Parameter Study of Carbon/Carbon in Hot Pressing Applications

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Abstract. The suitability of carbon/carbon as material for hot pressing moulds has been investigated in comparison to conventional graphite moulds. Various alloys like bronze, cobalt and tungsten carbide have been sintered. The quality of the sinter parts has been determined by tests of the Rockwell hardness and density measurements. These investigations have shown that carbon/carbon moulds can be more advantageous for hot pressing techniques than graphite moulds.

Introduction

Carbon/carbon is a high temperature material with better specific mechanical properties than graphite which is commonly used for hot pressing techniques. Therefore parameter studies have been performed to substitute graphite parts of a hot pressing mould by carbon/carbon.

The object was to investigate the suitability of carbon/carbon for hot pressing moulds. Comparative sinter experiments have been performed to demonstrate the influence of various sinter temperatures and different chemical conditions on the quality of the sintered parts. The suitability of carbon/carbon will be discussed from the viewpoint of the quality of the sintered parts, life-time of the mould, temperature distribution within the mould, failure propability and economic aspects.

Test methods and materials

The experiments have been performed with a commercially available hot-press (DSP 25, Dr. Fritsch KG). Sinter parameters, mould material as well as the quality requirements are given in table 1.

The quality of the sintered segments was determined by the Rockwell hardness according DIN 50103 and by density measurements. The weight-loss and failure of the moulds was taken as a measure about their life-time. The temperature distribution within the mould was controlled with 6 thermocouples.

3. Results

Some results of the parameter study are compiled in table 2. In case of carbon/carbon moulds the number of segments is higher as in case of electrographite moulds. However, the plate thickness for carbon/carbon was not yet optimized. This increased number of segments is caused by the higher specific properties of carbon/carbon resulting in thinner separator-, side- or end-plates of the mould.

The optimum sinter pressure was independent from the mould material. Variations of the sinter pressure have shown no influence on quality and homogenity of the segments for optimized sinter temperatures. In case of the bronze alloy neither the sinter pressure nor the sinter temperature was modified due to a complete fulfill of the quality requirements.

However, the quality of the sintered parts is strongly influenced by the sinter temperature. In case of cobalt alloys the optimum temperature for the carbon/carbon mould is 40 °C higher, whereas tungsten carbide could be sintered at the same optimum sinter temperatures.

The influence of the sinter temperatures on the quality of the segments is also reflected in the inhomogenity. The temperature distribution within the mould determines the homogenity of the segments. Lower temperature distribution results in a lower standard deviation of the physical properties of the sintered parts. Therefore, more homogenious segments have been obtained with carbon/carbon moulds in case of cobalt alloys. Whereas in case of bronze and tungsten carbide electrographite moulds are superior.

As can be seen, the quality requirements are fulfilled completely in case of bronze, whereas in case of cobalt alloys one segment per sinter process in the electrographite mould had to be rejected due to the unsufficient temperature distribution (table 2).

Table 1. Mould materials, sinter parameters and quality requirements

Moulds	Parameters	Alloys	Sinter Parameters*		Quality Requirements	
			Temp. (°C)	Pressure (kP/cm²)	Hardness (HRB)	Density (g/cm³)
Varied Parameters:	Sinter temperature	Bronze	680	250	75 - 78	8.4
Materials:	Sinter pressure					
Electrographite	Sinter time	Cobalt	800	350	98 - 102	8.5 - 8.6
CFC with electrographite stemps	Temperature distribution					
Combination of CFC and electrographite	Failure propability	Tungsten Graphite	1100	350	50	10.8
	Economics					
Types:						
same area						
same number of segments						

*given by the supplier of the powder

Table 2. Results of comparative sinter experiments

alloy		cobalt			bronze		tungsten carbide	
mould		Electro-graphite	CFC	CFC	Electro-graphite	CFC	Electro-graphite	CFC
		10 fold	10 fold	16 fold	10 fold	15 fold	7 fold	12 fold
Optimum pressure	(kp/cm²)	350	350	350	250	250	350	350
optimum temperature	(°C)	800	840	840	680	680	1080 – 1120	
standard deviation of temp. within the mould		±7.8	±9.55	±11.35	±9.25	±15.6	±10.6	±22.7
segments with theoretical value of hardness	(%)	90	100	100	100	100	71.4	83.3
segments with theoretical value of density	(%)	100	100	100	100	100	100	100
statistical failure propability of the separator plates per sinter process	(%)	0.53	0	0	0.13	0	0.38	0.006
statistical failure propability of the end and side plates per sinter process	(%)	0.06	0	0	·	·	0.03	0
statistical failure propability of graphite stemps	(%)	·	·	·	0.006	0.014	0.37	0.18
weight loss	(mg/100°C x mm)	17.24	6.73	7.26	13.86 (6.28)	17.84 (10.15)	10.0 (6.7)	6.7 (4.2)
time consumption per segment with sufficient properties	(sec)	66.7	60	37.5	56.2	32.2	193	86.02
segments per hour		54	60	96	62	113	19	42
energy consumption per segment with sufficient properties	(kWh)	2.36	1.38	1.36	0.36	0.22	·	·

the values in parentheses are results from oxidation protection

The influence of temperature distribution is most severe at higher sinter temperatures (tungsten carbide). After each sinter process the two outer segments had to be rejected for the carbon/carbon as well as the graphite mould. The graphite stemps of these outer segments, which are used for all moulds, were broken after each sinter process of tungsten carbide. Therefore the sinter pressure could be reduced drastically for these segments, resulting in less hardness.

The life-time of hot pressing moulds depends on handling parameters, oxidation, mechanical and chemical attack. The failure propability of the carbon/carbon parts is neglectable. During all sinter experiments only one separator-plate of carbon/carbon was damaged. In no case a failure of side- or end-plates occured.

In contrary to the carbon/carbon-material the failure propability of electrographite parts is significant higher especially for separator-plates and graphite stemps. The failure of the electrographite parts was always combined with a nonuseable segment. These segments had not been taken into account for the number of segments which fulfill the quality requirements.

A further limiting factor of the life-time is given by the weight-loss of the mould. In all cases the weigth-loss of moulds with carbon/carbon parts was lower compared to pure electrographite moulds.

From economic viewpoints time and energy consumption is of interest in regard to the life-time of the mould material. The number of sintered segments per hour is up to 120 % higher in case of carbon/carbon-moulds. Furtheron the energy consumption per segment is essentially lower.

Summary and conclusion

The parameter study under lab-conditions has shown clearly that carbon/carbon can be applied for hot pressing techniques as substitute of conventional electrographite. The superior mechanical properties of carbon/carbon resulted in a neglectable failure propability of the mould and therefore in a tremendous decrease of useless segments. Furthermore a gain in energy and time resulted by the use of carbon/carbon as mould material under lab-conditions.

A realistic estimation of the economic viewpoints must take into account the behaviour of carbon/carbon moulds under tests in praxis. The higher material prices of carbon/carbon moulds must be justified by an increase of life-time and a more economic sinter process under praxis conditions. The problems of handling, deforming, reproducibility of segment sizes and surface qualities in praxis are unknown and have to be investigated.

First tests in praxis have shown that carbon/carbon can be used for hot pressing moulds in some cases. However, often the life-time of the carbon/carbon parts can be limited by their surface quality, chemical attack of oxidizing components of the sinter powder, impregnation of carbon/carbon with liquid sinter components and by improper handling. Some of these problems in technique can be solved by increasing the possibilities of potential applications of carbon/carbon hot pressing moulds.

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