International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-9 Issue-2, December, 2019

Preparation and Characterization of Tungsten Carbide WC/Cobalt Composites by Powder Metallurgy Method

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***Abstract**: The Tungsten carbide (WC) based composites are good choice to replace the traditional conventional materials for obtaining high hardness and wear resistance. This work investigates the influence of cobalt content on the characterization of Tungsten carbide. The composite specimens are prepared by using powder metallurgy technique. The effect of cobalt material on the performance of Tungsten carbide hardness, fracture toughness is estimated by conducting suitable experiments. While performing experiments, a powder mixture of 89% WC, 11% of Co was manufactured with powder metallurgy, under appropriate milling conditions and Sintering temperature to ensure uniform microstructure. From the present work the optimum sintering temperature of Tungsten carbide mixed nano cobalt composite is identified. The crystalanity of the resulting materials is identified from a rapid analytical technique, X -ray Diffraction.*

***Keywords** : Tungsten carbide, cobalt, powder metallurgy, hardness, Fracture toughness, sintering temperature*

I. INTRODUCTION

Tungsten carbide is a multipurpose material due to its mechanical properties. These materials used in many applications such as ball point balls, bearings, nozzles, jewellery, cutting and drilling tools. There is always a scope to enhance the already available Tungsten carbide in the view of mechanical, electrical properties, cost and weight etc.With this aim, many researchers carried a research work on Tungsten carbide by adding different materials. Rengui He et al. [1] used sol-gel process to manufacture tungsten carbide with nano-cobalt coatings found that the coating of nano cobalt nano powder on the tungsten carbide improved the transverse strength.

The better bonding behaviour of tungsten carbide and cobalt particles was observed by GuoShengda et al. [2].

Using Vickers and Brinell (spherical) micro indenters, the elastic and plastic properties of Ge–Se binary and Ge–Sb–Se ternary chalcogenide glasses are identified [3]. The hardness and indentation load have an inversely proportional relation. These parameters are studied by Eswar Prasad and Ramesh [4] and identified the relation between the silicon crystals size and hardness. These finding are different for elastic modulus and this property is independent on the indentation.

Another case study is focused on flash sintering. Using this technique, the tungsten carbide and iron matrix composite is studied by changing the weight percentage of titanium carbide [5]. While designing a cutting tool, most importance will be given to the wear parameter. Carbide based tools are commonly used tools for cutting tool and these materials are investigated by infusing the cobalt content in the carbide to check the wear behaviour [6].

Considerable work has been performed on Nickel based alloys by using additives such as chromium carbides [7].

The performance or application of newly designed material can be obtained by their mechanical properties with the support of Microstructure. Using Thermodynamics and diffusion kinetics modelling tools, the above mentioned behaviour is explored [8].

Along with wear properties, the friction behaviour are also plays an important role. The friction, wear behaviour of cementite carbide is identified using ball on disk contrast test [9]. The high damage rate of titanium alloys machining rate is explored [10].

In the present work, the hardness and fracture toughness response with sintering temperature is explored using experimental and analytical studies.

II. EXPERIMENTATON AND METHODOLOGY

The Tungsten carbide and nano cobalt mixed composite specimens are prepared by using powder metallurgy technique. The composition of WC and nano cobalt is maintained at 89% and 11% respectively. Initially, the metal powders are collected according to their weight fraction and these powders are mixed in V-cone blender. After mixing of composite ingredients, compaction process has done by preparing a suitable mould.

Revised Manuscript Received on December 30, 2019.
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The prepared powder is transferred into the mould and die is pressed for compaction using a hydraulic press with the capacity of 10 tonne at a rated pressure of 100 bar. The specimens after compaction is presented in Fig.1

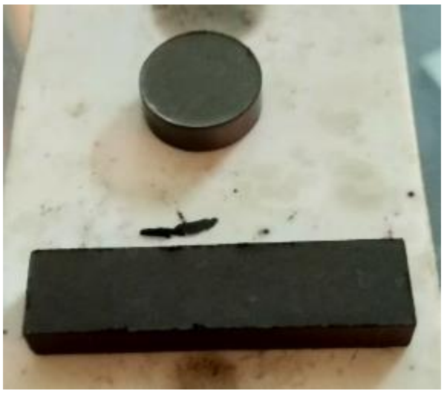

Fig.1. Testing Specimens after compaction

Fig.2. Tubular Furnace for sintering

The next operation followed to prepare a composite material is sintering. The specimens at this stage are sintered at different temperature of 1000-1800^{0}c with an interval of 100^{0}c for four hours in tubular microwave furnace.

This is very important stage to acquire the desired properties for prepared composite. Later the specimens are removed from the furnace and cooled in the atmosphere temperature.

The Micro structure report of composite material is presented in Fig.3. The contribution of each phase in composite material is conformed to with microstructure report produced in Microscope of V.R Siddhartha Engineering College, Vijayawada, Andhra Pradesh, India. The pixels/µm, calib: MS100X, Unit:µm, X:1.6233, Y:1.615.

The area considered for the analysis is 0.1163 sqmm. The standards used are ASTME 562. The information obtained from the Microstructure is in terms of Volume fraction Fig.2., shows the Microstructure along with the volume fraction of each material in the component (Bar graph) primary material about 69% cobalt is 32% and the remaining percentage is shared other elements.

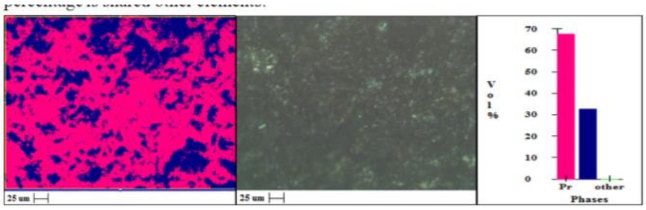

Fig.3. Microstructure Image of Tungsten carbide and cobalt composit

III. RESULTS AND DISCUSSIONS

In this section, the influence of sintering temperature on the hardness of the Tungsten carbide combined with the cobalt nano powder is provided. The sintering temperature decides the final properties of the composite materials. In this study, the sintering temperature is varied from 1000^0 to 1800^{0}c in tubular microwave sintering.

And these temperature influences on the hardness of the Tungsten carbide mixed nano cobalt composite is identified. In terms of hardness, the optimum sintering temperature is identified. Using Brinell hardness testing machine with diamond indenter and the range of load applied on the prepared specimen is 500 kg to 3000kg.

The variation of hardness with respect to the sintering temperature is identified and the same thing is represented in Fig.3. and up to the temperature of 1400^{0}c, the hardness of the Tungsten carbide with cobalt powder is increasing and later decrement in the hardness is observed.

The material prepared by power metallurgy is checked for XRD to know the crystal structure of the material.

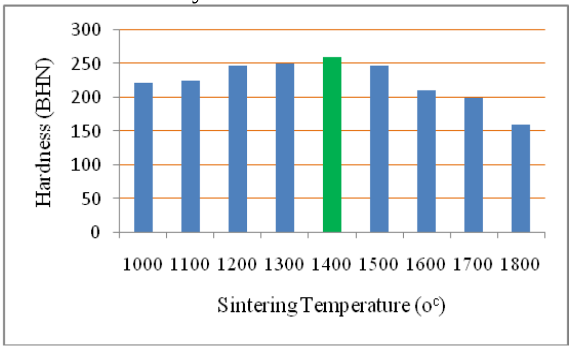

Fig.3. Hardness with sintering temperature

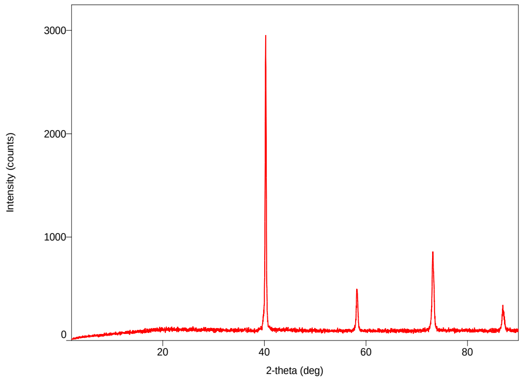

Fig. 4 XRD of tested specimen

Phase identification, crystal structure, and lattice parameter of the crystal solids are identified with X-ray diffraction (XRD) technique. The information obtained from the XRD is used to find the Bragg's law (θ).

To perform the XRD analysis, fine powder samples are used and these powders are placed on the sample holder. The incident light beam rays fall on the sample, will be scattered by the sample atoms. From the scatter rays, the maximum intensity and the corresponding angle will be identified.

The reflecting planes where the X-rays are scattered will be identified and these atomic planes are termed as reflecting planes.

Retrieval Number: B3628129219/2019©BEIESP
DOI: 10.35940/ijeat.B3628.129219
Journal Website: www.ijeat.org

Published By:
Blue Eyes Intelligence Engineering & Sciences Publication

The Bragg's law gives the relation between the wavelengths (α) of the X-rays, the atomic plane spacing (d) and the reflection angle (θ) and the law is 2d sin θ= n λ. Using this information the XRD peaks would be identified.

Table.1. XRD Results of tungsten carbide combined with nano cobalt

S,No.	2-theta (deg)	d (ang.)	Height (counts)	FWHM (deg)
1	40.222(5)	2.2403(3)	2211(47)	0.194(4)
2	58.182(10)	1.5843(2)	342(19)	0.262(11)
3	73.141(7)	1.29285(10)	654(26)	0.292(8)
4	86.938(16)	1.11968(17)	187(14)	0.33(2)

Table.2. XRD parameters of tungsten carbide combined with nano cobalt

S.No.	Int. I (counts deg)	Int. W (deg)	Asym. Factor
1	595(4)	0.269(8)	0.95(10)
2	124.5(19)	0.36(3)	0.69(12)
3	266(3)	0.41(2)	1.05(10)
4	87(2)	0.47(5)	1.1(3)

After characterizing the crystal structure from XRD analysis, using the analytical equations, the fracture toughness of the Tungsten carbide combined with nano cobalt is calculated from hardness of the composite.

The brinell hardness number is converted into Vickers hardness number using the conversion equation and using the following equation 1, the fracture toughness is identified.

$K_{IC}=0.16x(c/a)^{-1.5}x\sqrt{HV}$ [3]

Eq.1

Where HV is the Vickers hardness value obtained by converting Brinell number to Vickers hardness, P is the applied loads, d is the Mean length of the diagonals of the Indentation.

The fracture toughness is high at 1400^0c. [11]. Fracture toughness of the composite is increasing with the sintering temperature of 1400^0c. Later the magnitude is decreased (Fig.5).

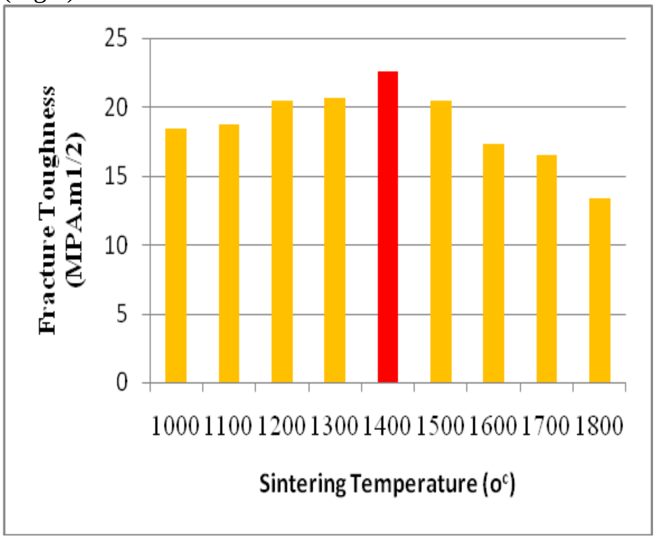

Fig.5. Fracture toughness with sintering temperature

IV. CONCLUSION

Tungsten carbide can use as a cutting tool because of its excellent mechanical properties such as hardness and fracture toughness, but due to its less toughness it may reduce the tool life. Cobalt is added to impact the strength and toughness of Tungsten carbide, and the mechanical properties are improved.

While designing cutting tools from these materials through power metallurgy technique, appropriate sintering temperature is very important parameter because the sintering temperature decides the final Microstructure. The higher the sintering temperature, the higher the hardness level of a material, as sintering temperature increase, the grain growth increased as well. The hardness of the matrix is about 280 HBN which was tested in brinell hardness test. So this ceramic composite matrix (WC-Co) can be used as a cutting tool. The optimum sintering temperature of the composite is 1400^0c for considered composite material

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