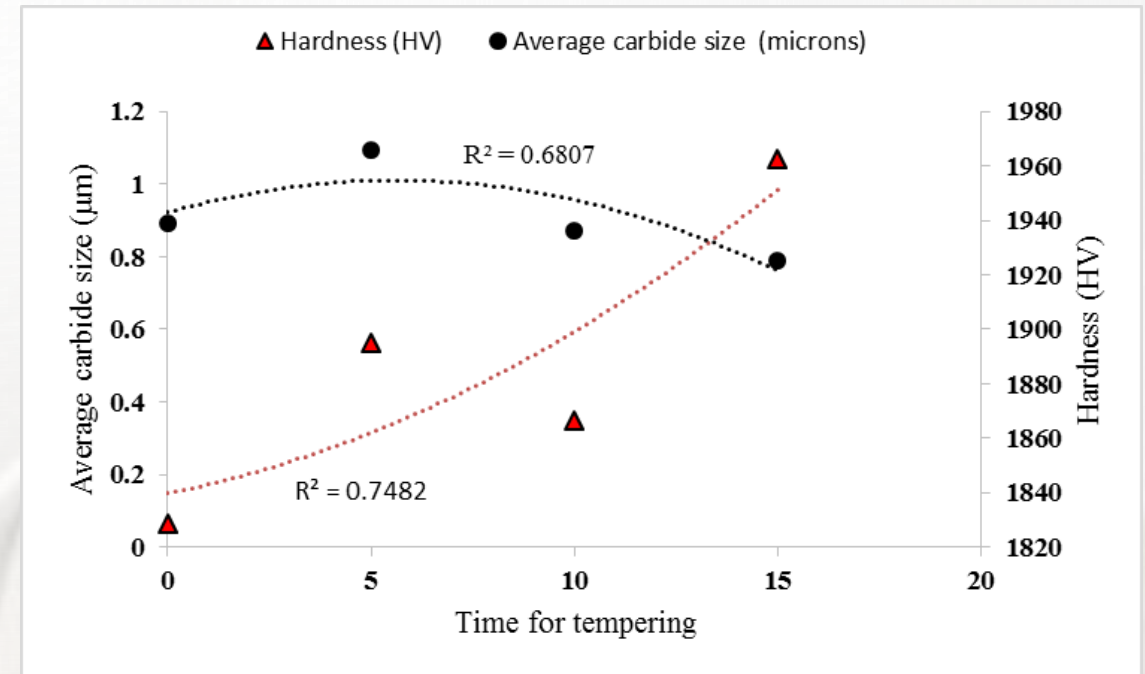
**Figure 18:** Phase analysis of HCT 15 sample showing appreciable drop in binder content



# Results and Discussion

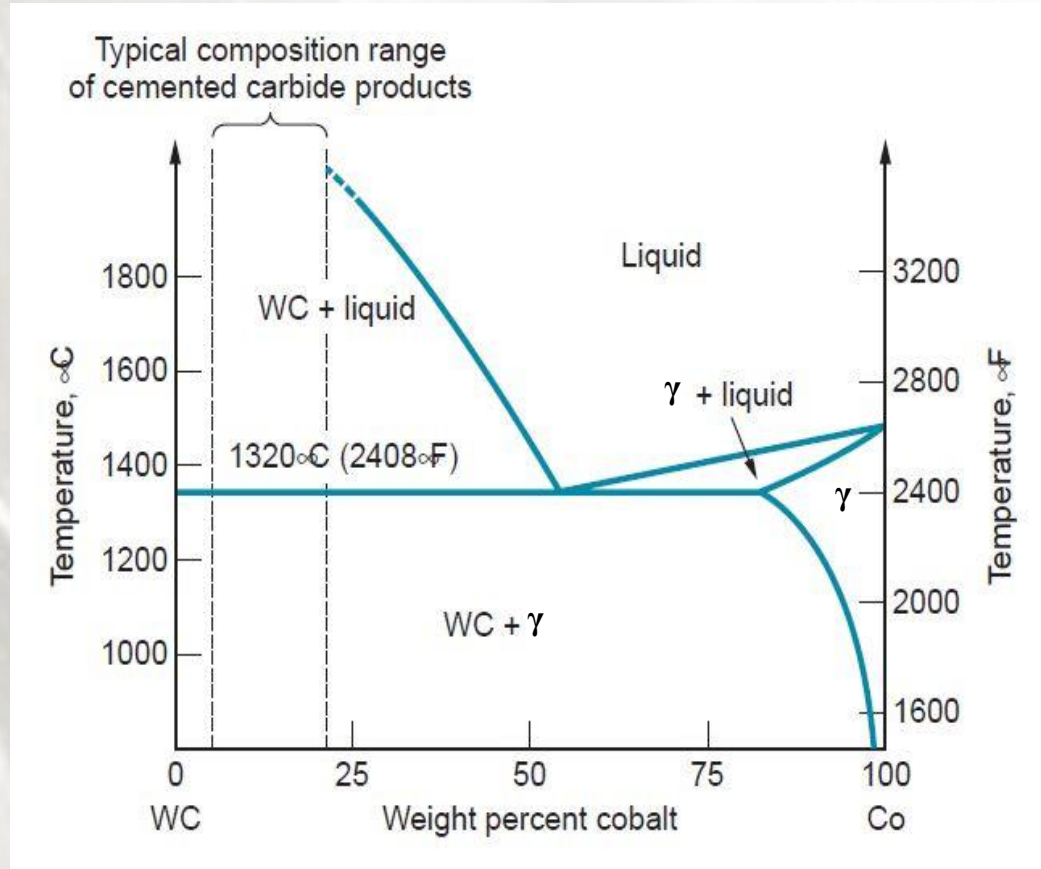


**Figure 19:** Variation in hardness and binder content as a function of tempering time



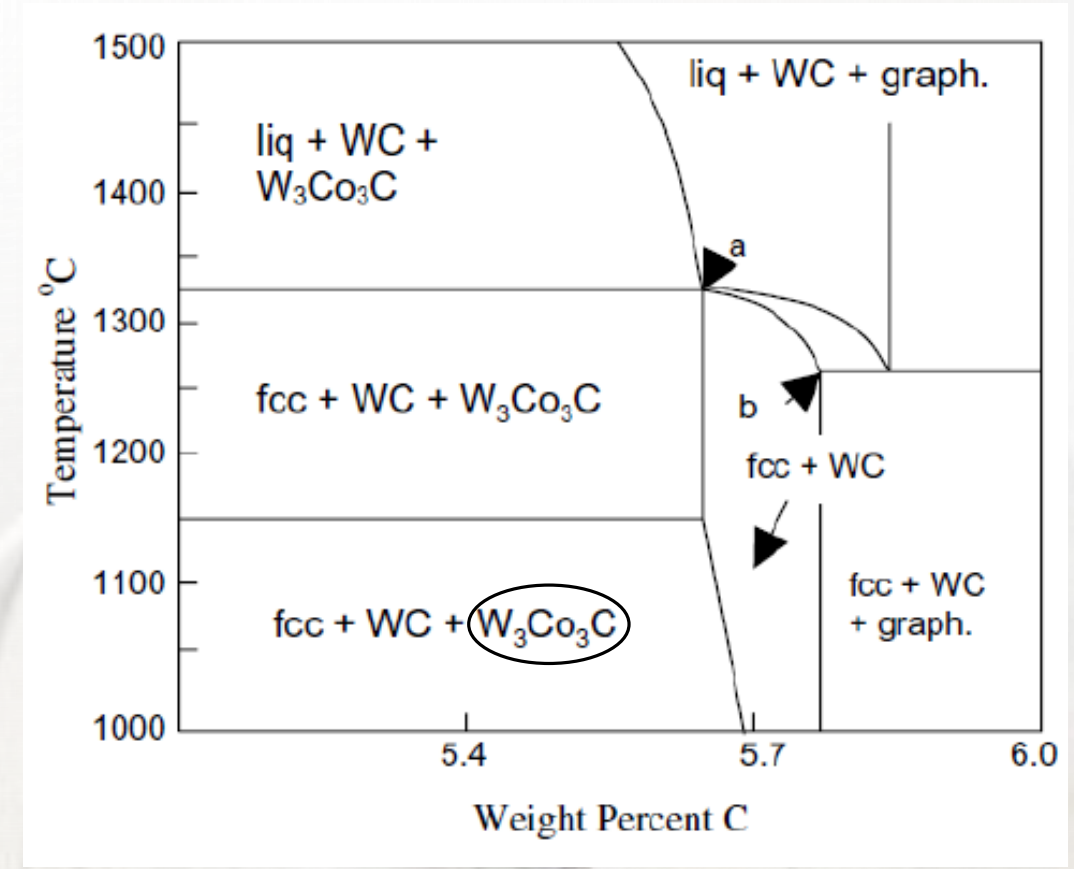
**Figure 20:** Variation in hardness and carbide size as a function of tempering time

# Discussion contd.



**Figure 21:** WC-Co binary equilibrium phase diagram

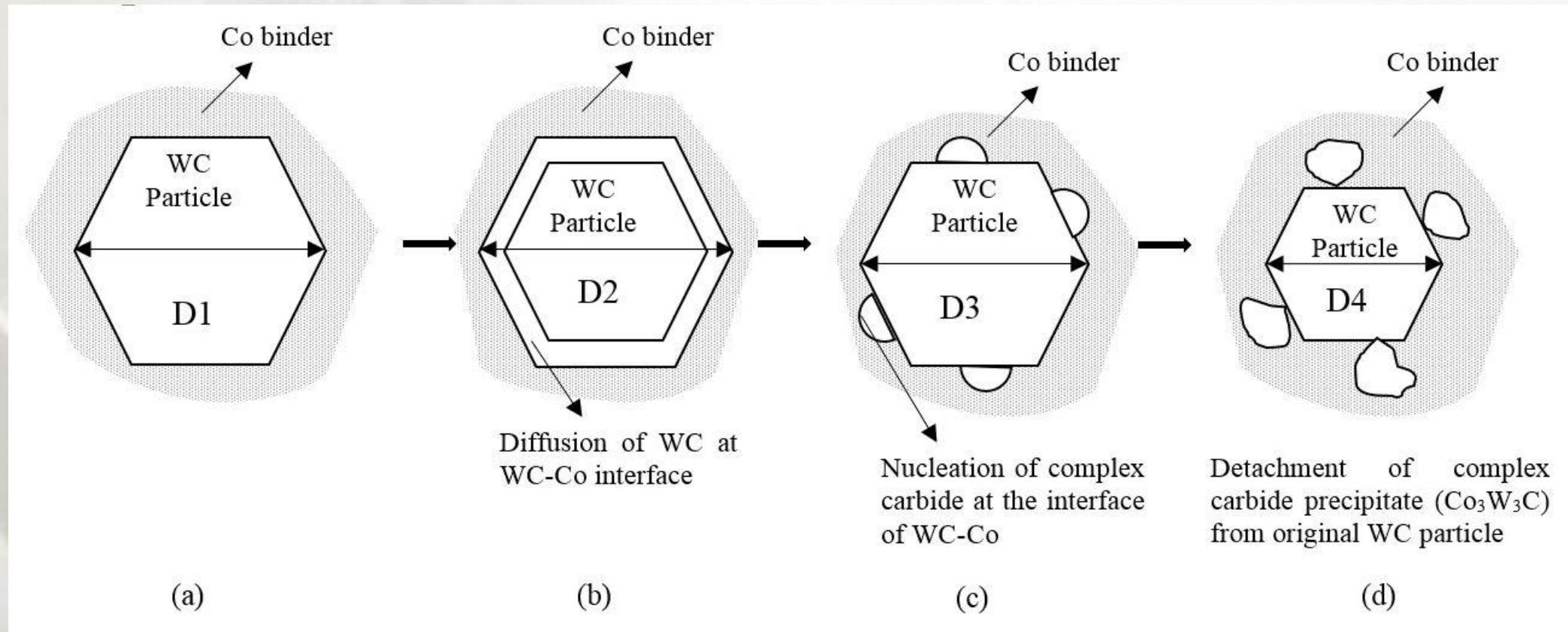
Ref: Groover Mikell, *Fundamentals of Modern manufacturing: Materials, processes and systems*, 4<sup>th</sup> Edition, Wiley Publications, 2010

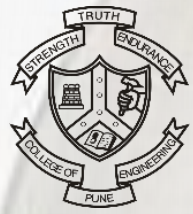


**Figure 22:** Vertical section of W-C-6Co ternary phase diagram

Ref: Z.Z. Fang, O.O. Eso, *Scripta Materialia*, volume 52 (2005), pp. 785–791

Schematic representation of proposed mechanism of complex carbide precipitation:





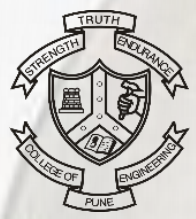
## Conclusion

- Cryogenic treatment is a promising treatment to improve wear and abrasion resistance of hard tool material like cemented carbide
- Cryogenic treatment for 24 hours and 15 hour of tempering gives optimum hardness of the WC-Co material with **7.6% increase in hardness** with peak value **1962.43 HV** and 13 weight % Co binder reduction from 19 weight % to 6 weight %
- Stress and diffusion induced **phase precipitation** of **complex  $\eta$ -carbides** with formula  **$\text{Co}_3\text{W}_3\text{C}$**  is predicted to be a reason behind improvement of abrasion resistant properties in the material



## Way forward...

- Characterization techniques can be carried out to confirm the results:
  - TEM analysis of the interface of WC and Co phases to check the presence and characteristics of complex carbides
  - Atom probe tomography to see the three dimensional distribution of cobalt binder
- Industrial trial of cryo-treated dies for confirming the improvement of die life during practical service



**THANK YOU!**

**ANY QUERIES?**