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HAL Id: hal-02369358

https://hal.archives-ouvertes.fr/hal-02369358

Submitted on 18 Nov 2019

A Experimental Research On The Anti-erosion Material For Hydraulic Machinery

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Abstract

Hydraulic machinery used in many fields was badly eroded, but it was found that not enough has been done on the erosion mechanism and the anti-erosion material. By using a rotating jet erosion testbed, four kinds of materials were tested under different dynamics parameters. At the same time, aluminum bronze was tested under different size of sand particle. Some conclusions can been obtained after observing material surface by SEM. With the increase of Impacting velocity , the damage of material surface became serious and weight loss got bigger. With the increase of the impacting angle, the weight loss first increased and then decreased. At the same dynamics parameters, because surface damages of 06Cr19Ni10 and 45Cr are small, so 06Cr19Ni10 and 45Cr had the better anti-erosion performance. However, Q235 had worse anti-erosion performance. With the increase of sand size, the erosion of material surface got worse, and weight loss had an obviously change between 0.4mm and 0.5mm.

Keywords

Dynamic parameters; Particle size; Interactive wear; Erosion; SEM.

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INTRODUCTION

Hydraulic machinery is widely used in many fields, and plays a significant role in social economy. At the moment of creating huge economic benefits, the problems of erosion in hydraulic machinery also should be attention. In hydraulic machinery field, the interaction between cavitation and impacting wear caused by sand are defined erosion. It leads the blades wear seriously and make the efficiency fallen. As a result, it shortens the repair cycle and increases the operating costs, moreover it was not avoided in the operation of the hydraulic machinery [1]. So new technologies or measures were used to reduce erosion damage by researching its mechanisms. Erosion can be influenced by many factors, such as the material performance, dynamics parameters and the characters of the sediment[2,3].

A lot of researches have been carried out on the anti-erosion of hydraulic machinery. Researchers from SEW and Voith companies think that the content, characteristic of sediment and the pattern of flow decide damage degree of the hydraulic turbine[4,5]. According to studying the influence of velocity and content of the sand on erosion, Liang considers that anti-erosion performance of material was related to sand velocity and content. Erosion mechanisms were investigated by scanning erosion location [6]. A way to optimize runner of hydraulic turbine through researching runner cavitation and wear in the flow with sands was presented by Romeo and Gabriel[7]. In this paper, by using the testbed which was built for researching the influence of rotating spray on material erosion[8], four kinds of materials on erosion were investigated under different dynamics parameters. Meanwhile, the anti-erosion performance of material was also studied under different sand particle sizes. At last, the surface morphology can be observed using SEM (scanning electron microscope) and the weight loss can be measured by electronic scale.

1. METHODS

1.1 Testbed

As the Fig. 1(a) and (b) show, the testbed consists of adjustable speed motor, diaphragm pump, mixed water tank, steady voltage system, air compressor, refrigeration system and rotary table room. In the testbed, with the help of diaphragm pump, the flow with sands went through steady voltage system into rotary table room, and impact rotary table surface by using nozzles where the velocity could be set. Furthermore, rotary table was driven by motor and in high speed, it made the rotating centre pressure decrease and formed pressure gradient, and created opportunity for cavitation. Flow pattern at the back of the hole was damaged owing to cavitation hole. The area in low pressure produced gas nucleus and the gas nucleus were broken in the high pressure area, which lead the phenomenon of cavitation damage. Moreover, the flow with sands in high speed impacted material surface through nozzles and lead wear damage. Cavitation and wear could affect each other and formed erosion. Eventually, the flow with sands returned to mixed water tank.
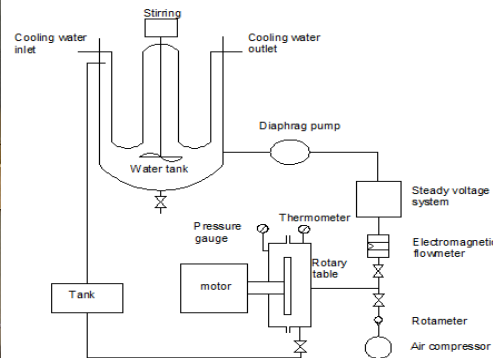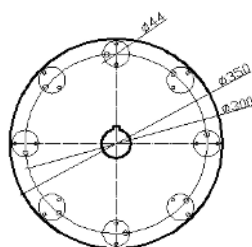
Figure 1. Rotary spray erosion testbed

To keep the temperature of the water in the mixed water tank below 50 degree centigrade, so the cooling system used to absorb energy from rotary table was been set. Besides, the impacting velocity and impacting angle were regulated by changing flow and rotational speed of the rotary table. Other functions could be achieved on the control cabinet. Fig. 2(a) and (b) show the diagram of rotary table. Eight test materials were installed in the rotary table. In present paper, same materials were installed at the opposite angle, so four kinds of materials could be tested at the same time.

(a)   (b)
Figure 2. Rotary table structure diagram and photo

Each test material was set a hole used to evoke cavitation. During the test, material weight loss was weighed by an electronic scale whose precision reached 0.1 mg after cleaning and drying every 2 hours. Aluminum bronze QAL9-4 was measured every 3 hours. In order to simulate the truth of the erosion, sands in the flow must be replaced every 6 hours. Finally, the result of this test was analyzed by using the SEM, it could clearly observe wear scratch and cavitation pits of the material surface.

1.2 Parameters setting

In this paper, two tests were finished. One was under different dynamics parameters, and the other was under different sand particle sizes. Four kinds of materials were used in the test to research influence of dynamics parameters on erosion and dynamics parameters included the impacting velocity and the impacting angle. Table1 shows the specific test parameters.

Table 1.

Impacting angle(degree)	24, 32 ,40	32
Impacting velocity (m/s)	35	30, 35, 40
Sand particle sizes (mm)	0.2-0.3	0.2-0.3
Sand content (kg/m³)	5	5
Test time(h)	10	10

Aluminum bronze QAL9-4 was used to research the influence caused by different sand particle sizes on erosion[9]. Table. 2 shows the specific test parameters.

Table 2.

Impacting angle(degree)	32
Impacting velocity (m/s)	30
Sand particle sizes (mm)	0.1-0.2, 0.2-0.3 0.3-0.4, 0.4-0.5
Sand content (kg/m³)	2
Test time(h)	18

3 Test result and analyze
3.1 Weight loss

After the test, four kinds of materials weight loss curves were shown in the fig. 3. The impacting velocity was set at 35 m/s, and impacting angle was set to 24 degree, 32 degree and 40 degree, respectively.
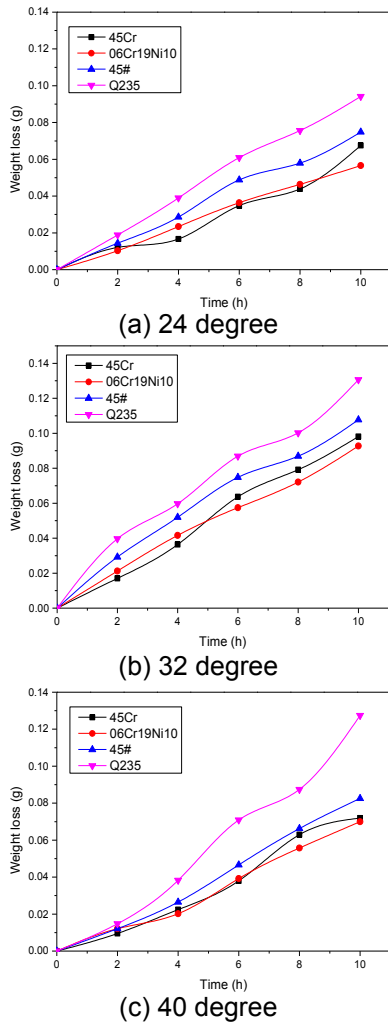
(a) 24 degree

(b) 32 degree

(c) 40 degree

Figure 3. Variation curves of weight loss of specimen under different erosion angle

As Fig. 3 shows, the four kinds of materials show the same rules of erosion weight loss under three kinds of impacting angle. The accumulated weight loss of Q235 was the maximum and the one of 06Cr19Ni10 was the minimum. According to the material weight loss curves under three different impacting angles, the anti-erosion performance of the four kinds of materials could be obtained. The accumulative weight loss of 06Cr19Ni10 was the smallest, so the anti-erosion performance was best. The accumulative weight loss of Q235 was the largest and the anti-erosion performance was poor. The curves in Fig3 also show that weight loss of the erosion material included the incubation period, the rising period and the stabilization period [10,11]. During the incubation period (from 0 to 2 hours), the surface of the material was damaged mainly by impacting wear. During the rising period (from 2 to 6 hours), due to wear and cavitation interaction, the material damage increased quickly. During stable period (6 hours later), wear and cavitation damage entered the relatively stable. Within the allowable range of test error, the trend of weight loss curve of four kinds of materials was almost the

same. Comparing the erosion weight loss curves under three kinds of angles, it could be seen that the gradient of the weight loss curves of four materials was larger than that of the other two angles when the angle of impacting was 32 degree. Therefore, it could be concluded that the wear damage of the material was the most serious when the impacting angle was about 32 degree.

Fig. 4 shows that the accumulative weight loss of four kinds of materials changed with test time when impacting angle was 32 degree and the impacting velocity were 30m/s, 35 m/s and 40 m/s, respectively. It had a positive proportion relation between the weight loss and the test time under the erosion damage. At the same impacting velocity, the weight loss of Q235 was the largest; the damage of 45Cr was close to the one of 06Cr19Ni10.

When the impacting velocity of Q235 was set at 30 m/s, 35 m/s, and 40 m/s, the accumulative weight loss was 65.45 mg, 117.3 mg,143.95 mg respectively after test. The weight loss of the largest is 2.19 times bigger than the smallest. Other materials had the same rules. According to these curves and experimental data, it could be concluded that the increasing of impacting velocity caused the sand particle momentum increase continuously. Which leaded material damage serious, and the weight loss of erosion increased quickly.
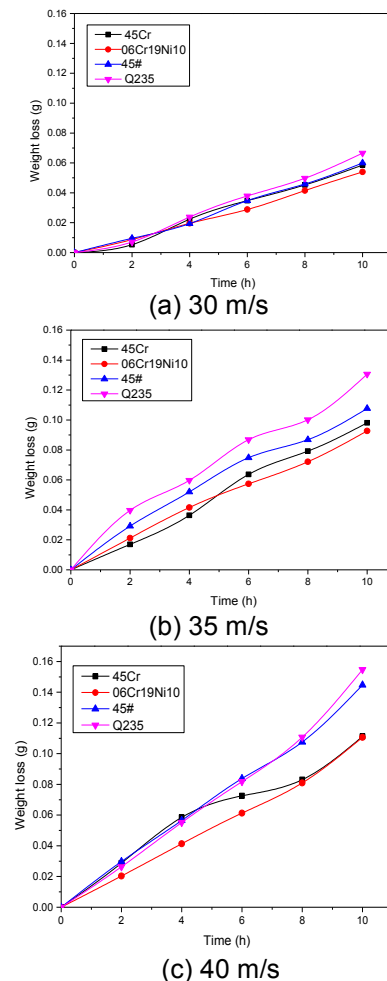

(a) 30 m/s

(b) 35 m/s

(c) 40 m/s

Figure 4.The variation curves of the weight loss of specimen under different erosion velocity

Aluminum bronze used in marine propellers was considered as study object to investigate the influence of sand particle diameter on erosion. Fig. 5(a) shows that the accumulative weight loss of aluminum bronze changed with the test time under different sand particle sizes. The accumulative weight loss of erosion was proportional to the increase of time, and the larger of the particle size, the greater of the weight loss. The weight loss of materials had a big difference between the biggest particle size (from 0.4 mm to 0.5 mm) and other particle sizes at the beginning of the test.
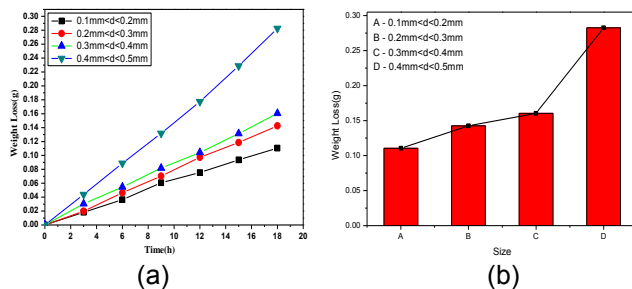

(a) (b)

Figure 5. The variation curves of the weight loss of specimen under different sand particle sizes

As Fig. 5(b), when the sand particle size was less than 0.4 mm, the increasing of accumulative weight loss of erosion was relatively slow. However, when the sand particle size was exceeded than 0.4 mm, the accumulative weight loss of erosion increased suddenly.

3.2 Surface topography analysis

To analyze easily, the original surface topographies of four materials which were not been tested after polishing were shown in Fig. 6. After polishing, the surfaces of the materials were relatively smooth without obvious scratches. Due to the defects of Q235, there were many pores in the surface of the material, but the influence of these pores was relatively small on test results, so it could be ignored.

(a) 45Cr (b) 06Cr19Ni10

(c) 45# (d) Q235

**Figure 6. Original specimen appearance**

The Q235 was chosen as the study object, Fig. 7 shows the surface topography after 10 hours of erosion under 24 degree, 32 degree and 40 degree, respectively. The surface damage of the material mainly concentrated in the back of the cavitation hole, and the surface appeared furrow, fish scales lip, small cracks and small pit.
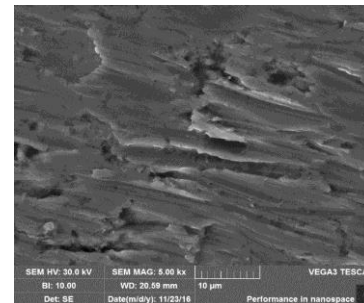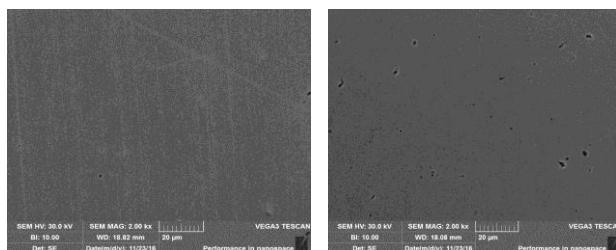

(a) 24 degree
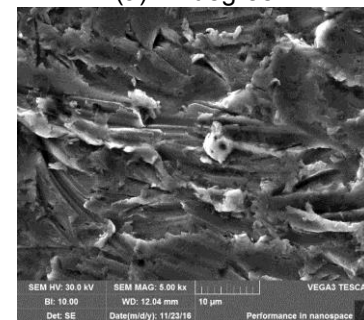
(b) 32 degree
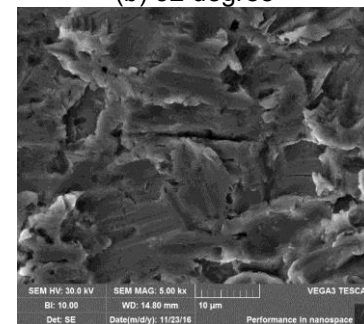
(c) 40 degree

Figure 7. SEM images with erosion angle 24degree, 32 degree, 40 degree .(5000x)

When the impacting angle was small, the interaction between cavitation and wear was mainly micro cutting and the second was the effect of cavitation damage. The velocity of the sands in the process of movement was constituted by horizontal component and vertical component. The vertical component determined the sand into the material surface depth. The horizontal component completed the micro-cutting on the material surface [12,13]. It formed a lamellar deformation layer after many times of impacting on the material surface. Subsequently, the layer at the edge cracked and formed some concaves and convex lips. Eventually it leaded the surface micro volume shedding. When impacting angle was large, the wear loss was mainly decided by sand kinetic energy, the influences
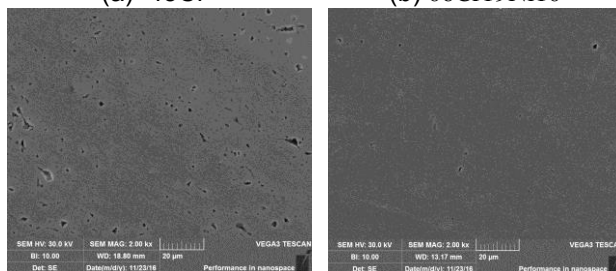
vertical impact and cavitation effect of the flow with sands on the material destroyed   structure of the surface layer, causing fatigue spalling and leaving the pitting on the surface of the material. When the impacting angle was 24 degree, the surface of material were mainly large lips and also appeared small amount of cavitation pits and furrows. Direction of the furrow was neat, and depth was shallow. When the impacting angle was 32 degree, the cutting of sands made the surface plastic deformation seriously. At same time, the direction of lips and furrow are more chaos, and lip flanging was more serious. When the impacting angle was 40 degree, material surface damage was mainly based on vertical impact and cavitation damage, furrow trip was short and the lips appeared as small patches.

Also, Q235 was chose as the study object. Fig. 8 shows the surface morphology after 10 hours of erosion under 30 m/s，35 m/s and 40 m/s.
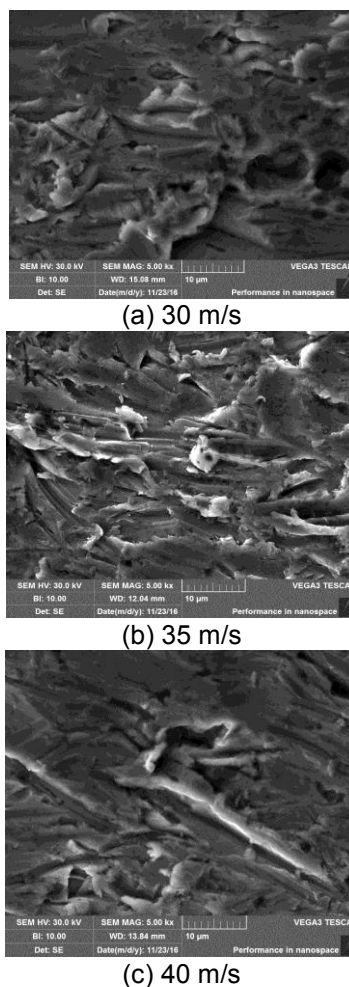

(a) 30 m/s

(b) 35 m/s

(c) 40 m/s

Figure 8. SEM images of erosion velocity 30 m/s 35 m/s, 40 m/s .(5000x)

In the erosion test, , the wear scar of the material surface was shallow and deep with the increasing of the impacting velocity, and the wear degree was also gradually increased . When the impacting velocity was 30 m/s, wear scar on the surface caused by sand were short and disorderly, the damage concentrated mainly in the surface layer. When the impacting velocity was

35 m/s, the surface cutting degree of the sand particles increased continually, and the furrow wear marks became longer and the wear direction was gradually neat. When the impacting velocity was 40 m/s, the cutting marks on the surface of the material were further increased and the furrow wear was deepened, and the damage of cavitation was further promoted.

The Fig. 9 shows the aluminum bronze surface morphology caused by erosion under four different particle sizes. The damage of the material surface became seriously with the increasing particle sizes of sand. The surface morphology of the material mainly included furrow, scaly lips and pits which came from lips spalling[14,15] .

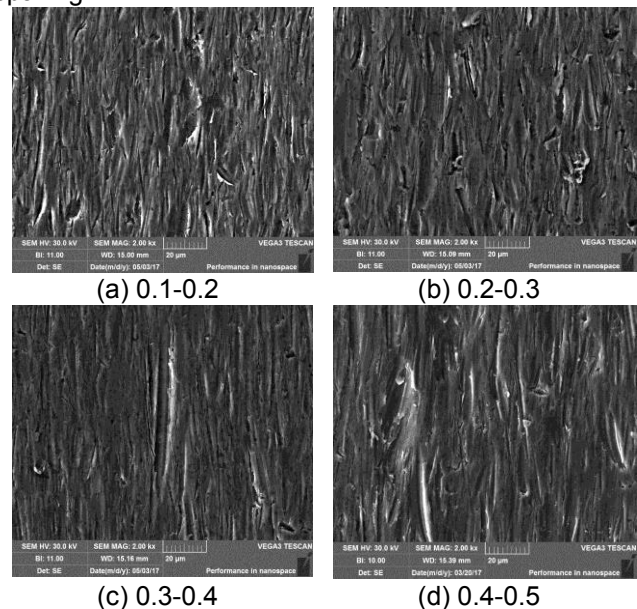(a) 0.1-0.2

(b) 0.2-0.3

(c) 0.3-0.4

(d) 0.4-0.5

Figure 9. SEM images of different particle sizes. (5000x)

As the hit of the sands again and again, the furrow overlap became serious, and lips fatigue loss increased quickly. The shedding lips from outside to inside and furrow leaded the material loss. As the Fig. 9(a) and (b) show, aluminum bronze surface was worn seriously. The cutting effect of the sands made the material surface produce plastic deformation and leaded to accumulation of materials, as well as appeared lips and short furrows whose width was a small, however it distributed uniform. As Fig. 9(c) and (d) show, with the increase of the particle sizes, the furrow width increased and the furrow length also increased correspondingly. The damage of the furrow between（d）and others had a clear difference, it kept consistent with the test date when the size of from 0.4 mm to 0.5 mm, whose weight loss increased suddenly.

4 Conclusion

1 The erosion of materials became seriously with the increasing of the velocity. Impacting velocity had positively correlated with the weight loss. Moreover, the cumulative weight loss of erosion increased firstly and then decreased with increasing of the impacting angel.
2 06Cr19Ni10 and 45 Cr had better anti-erosion performance, followed by 45 steel, and Q235 had the

worst erosion performance.

3 The interaction between cavitation and impacting wear leaded the damage of material surface. Cavitation damage leaded to the uneven surface of the material, which promoted the impacting wear of sands. Conversely, the impacting wear of sands aggravated the cavitation damage. According to impacting angle, impacting wear of the sands was divided into micro cutting caused by horizontal direction and repeated impacting caused by vertical direction.

4 When the particle size of sands were in the range of 0.5 mm, The damage of the material surface became seriously with the increasing particle size of sands The material weight loss had a clear difference when the particle size of the sands from 0.4 mm to 0.5 mm.

Acknowledgements

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