Sintering, Shrinkage and Microstructure of NbC-20Ni Cemented Carbide

Daniel Rodrigues[1], Eduardo Cannizza[2]

[1] BRATS Sintered Filters & Metallic Powders, São Paulo, Brazil
[2] EHTCANNIZZA – Consultoria em Engenharia, São Paulo, Brazil

Abstract: The well-established cemented carbides are composites of tungsten carbides (WC) bonded with cobalt, nickel or a mixture of these two binders. Additives as chromium, titanium, molybdenum or vanadium carbides are used to tailor microstructure and mechanical properties. Two general applications for these hardmetals are for machining and mechanical forming tools, and the binder content and grain size are the main adjustable variables regarding the compromise between hardness and toughness. The use of other carbide replacing WC, like NbC, has been hardly investigated. Nickel binding NbC carbides, during liquid phase sintering, works properly and full densification should be obtained. Mixtures of very fine carbides and carbonyl Ni powders were produce by intense ball and attritor milling. WC was used to adjust microstructure. These mixtures were pressed using uniaxial pressures, 50 or 200MPa. Shrinkage was evaluated using dilatometric measurements under an atmosphere of dynamic argon. Samples were also sintered in a DSC/TG equipment. The sintered samples were characterized in terms of microstructure, density, and hardness. Results were presented and discussed. A relationship between sintering cycles and microstructure was established.

Introduction

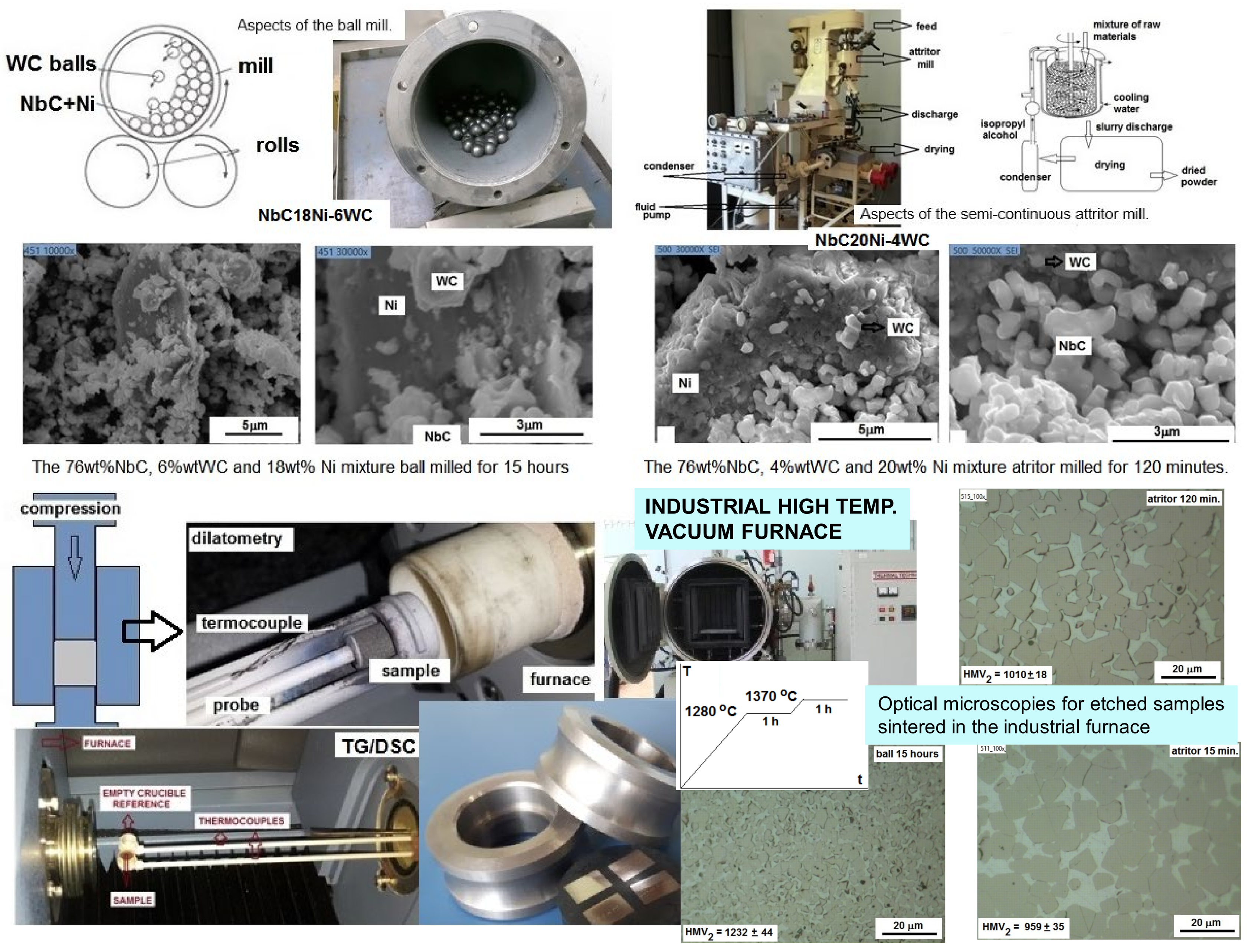
Cemented carbides, as WC-Co, can be used as tools for machining purposes or for processes involving plastic deformation of metals. The carbide provides hardness and the binders, usually cobalt or nickel, are the responsible for the toughness. Lower binder contents and small carbide grain size are used in applications that require very high hardness and high friction properties, like machining tools. On the other hand, the cemented carbides for plastic deformation (metal forming) should have higher binder concentration and large grain size, tailoring hardness and toughness in according the application of the component. These cemented carbides are produced by powder metallurgy, using as starting materials mixtures of carbides (WC, and other carbides) and binder (Co or Ni).

The replacement of WC for other carbides has been hardly investigated. Some authors tested different metals to bind niobium carbides (NbC). More recently, aspects like the addition of other carbides to control microstructure of NbC-Ni systems, the use of new techniques of sintering, as SPS, and the use of intermetallic binders [8], has been pointed out.

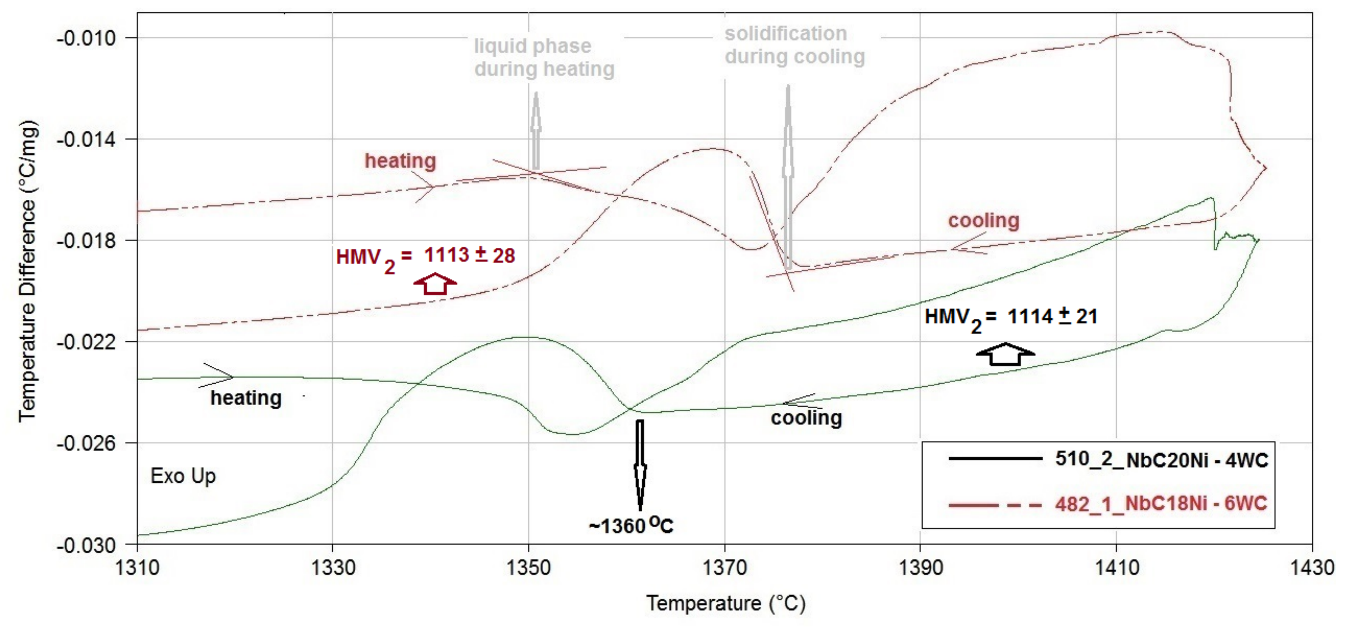
This paper considers the replacement of WC for NbC for hot rolling applications. The binder content used here was close to 20wt% and coarse grain size was the goal to be achieved. Densities close to 8.30g/cm^3 and Vickers Hardness (HMV_2) close to 1100 were expected. Two chemical compositions and two milling processes were investigated. The sintering was monitored in a dilatometer and also by thermal analysis. The presence of a liquid phase, the shrinkage and the microstructural aspects are presented and discussed.

Experimental Procedures

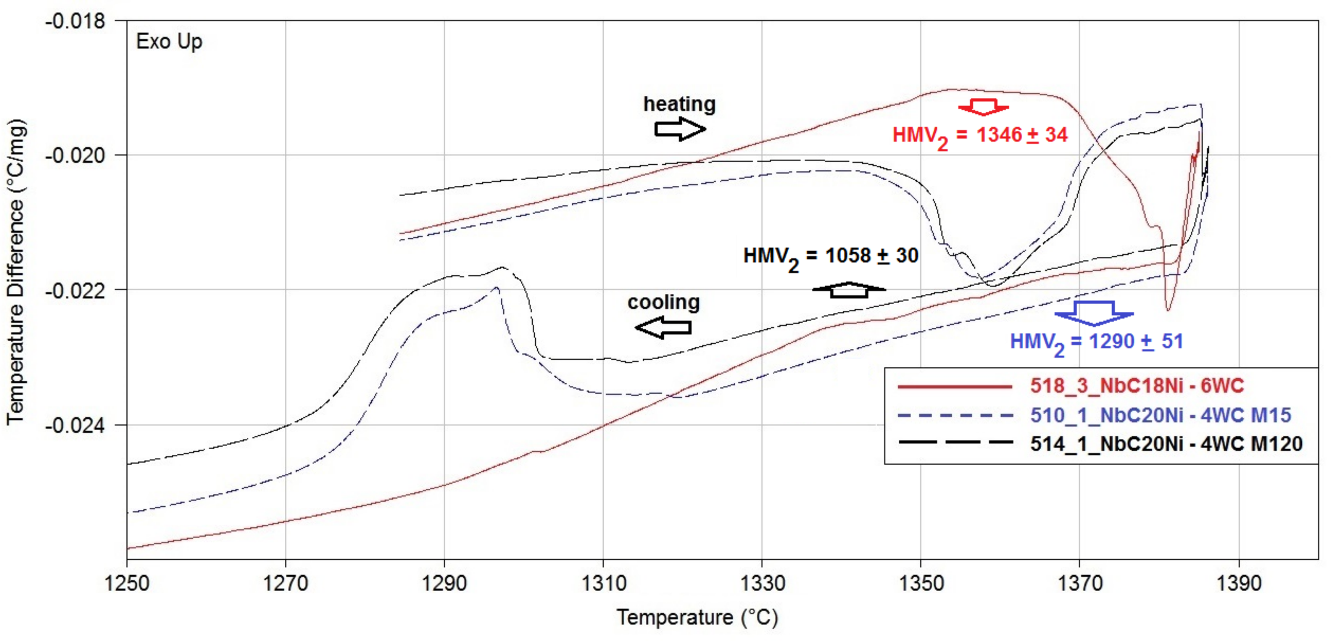
ball (15h) or atritor milling (15 or 120 min.)



Results and Discussion

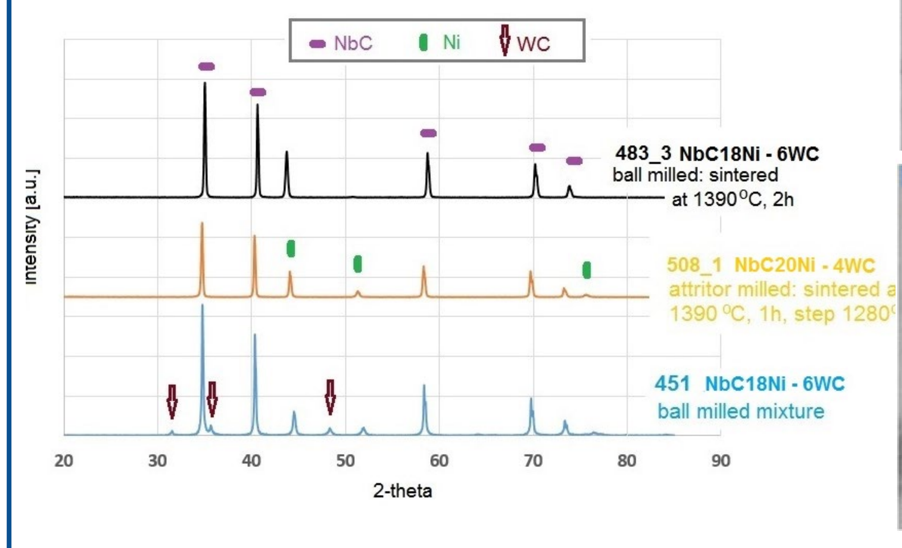


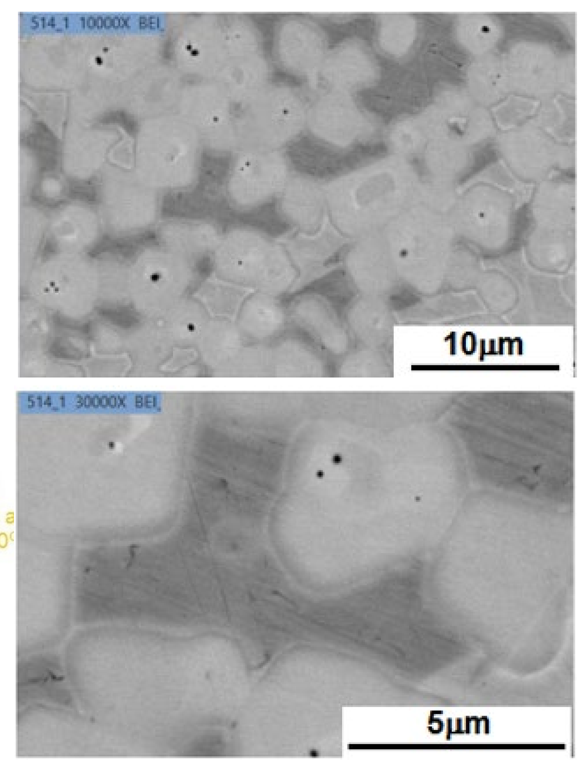
DSC curves for NbC-18N-6WC ball milled and NbC-20Ni-4WC attritor milled (15min.), pressed (50MPa) samples. Very quick heating up to 1200°C, heating up at 10°C/min. up to 1430°C, 5 min. at 1430 °C, and cooling down at 10°C/min. up to 1200°C. Dynamic atmosphere of Nitrogen, 200ml/min.



DSC curves for NbC-20Ni-4WC attritor milled (15 and 120 min.), and for NbC-18Ni-6WC ball milled, pressed samples. Heating at 20°C/min. up to 1280 °C, 60 min. at 1280 °C, 5°C/min. up to 1390 °C, 60 min. at 1390 °C and cooling down at 5°C/min. up to 1200°C. A dynamic atmosphere of nitrogen, 200ml/min., was used.

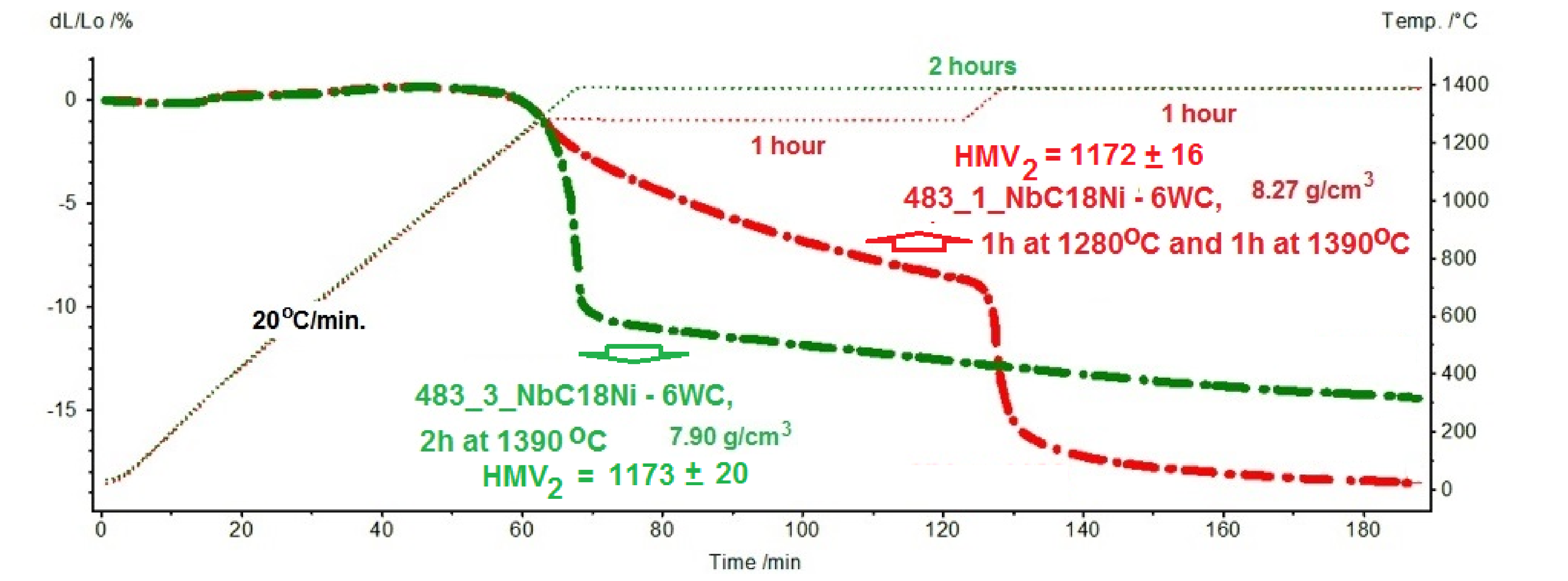
DRX for the ball milled mixture and for ball and attritor milled sintered samples. It was used a Cu k-α radiation



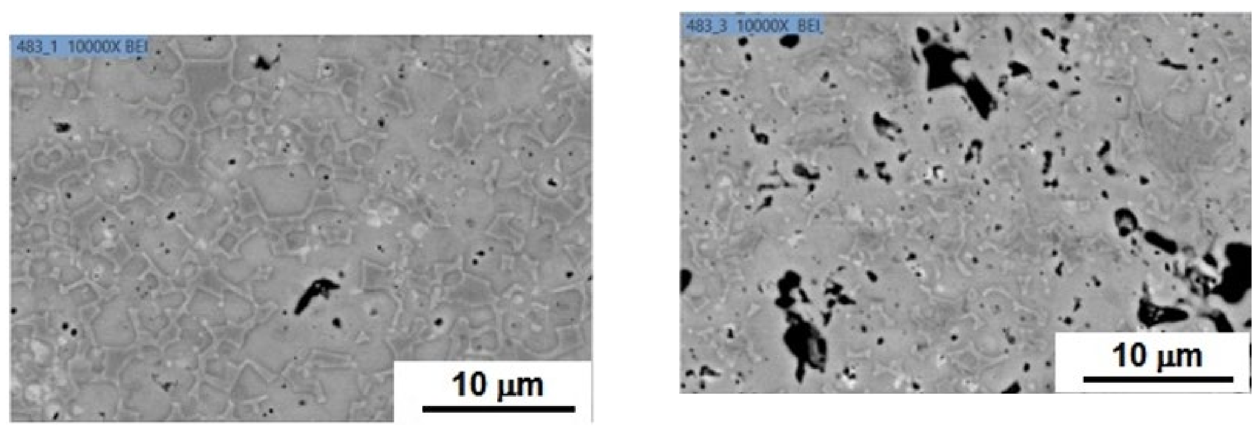


BSI: NbC20Ni-4WC attritor milled, pressed (50MPa) and sintered (1390°C) (DSC/TG) sample. Previous lower temperature (1280°C for 1 hour),.

Results and Discussion

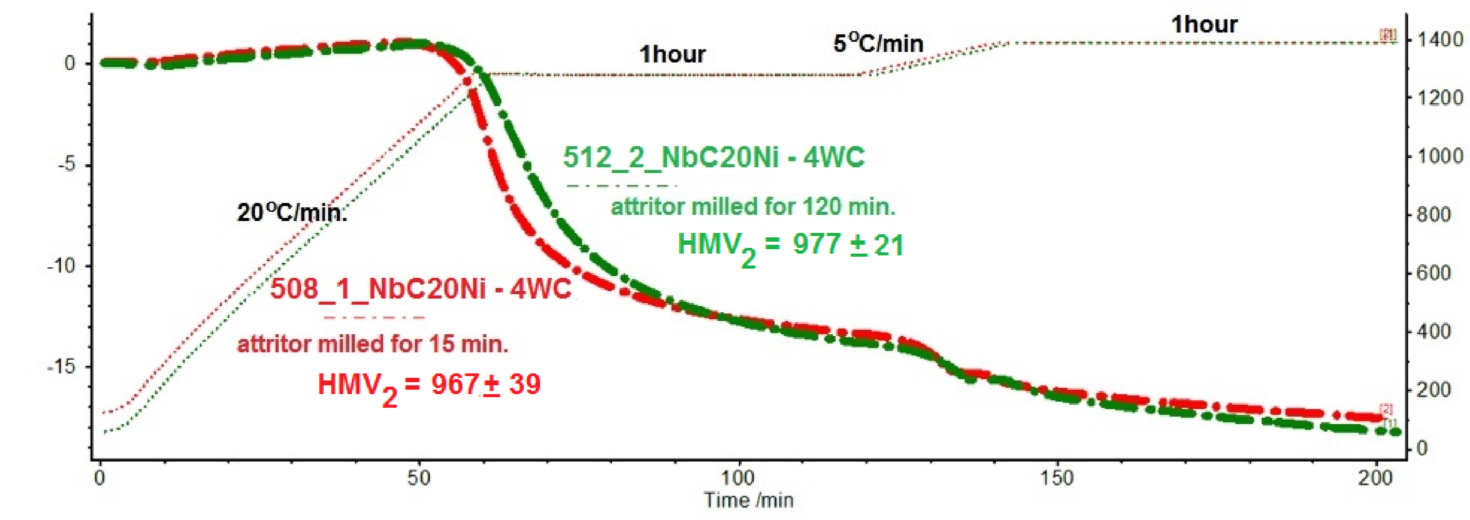


Dilatometric curves for NbC-18Ni-6WC ball milled samples pressed at 200MPa. Heating rates of 20°C/min., with (483_1) and without (483_3) a lower temperature (1280°C) step. Dynamic argon (200ml/min.) atmosphere.

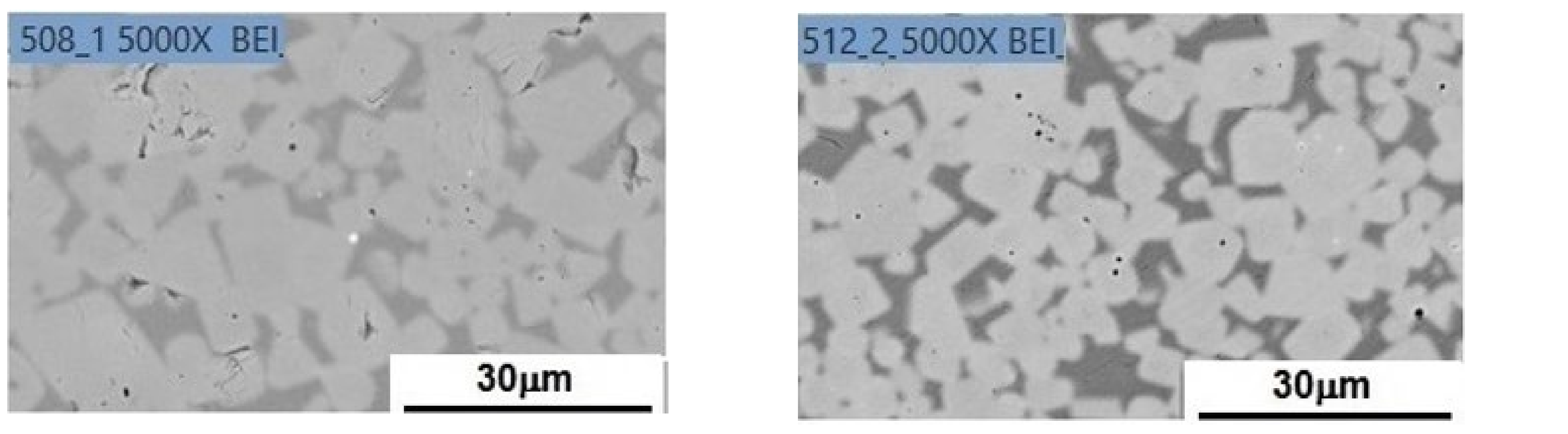


BSI: NbC-18Ni-6WC ball milled and pressed (200MPa) sample. One step: 2 hours at 1390°C.

BSI: NbC-18Ni-6WC ball milled and pressed (200MPa) sample. Two steps: 1h at 1280°C, and more 1h at 1390°C.



Dilatometric curves for NbC-20Ni-4WC attritor milled and pressed (200MPa) samples. Heating rates of 20°C/min., 1 hour at 1390°C and 1hour at 1280°C. The sample 508_1 was from powder milled for 15 minutes and the 512_2 was milled for 120 minutes. A dynamic argon (200ml/min.) atmosphere was used.



BSI: NbC20Ni-4WC attritor milled (15 minutes) and pressed (200MPa) sample. Two steps: 1 hour at 1280°C, and more 1 hour at 1390°C.

BSI: NbC20Ni-4WC attritor milled (120 minutes) and pressed (200MPa) sample. 1 hour at 1280°C, and more 1 hour at 1390°C.

Conclusions

- The interaction between carbides and carbonyl nickel powder seems to be more intense for attritor milled mixture. In this case, the nickel particles appear to be coated with carbides;
- A liquid phase occurs at around 1350°C during heating up. The chemical composition and sintering cycle affects the behaviour of this liquid phase during cooling;
- The "solid state" (1280°C) sintering, before sintering step, improves shrinkage and final density for the NbC-18Ni-6WC;
- It was observed that the WC strongly dissolves during sintering, since no DRX peaks for WC were observed on the sintered samples, and a high concentration of tungsten in the binder was determined;
- There are no shrinkage differences, considering dilatometric curves, for attritor milled and pressed samples, considering milling times of 15 and120 minutes. The grain size for sample produced with a longer time milled mixture showed a finer grain size;
- The carbides on the microstructure of the NbC-20Ni-4WC appear to have different chemical compositions, particularly on their surfaces.

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