Report of Cooperative Education

Improve Abrasive Property of High Emissivity Ceramic Coating

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Cooperative Title: Improve Abrasive Property of High Emissivity Ceramic Coating

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Abstract

Ceramic coating for heat exchanger needs to consider physical and chemical properties of the coating and the process structure-property-performance relationship. Nowadays, the commercial coating has a high abrasive resistance property than the coating of Thai Oil Public Company Limited (TOP). The objectives of this research are to propose methodology and improve abrasive property of coating and ceramic craze. There are 6 experiments to improve abrasive property of coating and ceramic craze include substrate blasting, coating chemical preparation, the coating on the substrate, thermal curing, film-forming checking, and abrasive resistance test. After modifying fillers and adjust the molar ratio of SiO_2: K_2O by increasing colloidal silica 1, 1.5, 2, 2.5, 3.3, 4.5 and 6.25 g, the result showed that molar ratio of SiO_2:K_2O are 6.12, 6.42, 6.73, 7.03, 7.52, 8.25 and 9.32, respectively. And it showed that the trend of mass loss after abrasive resistance test has the same trend. And the trend decreased to the optimum value. It means that the highest abrasive resistance is found for the A+2g colloidal silica and B+2g colloidal silica, the molar ratio of SiO_2 to K_2O at 6.73. The filler composition and the molar ratio of SiO_2 to K_2O significantly affected by abrasive resistance. The abrasive resistance and film-forming are related, if there is a high abrasive resistance then there will be a small ceramic craze.

Acknowledgements

I would like to express my very great appreciation to Thai Oil Public Company Limited for recruiting me as a co-operative education student and giving me the opportunity to do the co-operative education project. I am very grateful to Dr. Nikom Chawalitkijmongkol, researcher and all members in the research and development section for giving knowledge and supporting me to complete the co-operative education project successfully.

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Pongsakorn Khamchuaysin

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CHAPTER I

INTRODUCTION

1.1 Background

Ceramic Coating is a protective thin film for all kinds of parts and can dramatically increase their useful life, and therefore, productivity increases by reducing maintenance downtime and by achieving longer run times before repairs are needed. Ceramic coatings are inorganic, non-metallic solid and inert thin films made by deposition, heating and subsequent cooling, which may be crystalline. That is, the definition of ceramic coatings is often restricted to inorganic crystalline thin films. Ceramic coatings have been used for many years in a variety of industries. One particular use of ceramic coatings is in the field of furnace refractories. Specifically, ceramic coatings with high emissivity are applied to the interior of a furnace to improve the efficiency of the furnace.

Ceramic coating for heat exchanger needs to be considered physical and chemical properties of the coating and the process structure-property-performance relationship by using material analysis (characterization) to assist in this project. The chemical substances have properties that can be used during the maintenance period can be used at high temperatures without damage including able to resist stress from heat stress. The internal coating has good cohesion, adhesion and the coating layer should not have cracks after the coating. Nowadays, the commercial coating has a high abrasive resistance property than the coating of Thai Oil Public Company Limited (TOP).

Abrasive resistance has been widely used to reduce or eliminate wear, extending the lifetime of products. Abrasive resistant coatings can also be used in certain environments unsuitable for ceramic coating. Moreover, abrasive resistance has been employed to strengthen mechanical properties, such as hardness and toughness.

1.2 Objective

1.2.1 Propose methodology and improve abrasive property of coating.

1.2.2 Propose methodology to improve ceramic craze.

1.3 Scopes of work

1.3.1The substrate was used at chromium 12 weight percent (12Cr).

1.3.2 Laboratory in Thai oil research and development centre at National Science and Technology Development Agency (NSTDA).

1.4 Expected outputs

1.4.1 Method abrasive resistance of the coating.

1.4.2 Improved abrasive coating composition.

1.4.3 Method to improve ceramic craze.

Figure 3.2 The equipment and samples for blasting (a) Blasting equipment set (b) Garnet (c)Surface roughness tester and (d) Samples before-after blasting.

3.2 Raw material and ratio of ceramic coating

In this project, the formula of ceramic coating has 3 main components are used: 1.active agent & filler 2.binder and 3.co-binder or binder promoter to create a coating with reduced ceramic craze and increase adhesion (details of each component are shown in Table 3.1 and 3.2).

Table 3.1 The coating compositions.

Coating compositions	Amount (wt%)
1.Binder	X
2.Co-binder/Binder promoter	Y
3.Powder 3.1 Active agent (emissivity agent) 3.2 Filler	Z
4.Deionized water (type II)	/

Table 3.2 Filler contents in each case study.

Case study	Types of filler					
	A	B	C	D	E	F
1	x					
2		x				
3			x			
4				x		
5	z			y		
6		z		y		
7	z				y	
8		z			y	
9						w

Where x, y, z and w are the amount of filler in weight percent (wt%).

3.3 Coating chemical preparation

The process of mixing substance before spraying the coating in the project, weighing the substance 1.active agent and filler 2.binder 3.co-binder or binder promoter proportionally in table and mix the substances by using mixing sequence as shown in figure 3.4

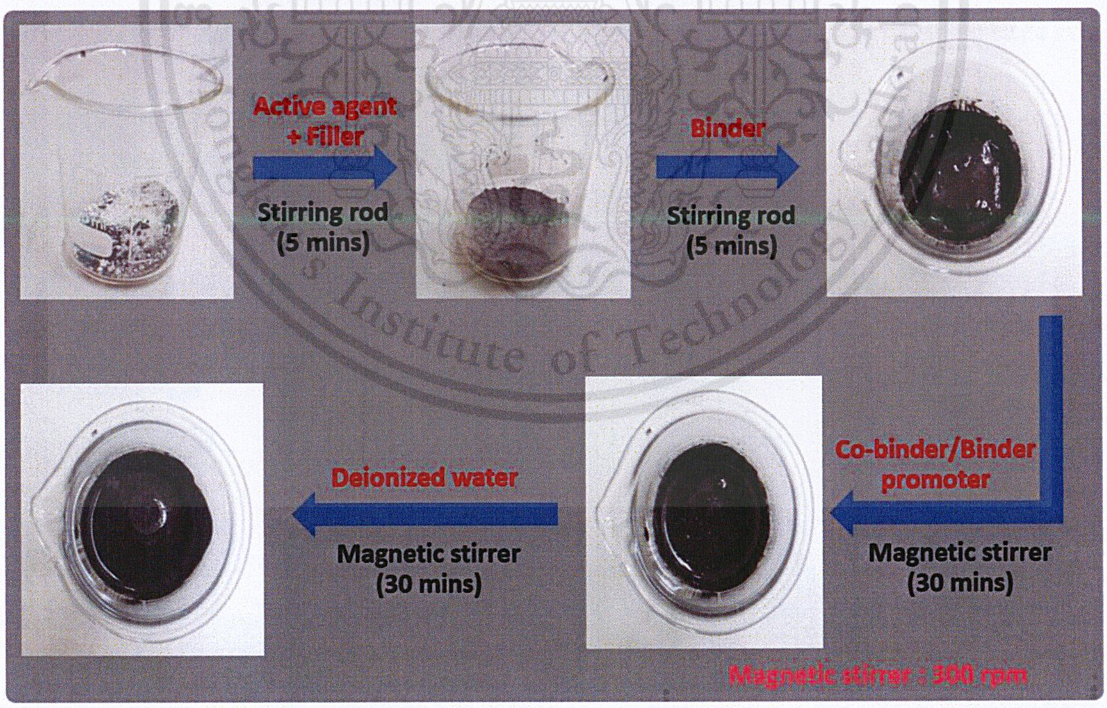

Figure 3.3 The sequence of coating chemical preparation process before spraying on a substrate.

3.5 Thermal curing

The heat treatment gives heat to the 12Cr substate to remove moisture and to create a bond, including the phase change in the coating, increasing the adhesion efficiency between the coating and the substance. By the order of thermal curing, as shown in Figure 3.6. When the heating process is finished and allow the system to cool at room temperature with a cooling condition in the furnace.

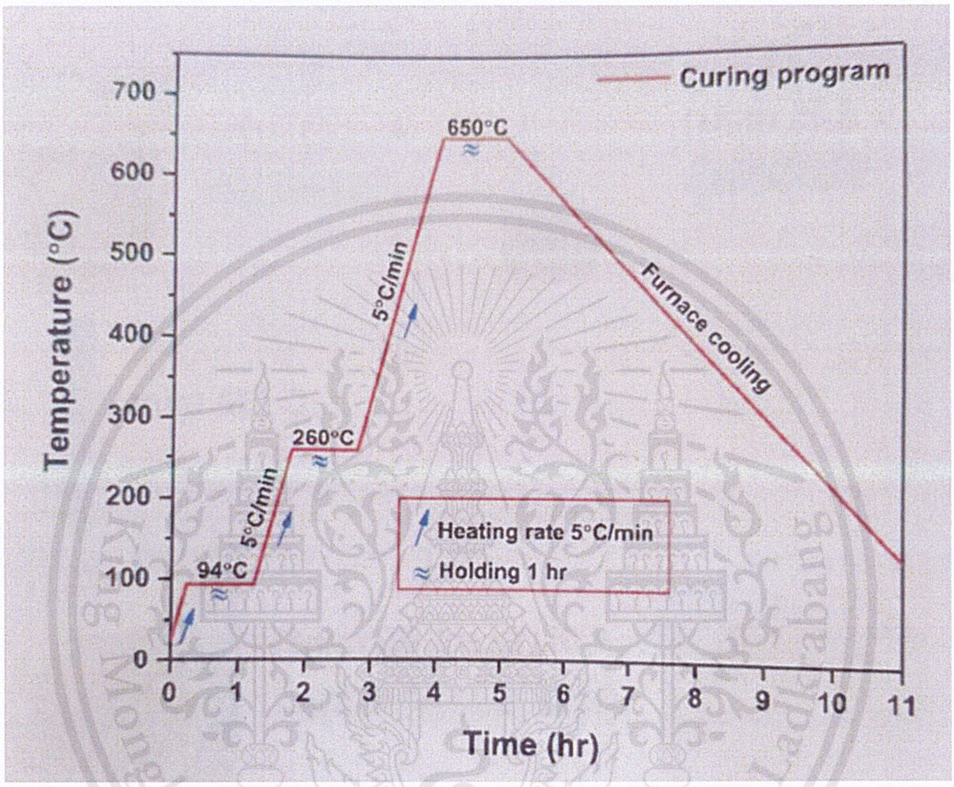

Figure 3.5 The order of thermal curing.

3.6 Inspection of physical characteristics of the coating after thermal curing by using an optical microscope (OM)

Optical microscopy (OM) is a form of light that helps visualize with a magnification of up to 2000 times. The working principle is that the light from the light source first hits the object and then the light is reflected through the lens at least 2 lenses that are inside the system and reflect back into our eyes will enable us to see the image, with the characteristics of the information being given as two-dimensional (2D) images.

3.7 Abrasive resistance test

This test is a test of physical property that simulates the phenomenon of being hit by contamination and running with friction on the samples. The equipment for the abrasive resistance test is shown in Figure 3.7.

Abrasion resistance test, beginning with weighting the sample before testing. Then control the rotation speed of 60 revolutions per minute (rpm) for a total of 1000 cycles. After that, the sample is weighed again to find mass loss from the abrasive resistance test. After every test, sandpaper will be used to scrub the contaminated material into 50 rounds.

Figure 3.6 Abrasive resistance analyzer.

CHAPTER IV

RESULTS AND DISCUSSION

4.1 The results of abrasive resistance test

The coating development project can develop the coating to have thermal properties similar to the thermal properties of the materials used in the industry. But still not able to be used because film-forming surface and abrasion resistance are not good enough. Therefore, has studied and developed the properties of abrasion resistance. Analysis of the effect of abrasion of the substrate. That has gone through the coating process according to the formula obtained The type of filler has changed. And add a hard binder type of colloidal silica to adjust the molar ratio of SiO_2: K_2O.

4.1.1 The results of abrasive resistance test in filler A

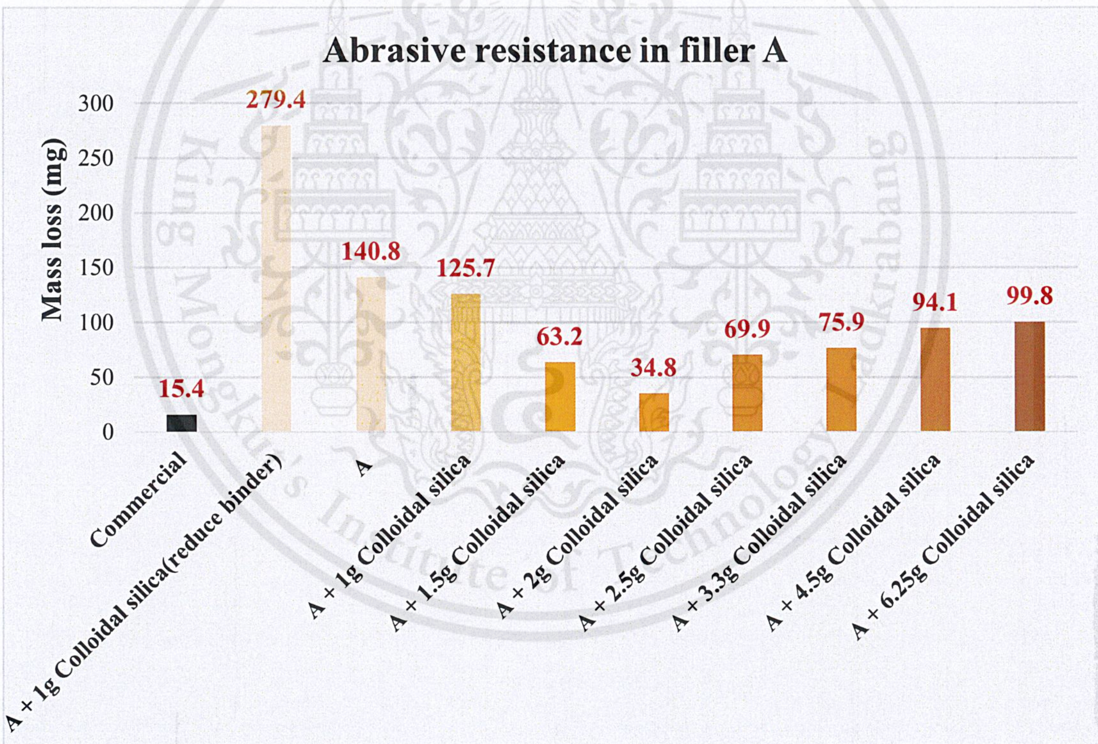

Figure 4.1 The bar graph of mass loss and samples (filler A) after the abrasive resistance test.

The results of the abrasion resistance test by modifying the filler at the molar ratio of SiO_2: K_2O were different, as shown in figure 4.This figure shows the bar graph of mass loss and filler A with colloidal silica. The contents of colloidal silica are 1, 1.5, 2, 2.5, 3.3, 4.5 and 6.25 g, the molar ratio of SiO_2: K_2O are 6.12, 6.42, 6.73, 7.03, 7.52, 8.25 and 9.32, respectively. After testing the abrasion resistance in case pure filler A, the mass loss is 140.8 mg but when adding colloidal silica, the mass loss in other cases is less than pure filler A with the smallest value at A+2g colloidal silica equals to 34.8 mg. It can be said that A+2g colloidal silica has the best properties of abrasion resistance. However, when the colloidal silica content was increased to 2.5, 3.3, 4.5 and 6.25 g, the mass loss was higher, but when the colloidal silica content decreased to 1 and 1.5g, the mass loss was higher.

4.1.2 The results of abrasive resistance test in filler B

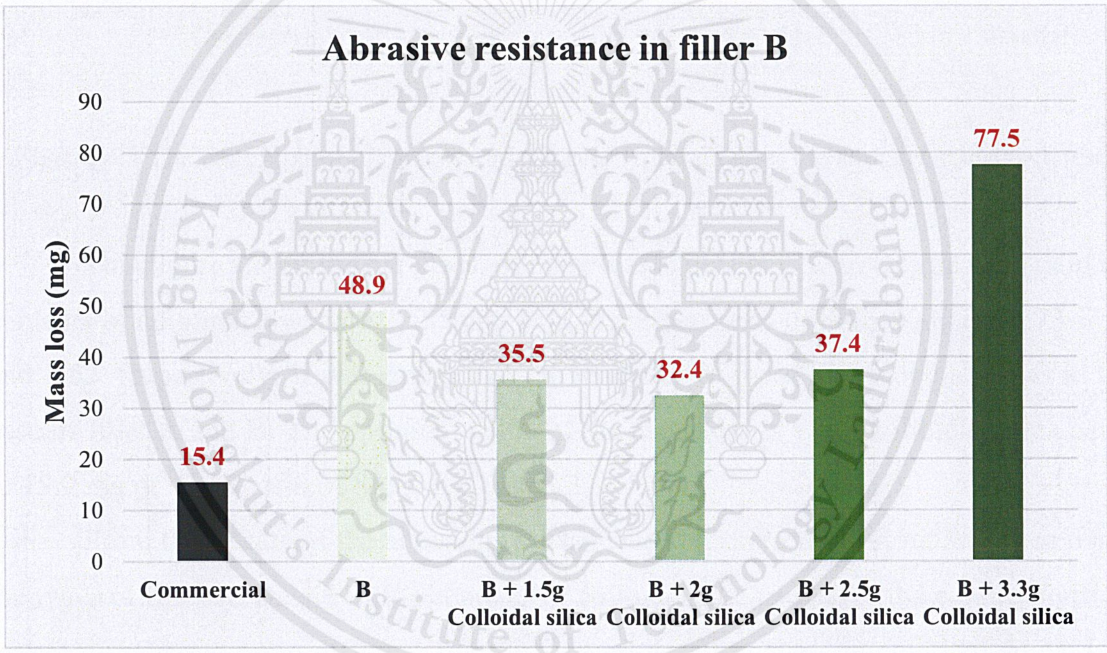

Figure 4.2 The bar graph of mass loss and samples (filler B) after the abrasive resistance test.

This figure shows the bar graph of mass loss and filler B with colloidal silica in the contents of colloidal silica are 1.5, 2, 2.5 and 3, the molar ratio of SiO_2: K_2O are 6.42, 6.73, 7.03 and 7.52, respectively. It was found that the tendency of mass loss is the same as in the case of filler A. The optimum value of the mass loss is B+2g colloidal silica equal to 32.4 mg or molar ratio of SiO_2: K_2O at 6.73.

4.1.4 The results of abrasive resistance test overall case study

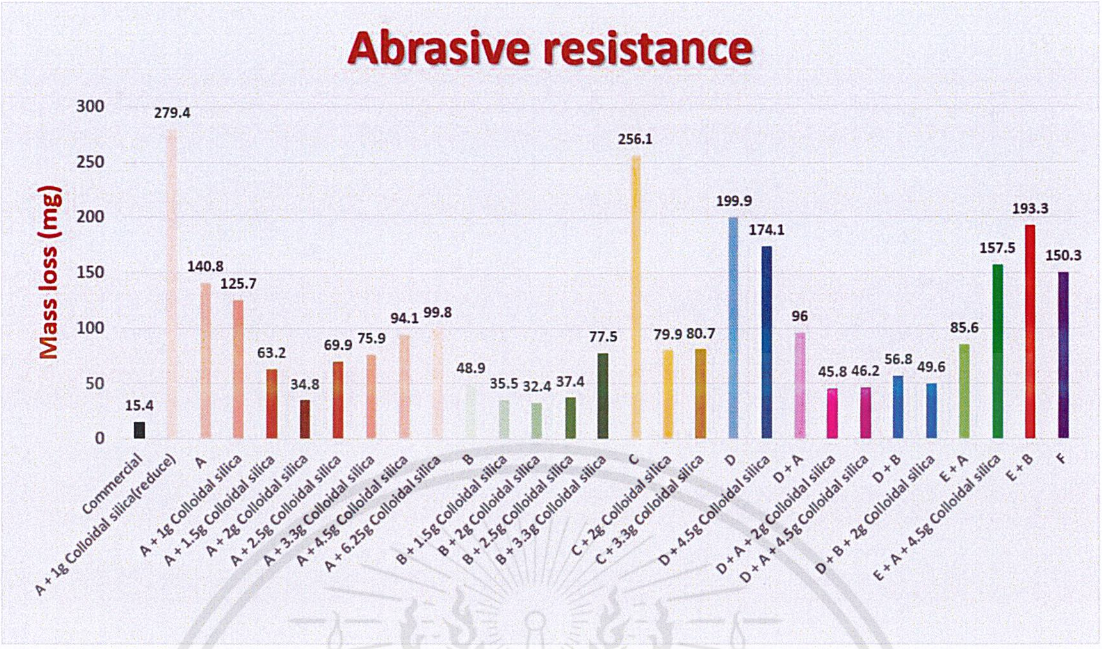

Figure 4.4 The bar graph of mass loss and types of each sample in case study after abrasive resistance test.

This figure shows the bar graph of mass loss and types of each sample case study. Considering the same filler indicates the optimum of filler A is A+2g colloidal silica, filler B is B+2g colloidal silica and filler C is C+2g colloidal silica. The tendency of fillers A, B and C are similar. Then, modified fillers are D, D+A, D+B, E+A, E+B and found that the mass loss is higher than the case of filler A and B. After, adjust the molar ratio of SiO_2: K_2O found that overall case studies have lower mass loss than pure filler, compared with commercial. The optimum value of the mass loss is 32.4 mg, but the commercial value is 15.4 mg, which is 2 times. Therefore, the type of filler and molar ratio of SiO_2: K_2O is just one way that can help increase the efficiency of abrasion resistance.

4.2 Film forming to different molar ratio of SiO_2 to K_2O in filler A

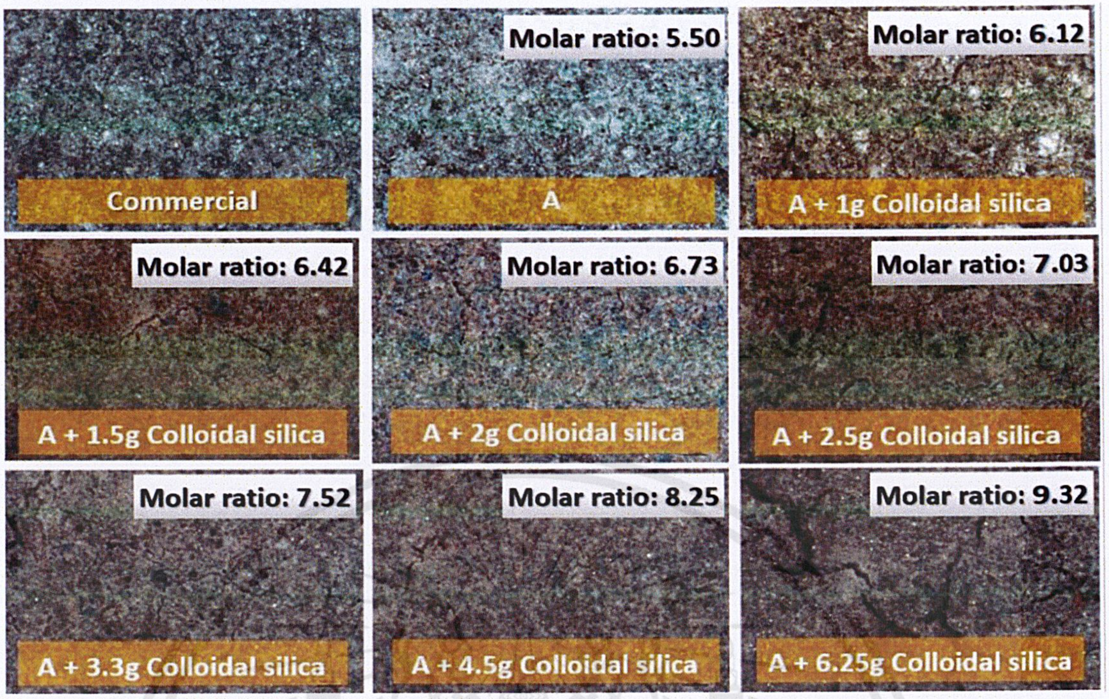

Figure 4.5 Optical microscope of the film-forming of the samples (filler A) with different the molar ratio of SiO_2 to K_2O at 200X.

When the filler A with a different molar ratio of SiO_2 to K_2O coating samples was examined for physical characteristics, the optical microscope (OM) at 200X c as shown in Figure 4.5. It is found that the adhesion between the coating and substrate are different, with sample A+2g colloidal silica is the smallest ceramic crack. But, when the colloidal silica content was increased to 2.5, 3.3, 4.5 and 6.25 g, the ceramic craze was increased significantly. And, when the colloidal silica content was reduced to 1 and 1.5g, the ceramic craze was increased significantly. The molar ratio of SiO_2: K_2O is different will affect the size and amount of ceramic craze on the samples.

APPENDIX B

SAMPLES DATA

B.1 Optical microscope of the film forming in each sample at 200X.

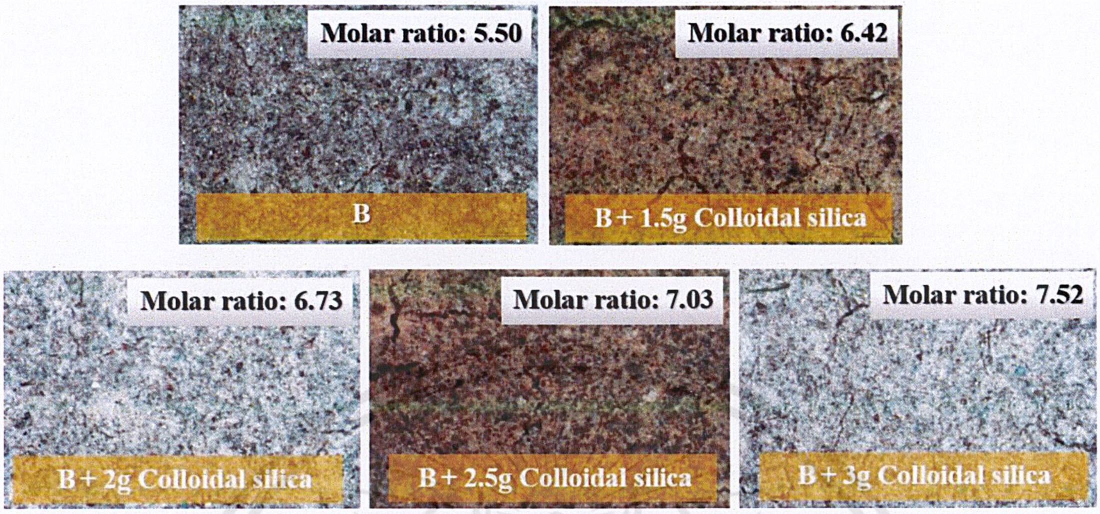

Figure B.1 Optical microscope of the film-forming of the samples (filler B).

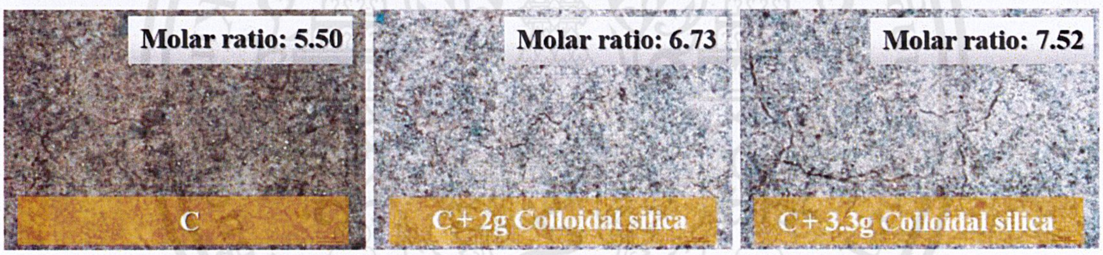

Figure B.2 Optical microscope of the film-forming of the samples (filler C).

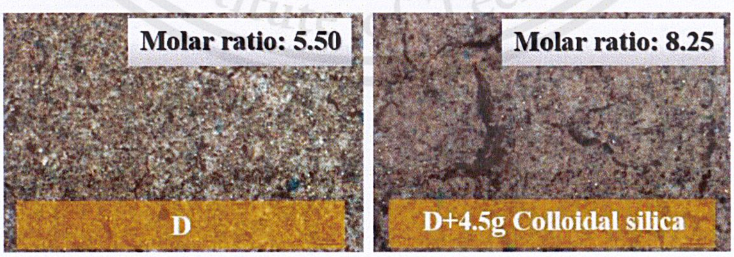

Figure B.3 Optical microscope of the film-forming of the samples (filler D).

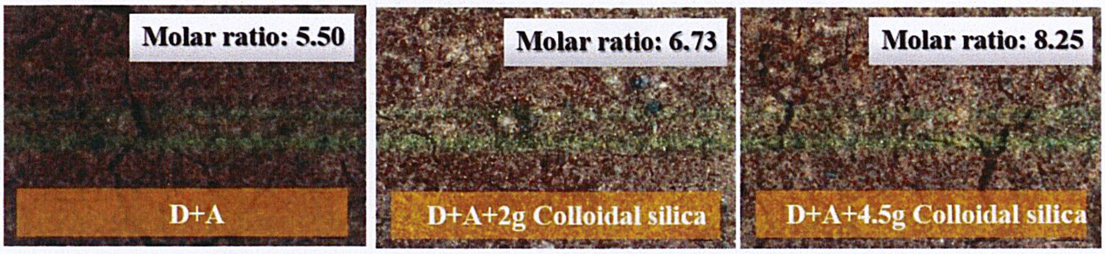

Figure B.4 Optical microscope of the film-forming of the samples (filler D+A).

Figure B.5 Optical microscope of the film-forming of the samples (filler D+B).

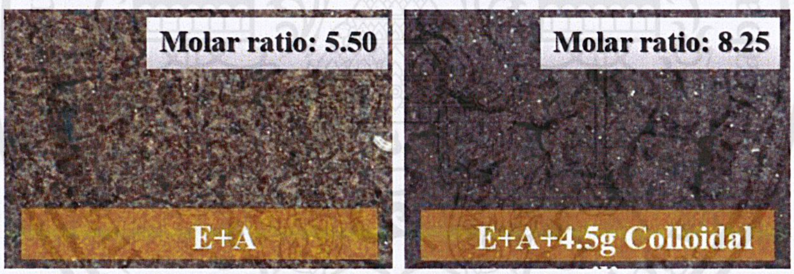

Figure B.6 Optical microscope of the film-forming of the samples (filler E+A).

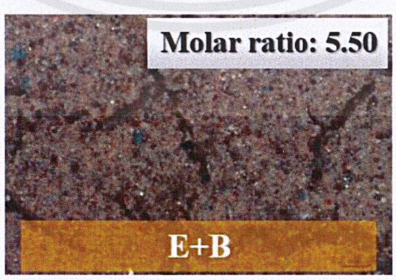

Figure B.7 Optical microscope of the film-forming of the samples (filler E+B).

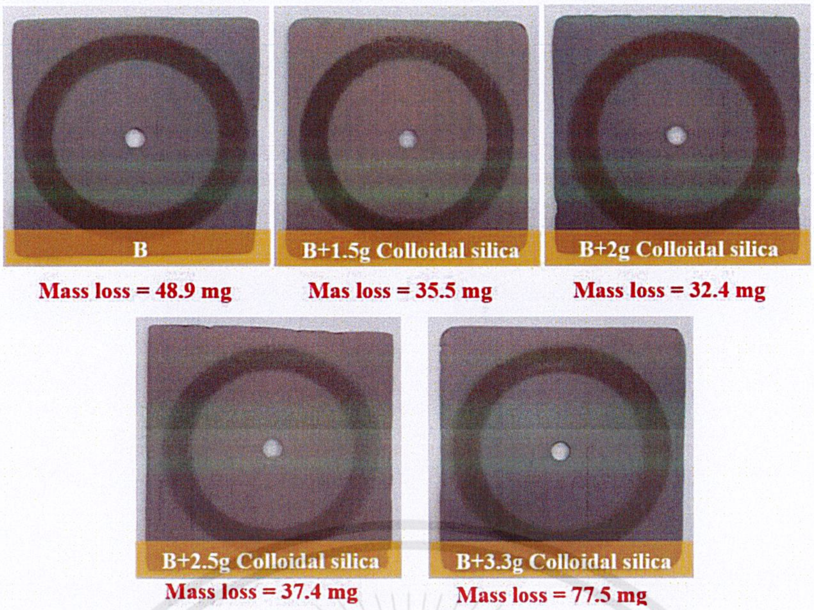

Figure B.11 The results of the abrasion resistance test of 12Cr samples coated with filler B.

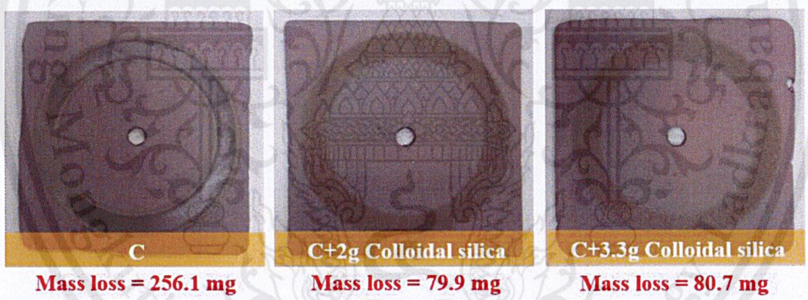

Figure B.12 The results of the abrasion resistance test of 12Cr samples coated with filler C.

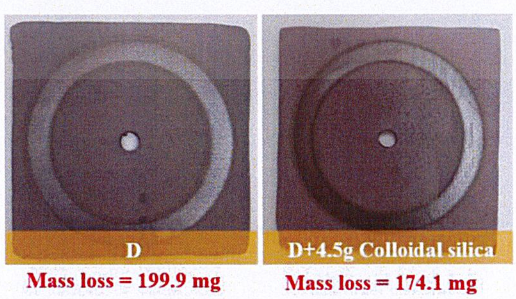

Figure B.13 The results of the abrasion resistance test of 12Cr samples coated with filler D.

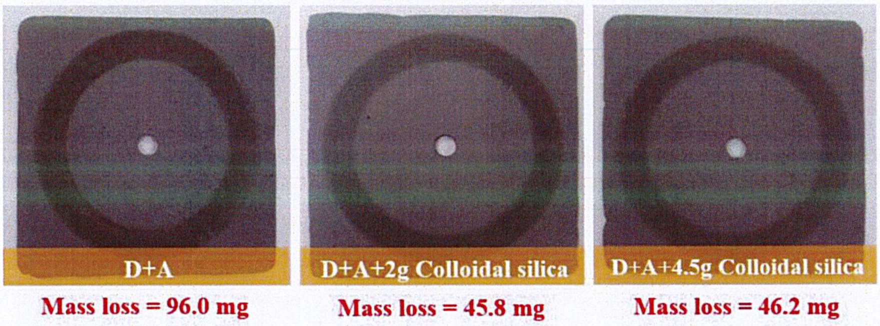

Figure B.14 The results of the abrasion resistance test of 12Cr samples coated with filler D+A.

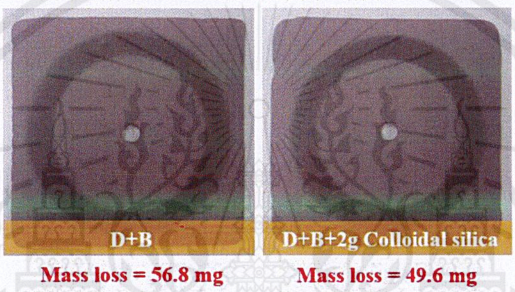

Figure B.15 The results of the abrasion resistance test of 12Cr samples coated with filler D+B.

Figure B.16 The results of the abrasion resistance test of 12Cr samples coated with filler E+A.

Figure B.17 The results of the abrasion resistance test of 12Cr samples coated with filler E+B.

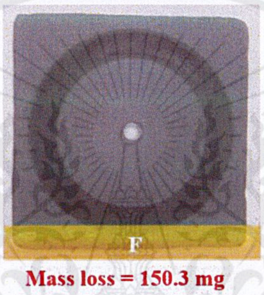

Figure B.18 The results of the abrasion resistance test of 12Cr samples coated with filler F.

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