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RESEARCH

About the Tribological Behaviour of Ceramic Materials

The process pumps, which are used in refineries and chemical industry, are equipped 90% with face seals. The economical functioning of various technological processes is and will remain tightly related to solving problems from the sealing system of dynamic equipments. This is also proven by the long experience of researches made at producers and some technical universities. The ceramic materials are being used for over three decades to improve tribological systems, as a result of their chemical stability and wear resistance. The paper presents some aspects of ceramic materials, use in primary seals construction, as well as results of their behaviour in different situations, compared with other material couples.

Keywords: ceramic materials, wear resistance, face seal, carborundum, material choice

1. INTRODUCTION

The materials, which are used in the mechanical face sealing systems, must contain some properties, in order to correspond to the exploitation conditions, required by the dynamic gears and the appliances they are used in.

The experience proved that a mechanical face seal presenting some accounting and some design errors, but made from a good material, is often more functional than one made from a worst material, but with no errors of any kind.

Knowing how important the material is for the mechanical face seal, we emphasize the conditions required in the primary mechanical seals:

a) Mechanical characteristics (Table 1,2): compression and contact pressure high resistance, wear resistance, impact resistance, high elasticity module and last, but not least, anti-friction properties even when the interstice fluid is partially or totally absent;

b) Chemical characteristics: corrosion or electrocorrosion resistance, good hydroscopic properties, good absorbency of the lubricant film;

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c) Thermal characteristics (Table 1,2): small dilation coefficient, high thermal conductance, heat shocks resistance, minimum changes of the required temperature domain properties;

d) Physical characteristics: high electrical resistance, good radiation resistance;

e) Production characteristics: measured stability, good processing, no opened pores included.

We can talk about convenient characteristics when the materials used for the mechanical face seal display resembling dilation coefficients and also when these materials are between the limits accepted for the thermo-conductibility coefficients.

The choice materials choice, according to the corrosion process, is not established only considering one usage case, but considering a lot of usage cases. The chemical stability and also the physical and mechanical properties are defined for the mechanical face seal design. The materials choice must be made according to the running and the execution conditions and also according tot the price.

Nowadays, we use for the mechanical face seals the following materials groups:

a) Plastic materials: polyamides, rubber, PTFE, graphite, bakelite, etc.

Table 1. Mechanical and thermal properties for the Wolfram Carbide.

Material	Wolfram Carbide (WC)		
	WC with Ni as binder		WC with Co as binder
	WC-Ni	WC-Ni-Cr	
Proprieties	91-94% WC 6-9% Ni	89-91% WC 9-11% NiCr	88-94% WC 6-12% Co
Density [g/cm3]	14,8 – 14,9	14,3 – 14,6	14,3 – 14,9
Strength Compressive [MPa]	4000 – 5000	4500 – 5600	3200 – 6200
Young Modulus [MPa 10^4]	60 – 63	57 – 59	55 – 63
Hardness [HV]	1390 – 1500	1375 – 1700	1230 – 1640
Dilatation Coefficient [α 10^{-o} (1/ k)]	4,8 – 5,6	5,0 – 5,6	4,6 – 7,0
Thermal conductivity coefficient [W/mk]	44 - 80	35 - 120	80 - 115

Table 2. Mechanical and thermal properties for the Silicon Carbide.

Material	Solid Material		Compound Material	
	SiC	SiC-Si	SiC-C-Si	C-SiC
Proprieties	98-100% SiC 2% C	86-92% SiC 8-14%Si	60% SiC	80% C 12% SiC, 8% resin
Density [g/cm3]	3,05 - 3,2	3,05 – 3,1	1,95	2,65
Strength Compressive [MPa]	2000 - 3900	1200 – 3000	82,7	600
Young Modulus [MPa 10^4]	39 – 43	30 – 41	1,39	13,5
Hardness [Skler]	2500 – 2600	1500 – 2900	90(HB)	125(HB)
Dilatation Coefficient [α 10^{-o} (1/ k)]	2,9 – 4,5	2,9 – 4,6	3,0	2,7 – 5,8
Thermal conductivity coefficient [W/mk]	89 - 115	100 - 130	125	50 - 52

b) Metals and metallic alloys: steel, high alloy steel with Cr, Ni, Mo, bronze, grey alloy cast iron with Cr and Ni;

c) Metallic-ceramic materials: $Al2O3$, MgO, $SiO2$;

d) Metallic carbide: WC, TiC, SiC (Fig.1).

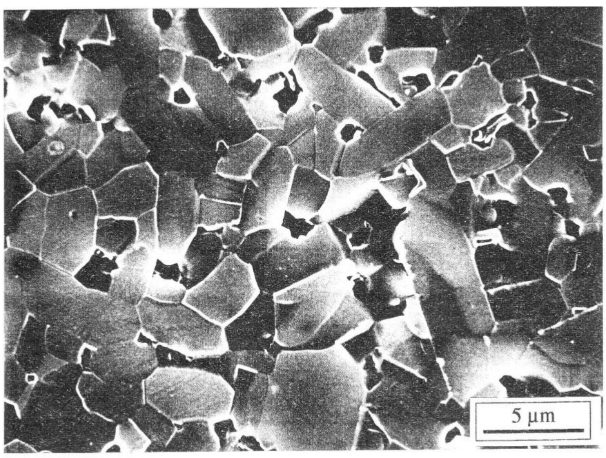

Fig. 1: Silicon carbide microstructure

The materials used in the face seals construction must prove a lot of proprieties to satisfy the working condition requirements. The experience showed that a wrong designed seal is often better that one is well designed but made from the inadequate materials. In most using cases, the synthetic and ceramic from carbon materials are opposite to another two types of materials: the metallic oxides and carbides. The materials choice has to be made according to working and manufacturing conditions and cost price.

2. CERAMIC MATERIALS USAGE AT MECHANICAL FACE SEAL

For 30 years, the ceramic materials have found their usage in the mechanical face seals construction. Their advantages – as chemical stability and high wear resistance – are preferred to their disadvantages - a hard primary mechanical seal's getting out and fabrication.

The ceramic materials usage started with the alumina, a material which is also used nowadays. Very important for the ceramic materials usage in the mechanical sealing techniques, were the high prices needed in order to obtain the end product.

So, these ones find their implementation necessary only when the other materials do not correspond to the requirements.

The requirements asked for the primary mechanical seal are different, depending on the work conditions. The materials couples which are composing the primary mechanical seal may be divided in two groups: hardmild and hard-hard.

From the hard-mild group we mention: SiC-Si and C, SiC-C, Al2O3-C.

From hard-hard group are taking part: Si C-Si, Si-C/Si C, Si C-Si/Si C-C-Si (Fig.2).

From the chemical requirement point of view (acids or alkalis), these two groups are acting differently, the hard-hard group being better used with acids.

From the abrasive wear resistance point of view, the first group is acting weakly than the second one. The same for the mechanic requirement point of view: heat shock, thermal conductance and form stability.

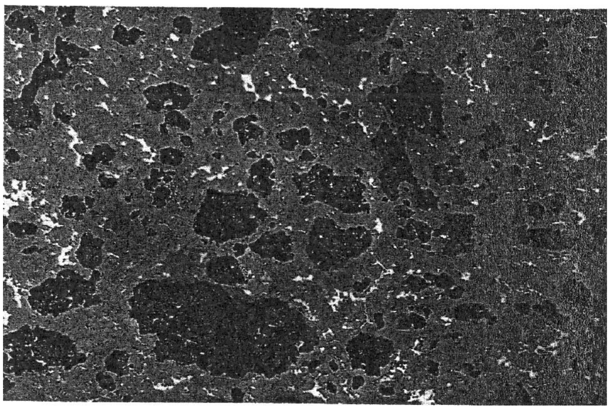

Fig.2: SiC-C-Si microstructure (50…300 μm size of pores)

From the friction behaviour point of view, the first group is better. That's why generally we prefer the hard-mild group. This materials combination is resistant and has a very proper behaviour in dry running. The low lubrication or even the absence of the lubricant cause the mild element wear. But we can be prepared for this case with a material supply, in order to keep the mechanical sealing function for a longer period of time. The abrasive substances presence inside the fluid leads to an uncontrolled wear and, in consequence, the usage may become a problem.

The stress to the high contact pressure and to the high sliding speed is limited because of the reduced elasticity module and also because of the weak thermal conductance. The hard-hard materials couples usage limits are definitely bigger. For these materials couples, theoretic speaking, the contact surfaces wear is null. The dry running and the direct contact of the mechanical sealing surfaces leads to uncontrolled impairments and to flows rising. In order to assure a safe running and to use the ceramic materials advantages, the primary mechanical seal must work contact less. The projects purpose is to attain primary mechanical seals which should run in HG mode of operation. In this way, the durability can be improved through friction losses reduction and also the leakage will decrease.

The projects results showed us ceramic materials couples, their surfaces having different bends and roughness, running in HG mode of operation.

Figure 2 presents the SiC-C-Si polished pattern structure which presents a very good heating transfer coefficient. This material can successfully substitute the graphite ring. The size, numbers and distribution of individual pores (unbounded) make the optimization studies object in the sense of hydrodynamic film apparition. The using of SiC-C-Si material is characterised by superior proprieties because in it composition exists free carbon (in fact is graphite).

The seal surfaces topography is optimised after calculus processes and experience and they must maintain the shape under pressure and temperature actions which can modify the interspace geometry. In this way it maintains the seal film loading capacity and the absence of seal surface direct contact.

The seal surfaces deviations can be avoided by constructive achievement of the primary seal geometry and using high resistance materials based on SiC. The same material choice is advantageous due to optimum thermal conductivity because are avoided the deviations given by the temperature gradients.

The Figure 3 presents different morphologies of the SiC-C material used at the gas lubricated face seal.

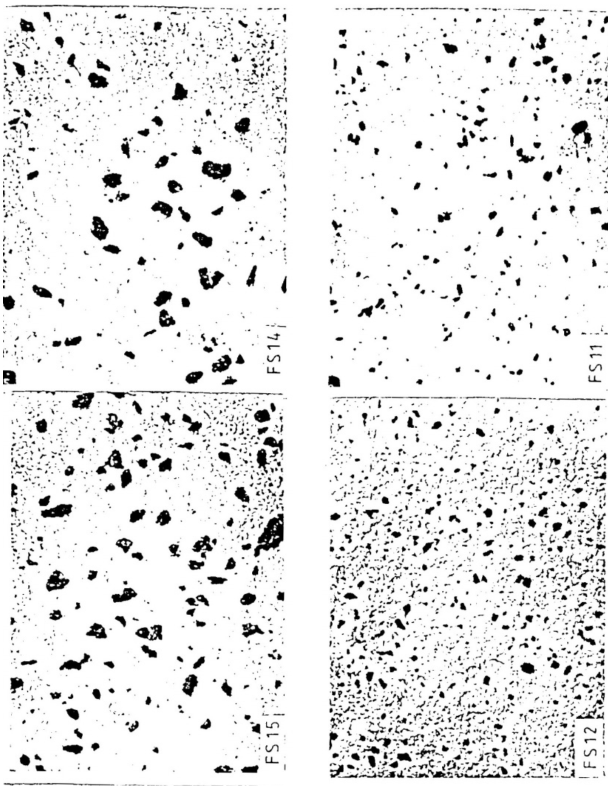

Fig.3: SiC-C microstructure.

3. MECHANICAL SEAL MATERIALS BASED ON MICRO-CONFIGURED CARBORUNDUM

Besides the hydro-dynamic action mechanical seal surface bend, the surfaces roughness is very important, due to the very small clearance. That's why the roughness is a very important parameter for the primary mechanical seal tribological behaviour. The running conditions in special cases can be improved, adopting the right micro-geometry structure. The carborundum based ceramics structure along with their high hardness allow such a processing that the formal error is lower than 0,1 μm and the roughness is approximately 0,003 μm. Such superior quality surfaces display an adherence tendency in the repose state. When the pump is set in, the entrainment part from the torsion moment transmission may clip an entrainment element of the rotary ring from the cinematic chain. That's why, through a poorly controlled processing of the surfaces, such phenomena can be avoided.

Researches have been made about the roughness and structure influence at the tribologic stressed surfaces. The result showed us a new ceramic material based on Si C-Si, having different dimensions plastic material pores.

In order to attain these materials having proper surfaces for a good tribologic behaviour, two kinds of problems must be solved: ceramic surfaces structure classification and the tribological quality.

a) Ceramic surfaces classification

The values which characterize the surfaces microgeometry parameters are statistical data and describe the processing state. All the usual measurement equipments feel the surface's linear profile and figure it out surfaces micro-geometry parameters, from the measured data. This is not enough in order to categorize the surface micro-structure from the tribological point of view. We will use an example to explain. If the micro-structure displays little cavities having a pore form, this means that the surface is characterized by a good bearing and also by a good tribologic behaviour, because inside those pores the liquid can be stocked and the friction regime at the departure is mixed.

If the little cavities are bound together, composing a channel, then the liquid is flowing and the tribologic behaviour is not proper.

Using the palpation unidirectional procedure, information about the micro-structure characterization can be lost.

The tribologic behaviour of the two surfaces is obviously different, although both of them display roughness parameters identical or alike, conforming with the usual measurement procedures. Unidirectional measurement procedures may be used, if the surfaces are identical from the structural point of view. If the information about the two-dimensional topography is missing, it is uncertain to use the usual indexes in order to characterize the tribologic behaviour.

b) In order to attain some micro-structured surfaces, the carborundum has been melt before the fritting process with delicately dispersed carbon.

The new born material micro-structured process may be influenced in large limits according to the carbon quantity and to the carbon particle size. This new ceramic product is called SiC-C-Si. During the friction surface furbishing, the carbon particles wears down more acute, leading to a pore functional surface.

4. CONCLUSIONS REGARDING THE MATERIALS CHOICE

The principal parameter which imposes the materials choice for the friction couple – primary seal is the kind of sealed environment which is characterised by the chemical and mechanical aggressiveness.

From the performed analyses, the conclusion we draw is that the graphite based on materials are used in almost 60% of the cases. From this group, the most used is the graphite allied with antimony. The next one is the graphite allied with artificial resin.

The graphite is used in 90% of the cases for the fixed ring making up and it forms the friction couple with the allied steel or with the metallic carbides.

Another category of the frequently used materials, in a 15-20 %, are the carbides. The most used ones are: the tungsten carbide allied with the nickel and also the carborundum. More and more frequently, the carbon composed ceramic materials (SiC-C-Si).

Besides the materials choice, their combination is the most important part of a mechanical seal project.

A good cooperation between the materials manufacturers and the users assures the improvements of existing materials and development of new materials.

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